Deliverable D9.3

Final Dissemination, Exploitation and Standardisation Planning and Report of Activities

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Abstract

This deliverable presents the final updated version of the SliceNet project's activities on the dissemination, exploitation and standardization, and 5G PPP liaison. It highlights all the major achievements in the various related aspects including publications, project awareness activities (webinars and videos, social media, websites, news and newsletters, press releases, brochures, public demonstrations and participation in events, etc.), standardisation contributions to international and European standardisation organisations, contributions to open source projects, exploitation activities and per-partner strategies, and collaboration with 5G PPP and other relevant projects.

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Executive summary

SliceNet has taken significant efforts over the last three years in various activities related to promoting project awareness and outcomes into a wide range of stakeholders' communities in Europe and around the world. Substantial achievements have been made in dissemination, exploitation and standardisation. In this document, key achievements together with main activities are summarised with the following highlights listed here for a glance of accomplishments:

- 60+ papers have been published or accepted in international journals, magazines or conferences including several top-tier journal publications in IEEE transactions or journals and other renowned periodicals;
- Numerous other project dissemination events and materials have been organised or produced including both live and recorded webinars for all the 7 technical work packages in the third year of the project, contribution to more than 10 white papers through liaison with 5G PPP program, among others;
- 7 formal contributions to international standardisation organisations including 5 official Work Items created in the third year of the project in ITU-T ML5G and ETSI GANA, in addition to the ETSI ENI POC and an IETF draft in previous years.
- Close collaboration with other 5G and Horizon 2020 projects, especially joint development and trial with Phase 2 project MATILDA for the Smart City Lighting use case, which has been deployed and demonstrated in real-world operational environment.

These highlighted achievements, plus other dissemination and exploitation outcomes reported in this document, will directly lead to maximising the impact of the project in the forthcoming years.

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Table of Contents

List of Figures 6
List of Tables 7
Abbreviations 8
1. Introduction 10
1.1. Objective of this document 10
1.2. Organisation of this document 10
2. Dissemination 11
2.1. Journal and Magazine Publications 11
2.2. Conference Publications 13
2.3. 5G-PPP White Papers and Brochures 18
2.4. Newsletters and News 19
2.5. Social Networking Media 23
2.6. Project Website 25
2.7. Webinars 27
2.8. Dissemination Videos 28
2.9. Demonstrations in Public Events 29
2.10. Additional Events 33
2.11. Brochures and Other Dissemination Materials 36
2.12. Press Releases 37
2.13. Evaluation of Dissemination Outcomes vs. DoW 38
3. Standardisation 40
3.1. Proof-of-Concept Contribution to ETSI ENI 40
3.2. Contribution to ETSI GANA 40
3.3. Contribution 1 to ITU-T Focus Group ML5G under SG13 41
3.4. Contribution 2 to ITU-T Focus Group ML5G under SG13 41
3.5. Contribution 3 to ITU-T Focus Group ML5G under SG13 41
3.6. Contribution 4 to ITU-T Focus Group ML5G under SG13 42
3.7. Contribution 5 to IETF 42
3.8. Per-Partner Standardisation Strategy 43
4. Exploitation 46
4.1. Project Assets 46
4.2. Open Source Software 49
4.3. Per-Partner Exploitation Activities and Strategies 49
5. 5G-PPP Program-Level Liaison and Collaboration 72
5.1. 5G-PPP Board and Working Group Activities 72
5.2. Cross-Project Collaboration 76
5.3. Advisory Board Activities 81
6. Conclusions 84

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List of Figures

Figure 1 Screenshot of newsletter #6 20
Figure 2 Screenshots of some of the news 22
Figure 3 Screenshots of Twitter Post Examples 23
Figure 4 SliceNet Group on LinkedIn – Homepage 24
Figure 5 SliceNet LinkedIn Sample Post 24
Figure 6 Statistics of SliceNet website: July 2019 to 23 June 2020 26
Figure 7 Statistics of SliceNet website: 1 June 2017 to 23 June 2020 27
Figure 8 SliceNet Brochure 37
Figure 9 Matilda – SLICENET Smart City Intelligent Lighting System testbed architecture 77
Figure 10 Video on MATILDA – SLICENET technical workshop available on YouTube 78
Figure 11 Viewing statistics for the smart city video 79

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List of Tables

Table 1 Summary of Peer-Reviewed Journal Publications 11
Table 2 Summary of Magazine Publications 12
Table 3 Summary of Submitted Journal/Magazine Manuscripts 13
Table 4 Summary of Published/Accepted Papers in Proceedings of International Conferences 14
Table 5 Summary of Co-authored White Papers 18
Table 6 List of SliceNet Webinars 28
Table 7 Summary of Public Demonstrations Conducted by SliceNet Consortium 29
Table 8 Summary of Events (Organisation, Panels, Keynotes and Tutorials) 34
Table 9 Dissemination KPIs in the DoW vs. Actual Dissemination Outcomes 38
Table 10 Per-Partner Standardisation Strategy 43
Table 11 List of Licensed Software Developed in SliceNet 46
Table 12 SliceNet Contributions to Open Source Software 49
Table 13 Summary of SliceNet 5G-PPP Program-Level Activities 72

Abbreviations

3GPP	3rd Generation Partnership Project
4G	Fourth Generation (mobile/cellular networks)
5G	Fifth Generation (mobile/cellular networks)
5G PPP	5G Infrastructure Public Private Partnership
AI	Artificial Intelligence
BMSB	Broadband Multimedia Systems and Broadcasting
CAPEX	Capital Expenditure
CN	Core Network
DDOS	Distributed Denial Of Service
DoW	Description of Work
DSO	Distribution System Operator
E2E	End to End
eMBB	enhanced Mobile BroadBand
EPC	Evolved Packet Core
ETSI	European Telecommunications Standards Institute
EuCNC	European Conference on Networks and Communications
FaaS	Function as a Service
FCA	Flow Control Agent
FMA	Flow Monitoring Agent
FPGA	Field-Programmable Gate Array
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
IETF	Internet Engineering Task Force
IioT	industrial IoT
IoT	Internet of Things
ITU	International Telecommunication Union
KPI	Key Performance Indicator
M2M	Machine to Machine
MANO	Management and Orchestration
MEC	Multi-access Edge Computing
ML	Machine Learning
mMTC	massive Machine Type Communications

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NB-IoT	Narrowband Internet of Things
NFV	Network Function Virtualization
NFVI	Network Function Virtualization Infrastructure
NFVO	Network Function Virtual Orchestrator
NGMN	Next Generation Mobile Networks
NMR-O	Network Domain and Resource Orchestrator
OAI	Open Air Interface
OSS	Operations Support System
OPEX	Operational Expenditure
OVS	Open Virtual Switch
PoC	Proof of Concept
QoE	Quality of Experience
QoP	Quality of Perception
QoS	Quality of Service
R&D	Research and Development
RAN	Radio Access Network
R-GOOSE	IEC 61850 Routable-Generic Object Oriented Substation Events
SDK	Software Development Kit
SDN	Software Defined Networks
SLA	Service Level Agreement
SliceNet	End-to-End Cognitive Network Slicing and Slice Management Framework in Virtualised Multi-Domain, Multi-Tenant 5G Networks
TAL	Tactic Autonomic Language
TR	Technical Report
TRL	Technology Readiness Level
TS	Technical Specification
UDP	User Datagram Protocol
vEPC	virtual Evolved Packet Core
VIM	Virtual Infrastructure Manager
VNF	Virtual Network Function
WDM	Wavelength Division Multiplexing

1. Introduction

Throughout the three years' execution of the SliceNet project, the consortium as a whole has produced numerous outcomes for dissemination, exploitation, standardisation and related purposes. These outcomes have significantly contributed to the awareness of the project and promoted the results of the project to various communities of stakeholders, thereby having helped maximise the impact of the project in Europe and international venues.

1.1. Objective of this document

The document reports the final version of dissemination, exploitation, standardisation and collaboration activities, focusing on reporting concrete and important achievements across all WP9 tasks and including per-partner standardisation and exploitation strategies.

1.2. Organisation of this document

The rest of the document is organised as follows:

Section 2 summarises dissemination outcomes, including publications, events, website, newsletters and news, social media, demos, brochures, webinars, videos etc.

Section 3 presents standardisation activities, featured by a significant number of official work items that have been successfully created in standardisation bodies and on the standardisation track.

Section 4 describes exploitation activities, covering contributions to open source projects, patents, exploitable software components and other project's assets, per-partner strategies and so on.

Section 5 includes 5G PPP programme-level liaison, cross-project collaborations and Advisory Board activities.

Section 6 concludes this deliverable.

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2. Dissemination

2.1. Journal and Magazine Publications

The project has promoted significant outcomes to international journals, focusing on renowned peer-reviewed journals with good impact factors, especially in the final year of the project with more technical outcomes becoming ready for dissemination. Some of them are top-tier journals such as *IEEE Journal on Selected Areas in Communications, IEEE Transactions on Network and Service Management, IEEE Transactions on Broadcasting* and so on. To sum up, the following **14 peer-reviewed journal papers** have been published (or accepted for publication) in journals, of which **13 have an impact factor**. Table 1 shows a summary of the peer-reviewed journals.

Table 1 Summary of Peer-Reviewed Journal Publications

ID	Title of the paper	Title of the journal (and impact factor)	Publication year
1	Virtual IoT HoneyNets to Mitigate Cyberattacks in SDN/NFV-Enabled IoT Networks	IEEE Journal on Selected Areas in Communications (Impact factor: 9.302)	2020
2	Scalable Virtual Network Video-Optimizer for Adaptive Real-Time Video Transmission in 5G Networks	IEEE Transactions on Network and Service Management (Impact factor: 4.682)	2020
3	Enabling Multi-segment 5G Service Provisioning and Maintenance through Network Slicing	Journal of Network and Systems Management (Impact factor: 1.676)	2020
4	Real-time Maintenance of Latency-sensitive 5G Services through Network Slicing	Photonic Network Communications (Impact factor: 1.328)	2020
5	Advanced Spatial Network Metrics for Cognitive Management of 5G Networks	Software Computing (Impact factor: 2.784)	2020
6	5G-Connected Virtualized Enterprise Infrastructure for Smart City	International Journal of Internet of Things and Web Services	2019
7	Enable Advanced QoS-Aware Network Slicing in 5G Networks for Slice-Based Media Use Cases	IEEE Transactions on Broadcasting (Impact factor: 4.374)	2019

8	Efficient QoE-Aware Scheme for Video Quality Switching Operations in Dynamic Adaptive Streaming	ACM Transactions on Multimedia Computing, Communications, and Applications (Impact factor: 2.25)	2019
9	Towards Hardware-Accelerated QoS-aware 5G network slicing based on data plane programmability	Transactions on Emerging Telecommunications Technologies (Impact factor: 1.535)	2019
10	Autonomic protection of multi-tenant 5G mobile networks against UDP flooding DdoS attacks	Journal of Network and Computer Applications (Impact factor: 5.273)	2019
11	RAN runtime slicing system for flexible and dynamic service execution environment	IEEE Access (Impact factor: 4.098)	2018
12	NFVMon: Enabling Multioperator Flow Monitoring in 5G Mobile Edge Computing	Wireless Communications and Mobile Computing (Impact factor: 1.396)	2018
13	Orchestration Architecture for Automatic Deployment of 5G Services from Bare Metal in Mobile Edge Computing Infrastructure	Wireless Communications and Mobile Computing (Impact factor: 1.396)	2018
14	5G NB-IoT: Efficient Network Traffic Filtering for Multi-tenant IoT Cellular Networks	Security and Communication Networks (Impact factor: 1.376)	2018

The following **6 papers** have been published (or accepted for publication) in magazines and **2 of them** have an **impact factor**. Table 2 shows a summary of magazines.

Table 2 Summary of Magazine Publications

ID	Title of the paper	Title of the magazine (and impact factor)	Publication year
1	Cognitive network slice management: The SliceNet approach	Eurescom message	2020

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2	SME Success Stories	5G PPP European Annual Journal 2019	2019
3	SliceNet Project	5G PPP European Annual Journal 2019	2019
4	Slice orchestration for multi-service disaggregated ultra dense RANs	IEEE Communications Magazine (Impact factor: 10.356)	2018
5	5G Control Apps: Enabling Multiservice Programmability in a Disaggregated Radio Access Network	IEEE Vehicular Technology Magazine (Impact factor: 6.145)	2018
6	End-to-end Cognitive Network Slicing: The SliceNet Framework for Slice Control, Management and Orchestration	Eurescom Message	2018

Submitted journal/magazine papers that are under review by the submission of this deliverable are shown in Table 3.

Table 3 Summary of Submitted Journal/Magazine Manuscripts

ID	Title of the paper	Title of the periodical (and impact factor)	Submission year
1	Quality of Perception Prediction in 5G Slices for E-health Services Using User-perceived QoS	Computer Communications, Special Issue on Network Intelligence (impact factor: 2.766)	2020
2	Enabling QoE-aware Cognitive Slice Management in 5G Networks	IEEE Communications Magazine, Network and Service Management series (impact factor: 10.356)	2020
3	Noisy Neighbours detection in 5G slices: Application to smart city use case	Journal of Network and Systems Management (Impact factor: 1.676)	2020

2.2. Conference Publications

The consortium has also been actively attending numerous international conferences to present project results in a timely manner. The following **40+ papers** shown in Table 4 have been published

(or accepted for publication) in conferences, with **10 out of Europe** to further increase the potential impact of the project.

Table 4 Summary of Published/Accepted Papers in Proceedings of International Conferences

ID	Papers / presentation title	Title of the conference	Publication year and venue (in **Bold** if out of Europe)
1	Autonomic 5G and beyond network management	IEEE International Conference on Transparent Optical Networks (ICTON) 2020	2020, Bari, Italy
2	Multi-domain Orchestration of 5G Vertical Services and Network Slices, Workshop on Intelligent 5G Network Slicing	IEEE International Conference on Communications (ICC) 2020	2020, Dublin, Ireland
3	Highly-Scalable Software Firewall Supporting One Million Rules for 5G NB-IoT Networks	IEEE International Conference on Communications (ICC) 2020	2020, Dublin, Ireland
4	Resilient 5G technologies optimized for power grid protection solutions using IEC 61850 time-critical communications	15th International Conference on Developments in Power System Protection 2020	2020, Liverpool, UK
5	5G technology and services for distributed protection and control solutions using IEC 61850 communications	PAC World Conference 2020	2020, Prague, Czech Republic
6	Root Cause Analysis of Noisy Neighbours in a Virtualized Infrastructure	IEEE Wireless Communications and Networking Conference (WCNC) 2020	2020, Seoul, **South Korea**
7	Network Management – Edge and Cloud Computing The SliceNet Case	IEEE 17th Annual Consumer Communications & Networking Conference (CCNC) 2020	2020, Las Vegas, **USA**
8	Topology Awareness for Smart 5G eMBB Network Slicing VNF Placement	IEEE 21st International Symposium on “A World of Wireless, Mobile and Multimedia Networks” (WoWMoM) 2020	2020, Cork, Ireland

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9	Slice Scheduling with QoS-Guarantee towards 5G	IEEE Global Communications Conference (GLOBECOM) 2019	2019, Waikoloa, USA
10	Real-Time Video Adaptation in Virtualised 5G Networks (poster)	IEEE 44th Conference on Local Computer Networks (LCN) 2019	2019, Osnabrück, Germany
11	Supporting QoE-aware end-to-end network slicing in future 5G-enabled optical networks	SPIE 10946, Metro and Data Centre Optical Networks and Short-Reach Links II	2019, San Francisco, **USA**
12	Smart Grid Protection and Automation Enabled by IEC 61850 Communications Over 5G Networks	25th International Conference and Exhibition on Electricity Distribution (CIRED) 2019	2019, Madrid, Spain
13	Cross-cutting Issues in the EPES Digital Era: An Overview of Prominent Smart Grid Use Cases (poster)	25th International Conference and Exhibition on Electricity Distribution (CIRED) 2019	2019, Madrid, Spain
14	NetFPGA-based firewall solution for 5G multi-tenant architectures	IEEE International Conference on Edge Computing (EDGE) 2019	2019, Milan, Italy
15	End-to-end Network Slicing in Support of Latency-sensitive 5G Services	IEEE International Conference on Optical Network Design and Modelling (ONDM) 2019	2019, Athens, Greece
16	Towards Automatic Deployment of Virtual Firewalls to Support Secure mMTC in 5G Networks	IEEE Conference on Computer Communications Workshop (INFOCOM) 2019	2019, Paris, France
17	Actuation framework for 5G-enabled network slices QoE/QoS guarantees	IEEE 21th International Conference on Transparent Optical Networks (ICTON) 2019	2019, Angers, France
18	5G Smart City Vertical Slice	IFIP/IEEE Symposium on Integrated Network and Service Management (IM) 2019	2019, Arlington, **USA**
19	Deploying Smart City components for 5G network slicing	European Conference on Networks and Communications (EuCNC) 2019	2019, Valencia, Spain

20	Inter-Business Orchestration for Resource and Service Provisioning in 5G Network Slicing	European Conference on Networks and Communications (EuCNC) 2019	2019, Valencia, Spain
21	Towards the Detection of Mobile DdoS Attacks in 5G Multi-Tenant Networks	European Conference on Networks and Communications (EuCNC) 2019	2019, Valencia, Spain
22	Self-Restoring Video User Experience in 5G Networks Based on a Cognitive Network Management Framework	European Conference on Networks and Communications (EuCNC) 2019	2019, Valencia, Spain
23	Cognitive, Multi-Domain Network Slicing: The SliceNet Framework (poster)	European Conference on Networks and Communications (EuCNC) 2019	2019, Valencia, Spain
24	Estimating Client QoE from Measured Network QoS (poster)	ACM International Systems and Storage Conference (SYSTOR) 2019	2019, Haifa, **Israel**
25	SliceNet Control Plane for 5G Network Slicing in Evolving Future Networks	IEEE Conference on Network Softwarization (NetSoft) 2019	2019, Paris, France
26	5G Network Slicing for Mission-critical use cases	IEEE 2nd 5G World Forum (5GWF) 2019	2019, Dresden, Germany
27	FlexVRAN: A Flexible Controller for Virtualized RAN over Heterogeneous Deployments	IEEE International Conference on Communications (ICC) 2019	2019, Shanghai, **China**
28	P4-NetFPGA-based network slicing solution for 5G MEC architectures	ACM/IEEE Symposium on Architectures for Networking and Communications Systems (ANCS) 2019	2019, Cambridge, UK
29	Spectrum management application – A tool for flexible and efficient resource utilization	IEEE Global Communications Conference (GLOBECOM) 2018	2018, Abu Dhabi, **UAE**
30	A Machine Learning Emotion Detection Platform to Support Affective Well Being	IEEE International Conference on Bioinformatics and Biomedicine (BIBM) 2018	2018, Madrid, Spain

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31	Towards a Realistic 5G Infrastructure Emulator for Experimental Service Deployment and Performance Evaluation	IEEE/ACM 22nd International Symposium on Distributed Simulation and Real Time Applications (DS-RT) 2018	2018, Madrid, Spain
32	Enabling Vertical Industries Adoption of 5G Technologies: a Cartography of evolving solutions	European Conference on Networks and Communications (EuCNC) 2018	2018, Ljubljana, Slovenia
33	SliceNet: E2E Cognitive Network Slicing and Slice Management in 5G Networks	European Conference on Networks and Communications (EuCNC) 2018	2018, Ljubljana, Slovenia
34	SliceNet: End-to-End Cognitive Network Slicing and Slice Management Framework in Virtualised Multi-Domain, Multi-Tenant 5G Networks	IEEE 13th International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB) 2018	2018, Valencia, Spain
35	5G Network Architecture, Functional Model and Business Role for 5G Smart City Use Case: Mobile Operator Perspective	International Conference on Communications (COMM) 2018	2018, Bucharest, Romania
36	End-to-End 5G Service Deployment and Orchestration in Optical Networks with QoE guarantees	IEEE 20th International Conference on Transparent Optical Networks (ICTON) 2018	2018, Bucharest, Romania
37	SliceNet: Cognitive Slice Management Framework for Virtual Multi-Domain 5G Networks	ACM International Systems and Storage Conference (SYSTOR) 2018	2018, Haifa, **Israel**
38	Dynamic Service Reallocation in NFV-based Transport WDM Optical Networks	Photonics in Switching and Computing 2018	2018, Limassol, Cyprus
39	Plug & play network application chaining for multi-service programmability in 5G RAN	16th ACM International Conference on Mobile Systems	2018, Munich, Germany
40	JoX: An event-driven orchestrator for 5G network slicing	IEEE/IFIP Network Operations and Management Symposium (NOMS) 2018	2018 Taipei, **China**

41	LL-MEC: Enabling low latency edge applications	IEEE 7th International Conference on Cloud Networking (CloudNet) 2018	2018, Tokyo, **Japan**
42	Hardware-Accelerated Firewall for 5G Mobile Networks	IEEE 26th International Conference on Network Protocols (ICNP) 2018	2018, Cambridge, UK
43	Development and Implementation of a Smart City Use Case in a 5G Mobile Network's Operator	25th Telecommunication Forum (TELFOR) 2017	2017, Belgrade, Serbia
44	5G challenges, requirements and key differentiating characteristics from the perspective of a mobile operator	International Conference on Future Access Enablers of Ubiquitous and Intelligent Infrastructures 2017	2017, Bucharest, Romania
45	Detecting Demeanor for Healthcare with Machine Learning	IEEE International Conference on Bioinformatics and Biomedicine (BIBM) 2017	2017, Kansas City, **USA**

For more details of the publications, please refer to [1].

2.3. 5G-PPP White Papers and Brochures

In addition to papers published in journals, magazines and conferences, SliceNet has contributed to the **10+ white papers and brochures** by including inputs from the project, in collaboration with 5G PPP working groups, as shown in Table 5.

Table 5 Summary of Co-authored White Papers

ID	Title of the white paper	Working group	Publication year
1	Delivery of 5G services indoors – the wireless wire challenge	5G PPP Technology Board	Ongoing, to be published in 2020
2	Edge Computing for 5G Networks	5G PPP Technical Board 5G IA Verticals Task Force	Ongoing, to be published in 2020
3	SDN/NFV virtualisation, 5G Slicing and Security Considerations	5G PPP Security WG	Ongoing, to be published in 2020

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4	Empowering Verticals industries through 5G Networks – Current Status and Future Trends	5G PPP Technology Board	Ongoing, to be published in 2020
5	View on 5G Architecture, Version 3.0	5G PPP 5G Architecture	2020
6	Cloud Native and 5G Verticals' services	5G PPP Software Network	2020
7	The 5G PPP Infrastructure -Trials and Pilots Brochure	5G PPP Trials	2019
8	Cloud-Native and Verticals' Services: 5G-PPP Projects Analysis	5G PPP Software Network	2019
9	Roadmap Version 5.0 – 10 Phase 2 Projects Trials & Pilots	5G PPP Trials	2019
10	From Webscale to Telco, the Cloud Native Journey	5G PPP Software Network	2018
11	5G Pan-European Trials Roadmap Version 4.0	5G PPP Trials	2018
12	5G Trials Roadmap, Observatory and Cartography	5G PPP Trials	2018
13	Tackling Network Management Challenges for Vertical Sectors Brochure	5G PPP Network Management	2018

2.4. Newsletters and News

Newsletters

Newsletters are built on the WordPress website using software called MailPoet. The newsletters can then be sent out to those who subscribe to the newsletter as the number of newsletters grow and the project develops content and gathers interest. Six newsletters have been created as part of the project on meaty subjects such as frameworks built in the project, vertical use cases such as the eHealth, Smart Grid and Intelligent Street Lighting demonstration achievements, standardisations achievements, EuCNC and MWC and other event booths, presentations and videos.

List of the 6 newsletters:

- Newsletter #1 – December 2017 (https://slicenet.eu/newsletter-1-december-2017/)
- Newsletter #2 – March 2018 (https://slicenet.eu/newsletter-2-march-2018/)
- Newsletter #3 – July 2018 (https://slicenet.eu/newsletter-3-july-2018/)
- Newsletter #4 – March 2019 (https://slicenet.eu/newsletter-4-march-2019/)
- Newsletter #5 – July 2019 (https://slicenet.eu/newsletter-5-july-2019/)
- Newsletter #6 – December 2019 (https://slicenet.eu/newsletter-6-december-2019/)

The next figure show a screenshot from the newsletter #6:

Figure 1 Screenshot of newsletter #6

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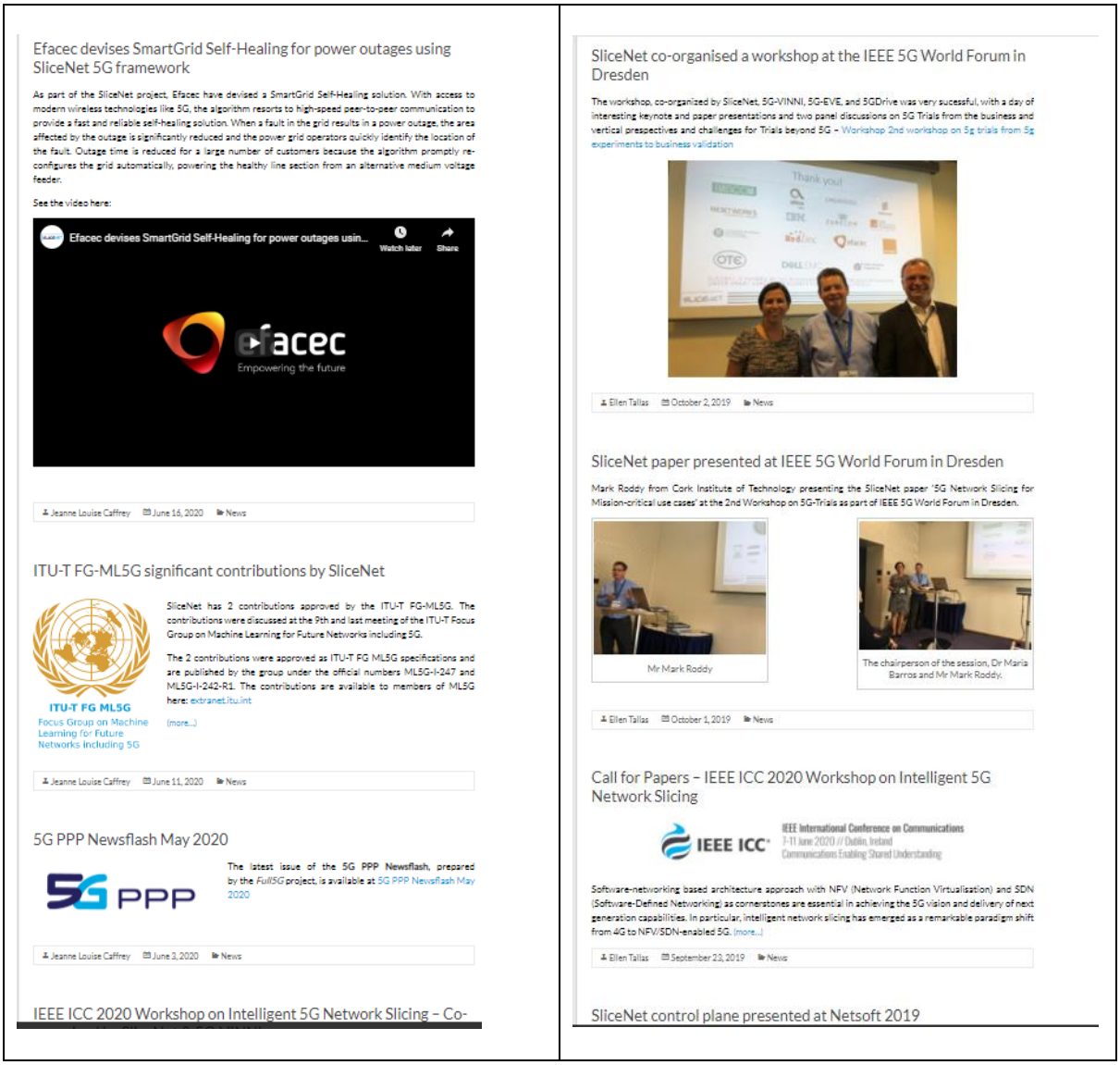
News

The news section of the website is regularly updated by all partners and co-ordinated by RedZinc. There is a rolling call for news within the project with, at least one every two to four weeks. News posts are project related on various topics such as the webinar series, presentations, publications, project demonstrations, calls for papers, videos created, workshops, Working Group meetings, standardisation meetings, 5GPPP news and events, etc.

Total number of news posts: **130**



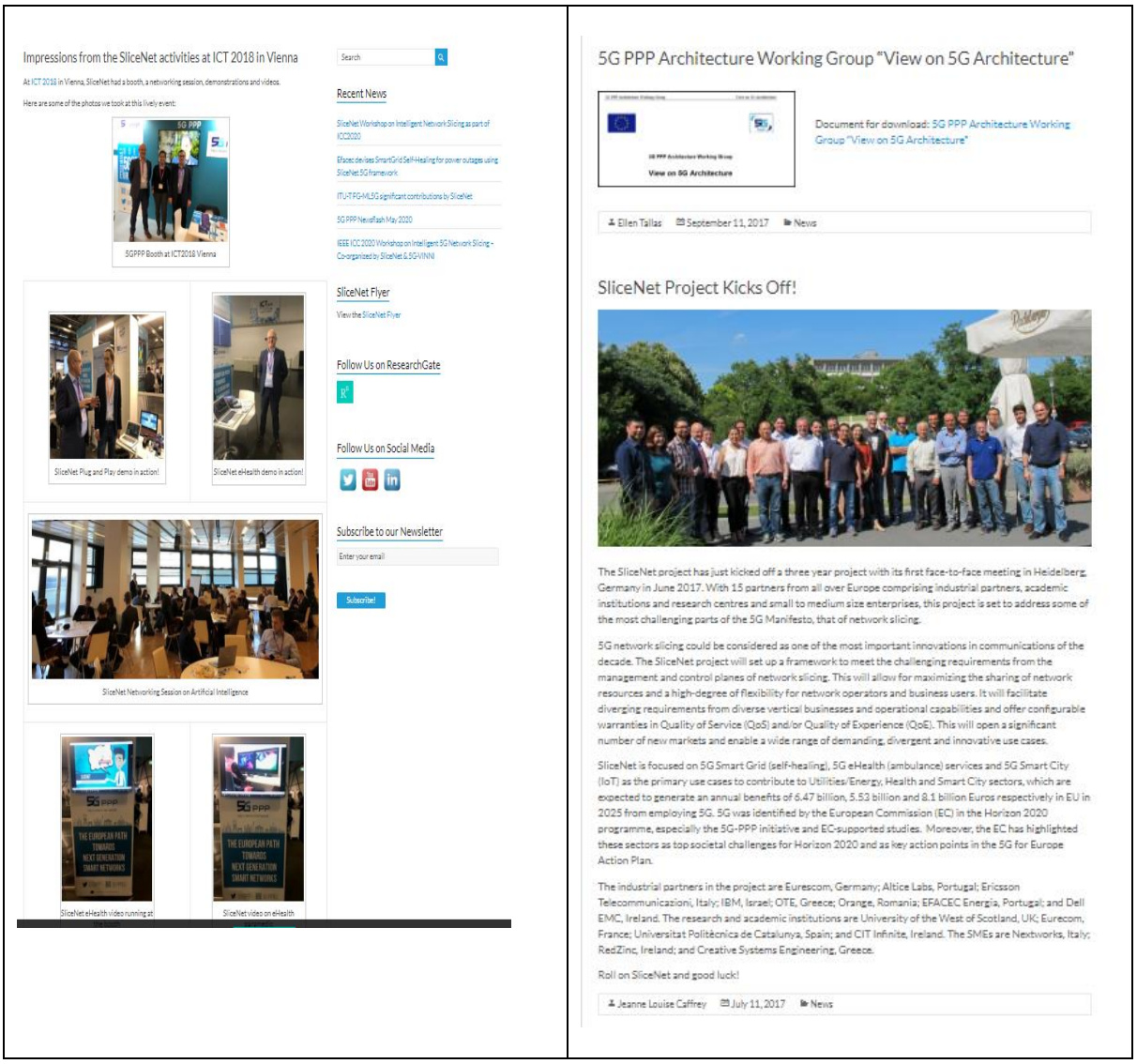


Figure 2 Screenshots of some of the news

For more details of the news, please refer to [2].

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2.5. Social Networking Media

Twitter

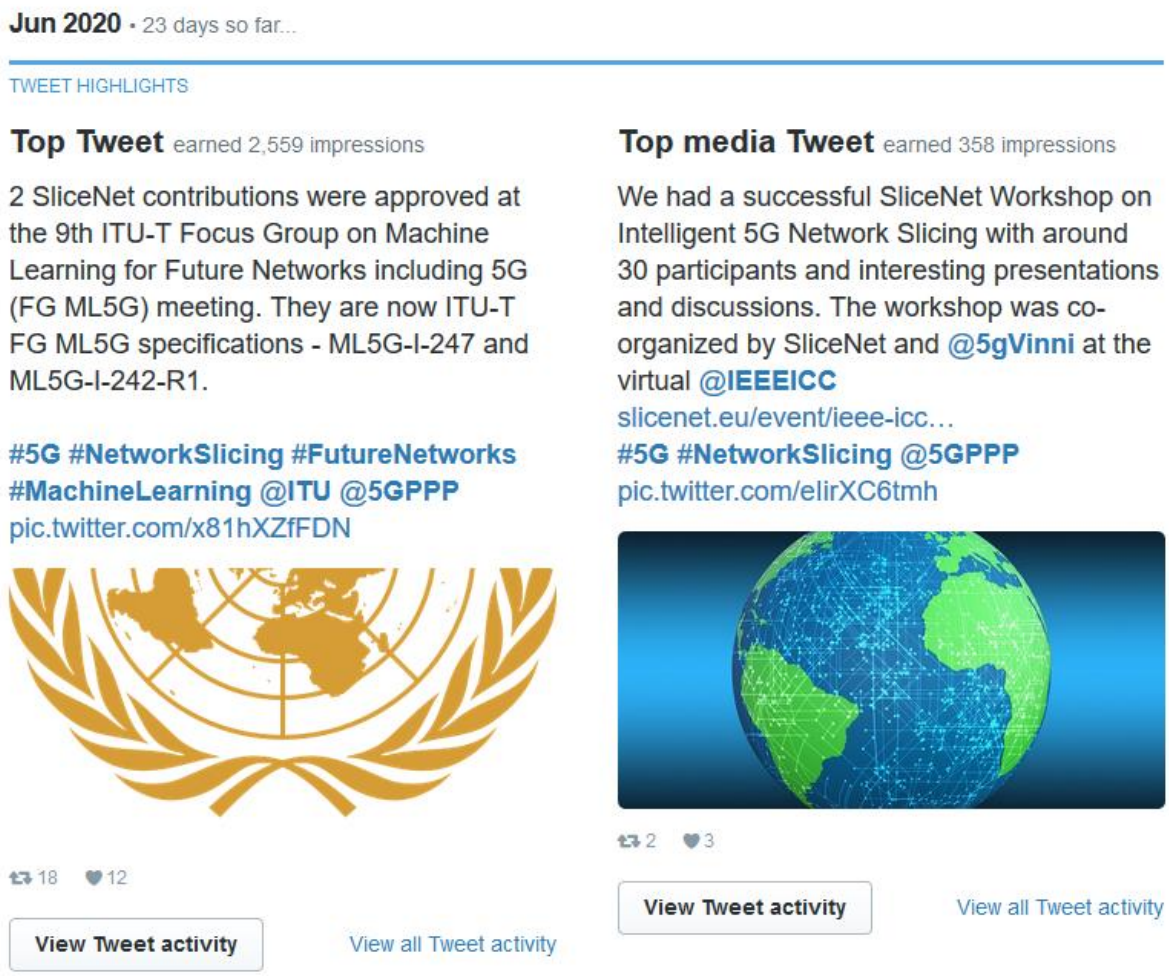

Figure 3 Screenshots of Twitter Post Examples

The SliceNet Twitter account @SliceNet_5G has been the central Social Media channel of the project. It helped promote events and news items towards the target audiences. Figure 3 shows some examples and statistics.

As of 24th June 2020, the project had posted 129 Tweets and attracted 531 followers. In the best month, April 2020, SliceNet achieved 12,800 monthly Tweet impressions. SliceNet's top tweet alone, on the ITU-T contribution (see above), achieved more than 2,500 Tweet impressions. The Twitter account has been instrumental in attracting target audiences to events and raising awareness for the SliceNet results.

LinkedIn

SliceNet has 99 members on LinkedIn. A total of 50 posts were created over the life of the project. Up to 18 likes per post.

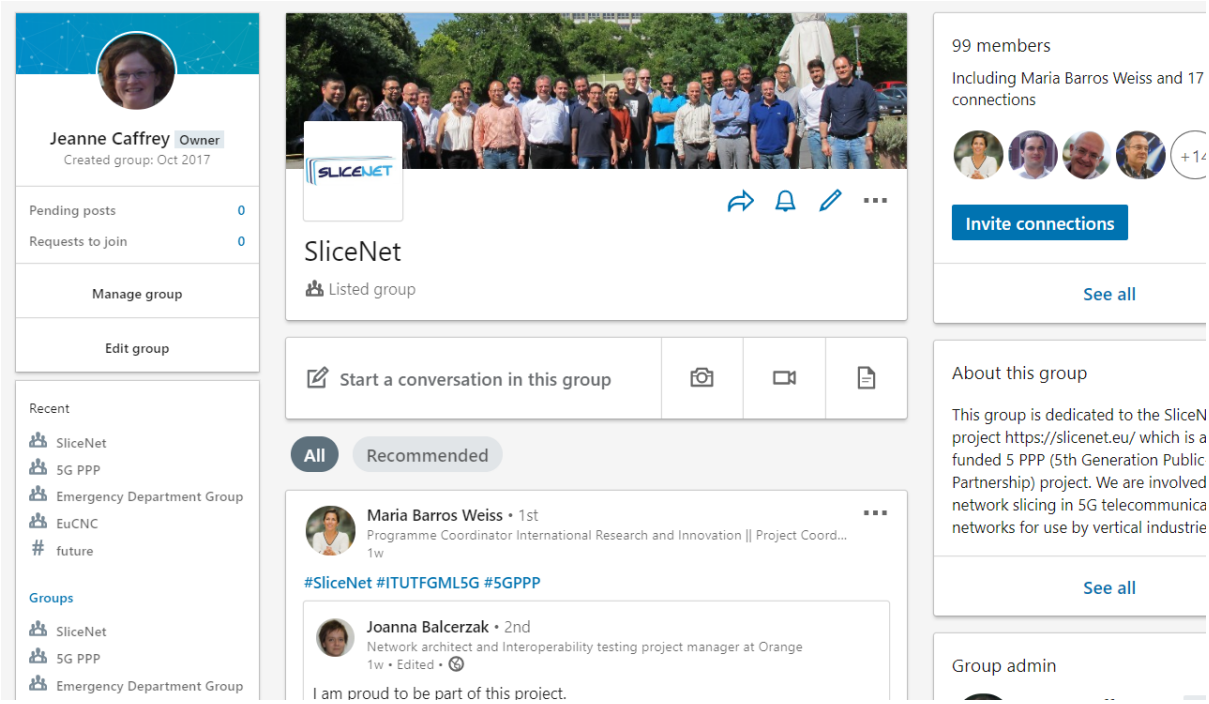

Figure 4 SliceNet Group on LinkedIn – Homepage

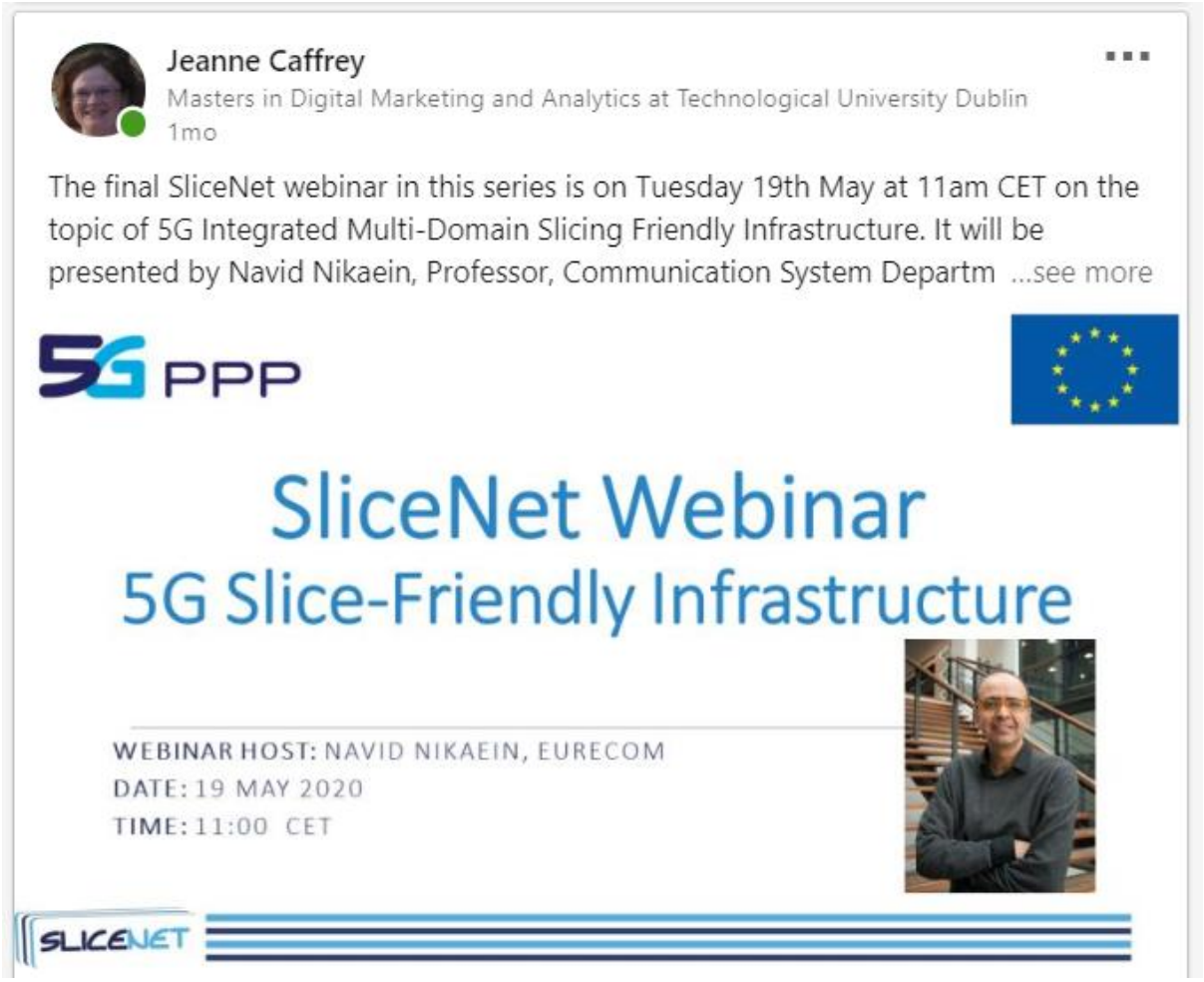

Figure 5 SliceNet LinkedIn Sample Post

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2.6. Project Website

The news section of the website is regularly updated, at least on a two to four weekly basis, with news posts from different partners on project events such as webinars, presentations, publications, project demonstrations, calls for papers, videos created, workshops, Working Group meetings, standardisation meetings, 5GPPP news and events, etc. (See https://slicenet.eu/news/).

There are a number of different publications on the website https://slicenet.eu/publications/ listing all the latest in Deliverables, Conference Publications, Journals, Magazines and Books, and other Videos which are updated regularly. All publications are documented by each partner as they are published.

The Events section of the website https://slicenet.eu/events/ has been updated to present events SliceNet Project Outcomes Webinar Series, List of Event Participation, Cross Project Collaborations and 5G PPP Activities.

The Project Approach and Partners are detailed in a further two sections of the website https://SliceNet.eu/project/ and https://SliceNet.eu/partners/ .

Software contributions section keeps an updated list of all the prototype software which has been created in the project and is publicly available in either open source or licensed format, as well as a list of the PoC software developed in the project.

Figure 6 and Figure 7 show some statistics of the project website for the period of 1 July 2019 to 23 June 2020 (Year 3) and the overall 3-year duration of the project respectively. As can be seen, overall there have been **over 13,000 users of the website**, and over 6,000 new users in the 3rd year, indicating increasing popularity of the project.

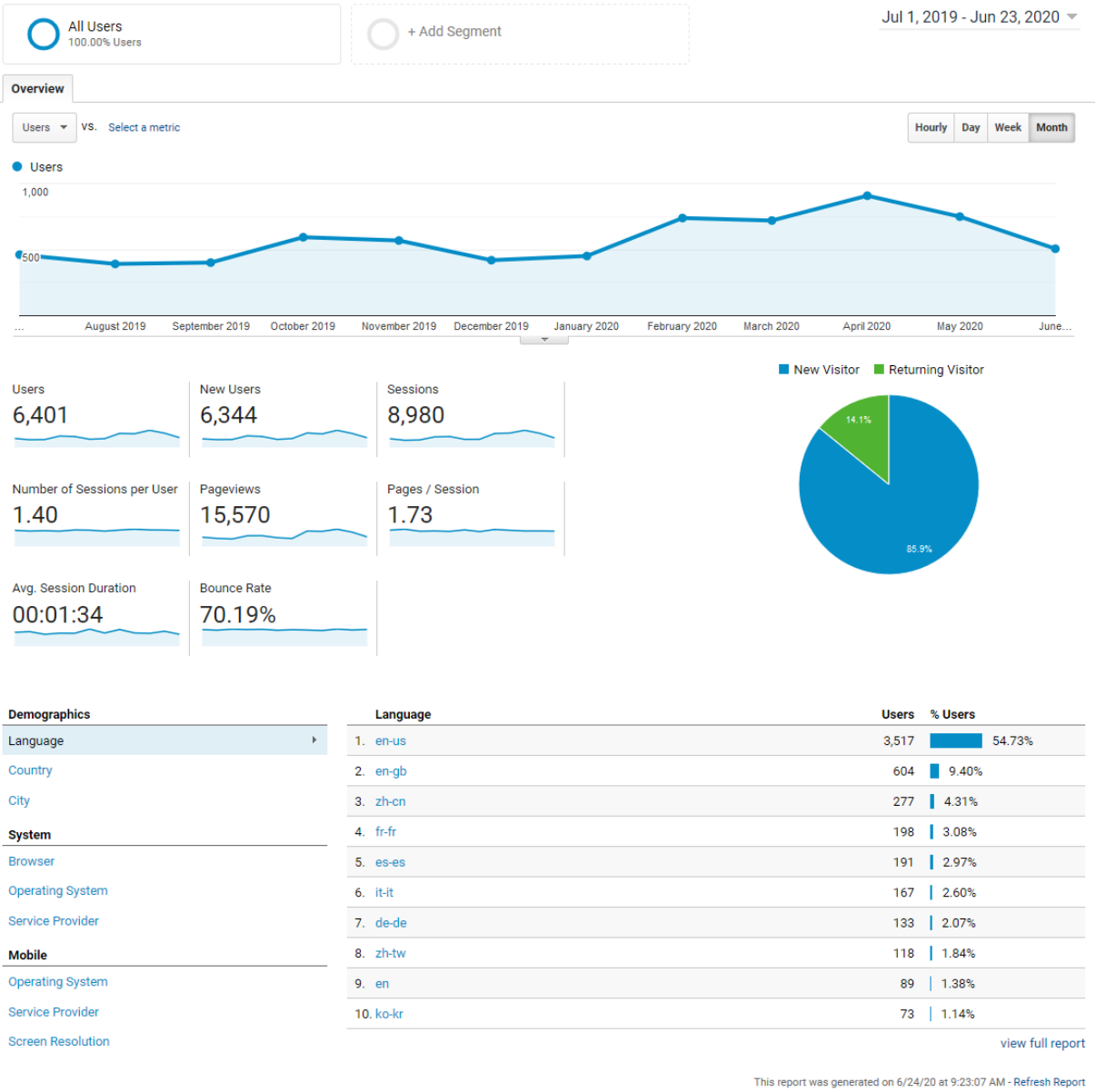

Figure 6 Statistics of SliceNet website: July 2019 to 23 June 2020

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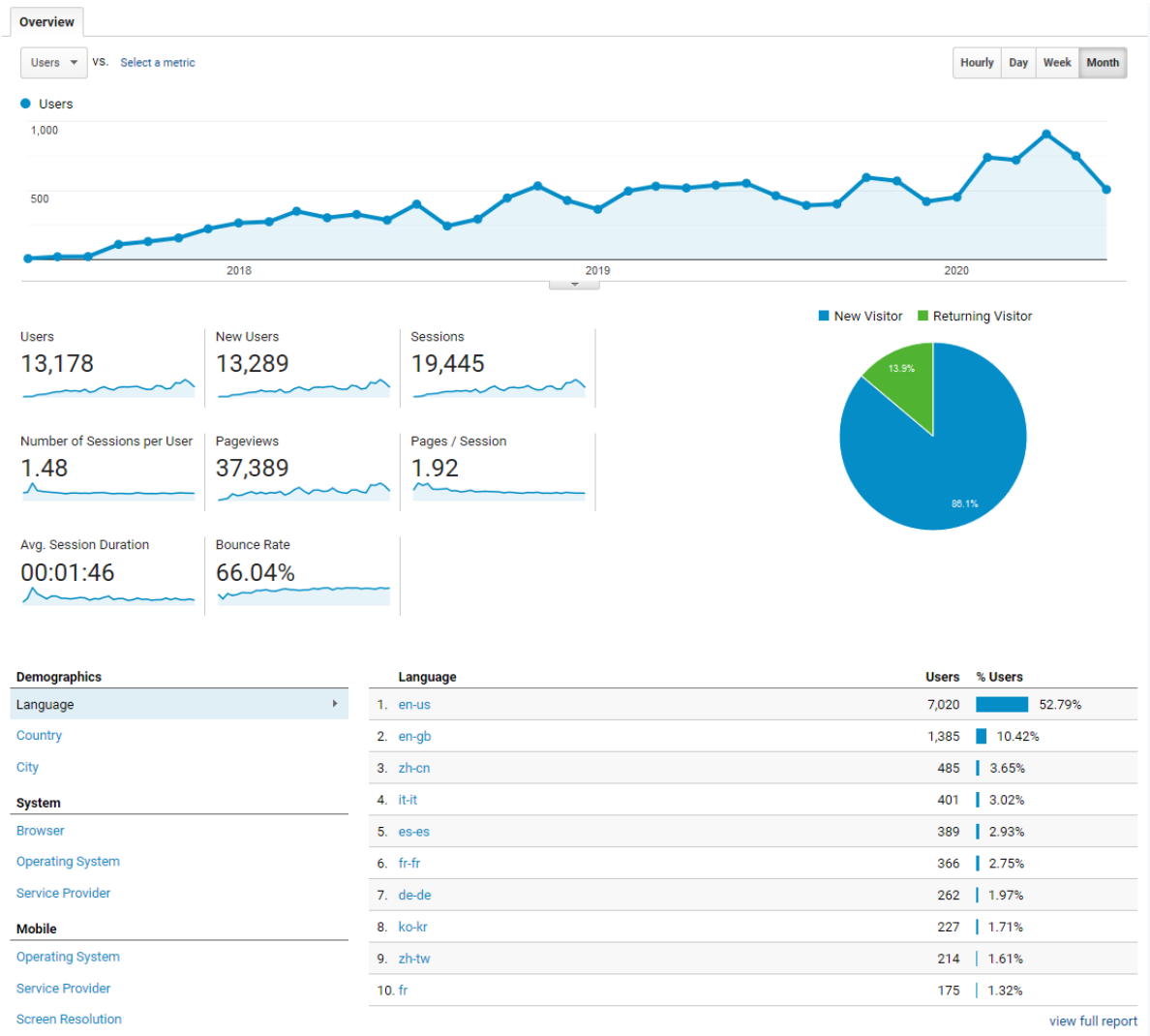

Figure 7 Statistics of SliceNet website: 1 June 2017 to 23 June 2020

For more details of the project website, please refer to [3].

2.7. Webinars

A series of webinars to promote the achievements and innovations of the different aspects of the SliceNet project was created and offered to the public. Each webinar was presented by the corresponding WP leader and was live with a Q&A session at the end for attendees. Promotional material was created and posted/emailed approximately 2 weeks in advance with a reminder email the day before the webinar. Each webinar was promoted in a news post on the website. Each webinar was approximately 30 minutes with 10 minutes Q&A time at the end. The slides were presented in “layman’s terms” so that a non-technical person could understand the content. A suggested agenda was given to keep content consistent across all webinars and each webinar was held on a Tuesday at 11am CET for consistency. Invitations were sent directly to the 5GPPP distribution list, SliceNet members, social media and the website news posts in order to promote the webinars in advance. Each webinar was recorded, and the recording made available on the website

and the SliceNet YouTube Channel. The webinar series was very successful with an **average of 70 registrants per webinar.** Table 6 shows the list of webinars held along the execution of the project.

Table 6 List of SliceNet Webinars

#	WP	Title	Lead Responsible	Date of Webinar	YouTube Link
1	WP 4	5G Multi Domain Slice Control Plane	Ciriaco Angelo, TEI	25 February 2020	https://www.youtube.com/watch?v=plyopOq437Y
2	WP 5	Cognitive, Service-Level QoE Management	Kenneth Nagin, IBM	17 March 2020	https://www.youtube.com/watch?v=mMTzCxLL0-c
3	WP 6	5G Multi domain Slice Management	Thuy Truong, DellEMC	31 March 2020	https://www.youtube.com/watch?v=skyQds_QXAM
4	WP 2	System Architecture	Marius/Cristian Orange Romania	7 April 2020	https://youtu.be/CmDVhT73tSo
5	WP 7	Cross-Plane Orchestration and Use Cases Prototyping	José Cabaça, Altice Labs	21 April 2020	https://www.youtube.com/watch?v=deKSGoHMxJ0
6	WP 8	System Integration and Demonstration	Georgios Tsiouris, OTE	5 May 2020	https://youtu.be/bgJWevMbYKQ
7	WP 3	5G Integrated Multi Domain Slicing Friendly Infrastructure	Navid Nikaein, Ecom	19 May 2020	https://youtu.be/IMTMX-my3Lk

2.8. Dissemination Videos

A number of videos have been created throughout the project and uploaded onto YouTube and promoted on the website and other social media. The webinar series has been recorded and uploaded to YouTube and the website as videos for people to view. Videos created including the following:

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As well as the 7 webinars recorded and uploaded to YouTube, a variety of other videos were created about the project

1. Introduction to SliceNet – Interview with Project Co-ordinators https://www.youtube.com/watch?v=z-T-IbK9pG0
2. eHealth emergency scenario animation video https://www.youtube.com/watch?v=xlpeytrF21Y
3. ICT2018 Nextworks Plug and Play https://www.youtube.com/watch?v=ADWeeOxtwrY
4. Matilda-SliceNet Collaboration Workshop Live Action Video https://www.youtube.com/watch?v=zmxJbxpSTYQ
5. SliceNet project featured in this video EUCNC 2019 & Global 5G Event – 5G for Verticals https://www.youtube.com/watch?v=kPvmUwbzPvI
6. Smart Grid Self-Healing animation video https://www.youtube.com/watch?v=o6duQ9ezWiU&feature=youtu.be

2.9. Demonstrations in Public Events

To showcase the tangible results of the project to the community and wider audiences, the project has performed **10 public demonstrations** (the 11th was prepared but cancelled due to Covid-19) in international venues as described in Table 7, which shows the exhibitions/demos/booths that took place.

Table 7 Summary of Public Demonstrations Conducted by SliceNet Consortium

#	Title of demo	Title of Event	Date	Description
1	Demo: Plug & play network application chaining for multi-service programmability in 5G RAN	MOBISYS 2018	2018-06-10	RAN slicing is one of the key enablers to enable virtualization of a BS and its delivery as a service with different levels of network isolation and sharing so as to accommodate the needs of mobile network operators and verticals. In this demonstration, we show a prototype of a RAN slicing runtime system to enable flexible slice customization on the top of a disaggregated RAN infrastructure with different levels of isolation and sharing in terms of resources and network functions, while retaining the quality of service (QoS) for different slice instances. Furthermore, a novel plug & play network application chaining framework empowered by a network software development kit (SDK) is demonstrated to show how the multi-service programmability on a per-slice basis can be achieved. Our demonstration is based on the OpenAirInterface [4], Mosaic-5G FlexRAN [5] and LL-MEC [6] platforms. Finally, we highlight how the proposed approach can be extended to an end-to-end network slicing scenario.

2	Demo/ Booth RAN Runtime Slicing System	EUCNC 2018	2018-06-18	We demonstrate a prototype of a RAN and CN slicing runtime system with a novel plug and play network application chaining framework empowered by a runtime software development kit (SDK) to show the multi-service programmability on a per slice basis. Our demonstrator is based on a prototype implementation of the OpenAirInterface and Mosaic-5G platforms. We will use three commercial smartphones, 4 Intel-based PCs/Laptops (Intel i7 at 3.4GHz and 8GB RAM) and 2 Ettus USRP B205 RF front-end. The USRP is connected to two of the PCs, over which the eNodeB data plane and the slicing system runtime is deployed. The runtime communicates through an OpenFlow-enabled Open Virtual Switch (OVS) to the multi-access edge computing (MEC) node, where the slice network control application chains of three RAN slices are deployed. Each slice-specific chain is deployed in the form of plug & play virtual network functions on the top of the MEC platform, running in isolation from each other. The eNB also communicates with the third PC, which acts as an EPC (MME and SP-GW) and HSS shared among all three slices.
3	Hardware - Accelerated Firewall for 5G Mobile Networks	P4EU 2018 at IEEE ICNP 2018)	2018-06-22	The evolution from the current Fourth-Generation (4G) networks to emerging Fifth-Generation (5G) technologies implies significant changes in the architecture and poses demanding requirements on network infrastructures. One of the Key Performance Indicators (KPIs) in 5G is to ensure a secure network with zero down time. In this paper, we focus on the provisioning of protection capabilities for 5G infrastructures. Our objective is to implement a new 5G firewall that allows the detection, differentiation and selectively blocking on demand of 5G network traffic in the edge-to-core network segment of a 5G infrastructure, using a novel 5G Field Programmable Gate Arrays (FPGA) based hardware-accelerated framework, developed using P4 language. The proposed 5G firewall prototype has been empirically evaluated to validate the new capabilities. Moreover, an extensive performance, scalability and reliability test of the prototyped system has been carried out in a realistic testbed.

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4	Network Slicing with QoS support in 5G	Third annual ITU IMT-2020/5G Workshop and Demo Day	2018-07-18	Network slicing is one of the key mobile network segments to provide the required flexibility with different levels of resource isolation and sharing for accommodating the needs of mobile network operators and verticals in an end-to-end (E2E) service. The demonstration shows a prototype of a RAN and CN slicing runtime system with novel plug and play network application chaining framework empowered by a runtime software development kit (SDK) to show multi-service programmability on a per slice basis. Through the demonstration, it is shown how the network slicing runtime system enables the dynamic creation of slices with service-level agreement (SLA) support and provides an efficient and flexible resource allocation among the different slices based on per slice quality-of-service (QoS). In addition, a novel plug & play E2E execution environment is offered to customize and control RAN/CN slices as per service requirements. The prototype implementation is based on the OpenAirInterface and Mosaic-5G platform. Specifically, the slicing system runtime communicates through an OpenFlow-enabled OpenVirtual Switch (OVS) to the multi-access edge computing (MEC) node, where the slice network control application chains of three RAN slices is deployed. Each slice-specific chain is set up in the form of virtual network functions (VNFs) on the top of MEC platform, running in isolation from each other.
5	TeleHealth: A Mission Critical 5G Use Case	Mobile World Congress	2019-02-25	5G, IoT, Network Slicing and Multi-Access Edge Computing are transformative to the Telecom architecture, ecosystem and partnerships, as well as operating model. Dell Technologies is at the forefront of 5G innovation and actively participating in EU 5G research projects, relevant standards & open source consortia and with 5G/Edge use case development with the leading Telecom Service Providers. We are leveraging this innovation work to solve real problems as well as increase our understanding of vertical solution requirements and business drivers to build our 5G partner ecosystem. Dell Technologies provides common validated 4G and 5G NFVi and edge computing solutions that are open and integrated with

				both commercial and open source partners.
6	5G Smart Networks	Ministerial Visit to UWS	2019-03-14	UWS presented their R&D outcomes and demos based on the 5G PPP SliceNet and SELFNET project, among other projects, to the Minister for Further Education, Higher Education & Science, Scotland and his colleagues during their visit to the new Lanarkshire campus of UWS on 14th March 2019.
7	Exhibition and Demos – SliceNet – Booth 44 The Smart City demo	EuCNC 2019 – Exhibition & Demonstration booth	2019-06-17	The Smart City demo integrates work from SliceNet and MATILDA projects to show interslice resources conflict mitigation, by onboarding an application in a Marketplace, deploying 2 slices and providing an ML model to monitor slice-level metrics, predict service-level degradation, and locate its source.
8	Demo: "SliceNet eHealth use case"	EuCNC 2019 – Exhibition & Demonstration booth	2019-06-10	The goal of this demo is to show the ability to apply cognitive methods to predict the quality of services as perceived by the vertical in a eHealth use case. This demo shows that the anomaly detection model retrieves periodically QoS metrics from as perceived by a UE in the ambulance. Future signal degradations are predicted using a machine learning algorithm. A notification is sent to the QoE optimizer to ask for correction actions (actuation).
9	Demo: "Cognitive 5G Network Slicing Management for Vertical Businesses – Noisy neighbour detection"	EuCNC 2019 – Exhibition & Demonstration booth	2019-06-10	The goal of this demo is to show the ability to apply cognitive methods to predict the status of the VNF (IoT application) composing the network slice of the smart lighting use case. This demo shows that the noisy neighbour detection model retrieves periodically QoS metrics from the Prometheus server and then requests for correction actions (actuation), based on the predicted VNF status. In this regard, we experiment a situation where the VNF is stressed by another VM located in the same server in order to simulate the noisy neighbour phenomena. Then, we show that the proposed ML model will detect the performance degradation due to noise and finally VNF migration is

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				contemplated as potential actuations to avoid performance degradation
10	The Digital Assembly 2019 has been a forum for stakeholders to take stock of the achievements of the Digital Single Market Strategy.	Digital Assembly 2019	2019-06-13	Orange Romania participated with a demo booth at Digital Assembly 2019, highlighting for the SliceNet project the Smart City use case, demo with lighting pools using ORO testbed infrastructure and also highlighting the other two use cases Smart Grid and eHealth, as a common achievement of the project. An impressive number of visitors were present at the boot, including Mr. Alexandru Petrescu, the Romanian Minister of Communications and Mr. Roberto Viola, Directorate- General for Communications Networks, Content and Technology (DG CONNECT).
11	Exhibition and Demo: "EU 5G-PPP SliceNet Project"	Mobile World Congress 2020	2020-02	Project dissemination with Scotland stand, 5G PPP and 5G Barcelona stands (registered but event cancelled due to Covid-19)

2.10. Additional Events

This section reports highlighted project awareness activities in terms of efforts rather than presenting a normal paper in conferences as reported in Section 2.2. These activities mainly include organising/co-organising workshops/panels/special sessions in events, presenting the project as keynote speakers or panellists, or providing tutorials in the context of the project. In that sense, SliceNet has a significant contribution to several international events considered relevant for the project topics. A summary of **19 such contributions** are presented in Table 8.

Table 8 Summary of Events (Organisation, Panels, Keynotes and Tutorials)

ID	Event	Activities	Activity type	Venue and year (in Bold if out of Europe)
1	IEEE ICC 2020	Co-organisation of Workshop on Intelligent 5G Network Slicing, in collaboration with 5G-VINNI	- Workshop organisation and chairing	Virtual, 2020
2	IEEE ICC 2020	Keynote speech for Workshop on Intelligent 5G Network Slicing, in collaboration with 5G-VINNI	- Keynote	Virtual, 2020
3	IEEE ONDM 2020	Co-organization of Workshop The role of computing in the post 5G-era: Architectures and enabling technologies	- Workshop organisation and chairing	Virtual, 2020
4	EuCNC 2020	Co-organisation of Workshop on 5G Verticals (proposal submitted but event cancelled due to Covid-19)	- Workshop organisation	Dubrovnik Croatia, 2020
5	IEEE 5G World Forum 2019	Workshop Organisation: 2nd Workshop on 5G-Trials – From 5G Experiments to Business Validation	- Workshop organisation and chairing	Dresden, Germany, 2019
6	5th IEEE International Conference on Network Softwarization (NetSoft) 2019	Organisation of 2nd Workshop on Advances in Slicing for Softwarized Infrastructures	- Workshop organisation and chairing	Paris, France, 2019
7	EuCNC 2019	Co-organisation of Workshop 2 – From Cloud-ready to Cloud-native transformation	- Workshop organisation and chairing	Valencia, Spain, 2019
8	EuCNC 2019	Organisation of Workshop 7 – Artificial Intelligence for 5G Networks	- Workshop organisation and chairing	Valencia, Spain, 2019

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9	IEEE Global Communications Conference (GLOBECOM) 2018	Organisation and moderation for IEEE GLOBECOM 2018 Industry Panel on 5G Network Slice Management	- Panel organisation and chairing	Abu Dhabi, **UAE**, 2018
10	The 12th International Conference on Communications – COMM2018	Steps towards the future of telecom	- Keynote	Bucharest, Romania, 2018
11	COMM 2018 international conference	5G Network Architecture, Functional Model and Business Role for 5G Smart City Use Case: Mobile Operator Perspective	- Keynote	Bucharest, Romania, 2018
12	IEEE/IFIP Network Operations and Management Symposium (NOMS) 2018	RAN slicing: challenges, technologies, and tools	- Tutorial	Taipei, **China**, 2018
13	Annual Conference of the ACM Special Interest Group on Data Communication (SIGCOMM) 2018	RAN slicing: challenges, technologies, and tools	- Tutorial	Budapest, Hungary, 2018
14	EuCNC 2018	Co-organisation of Workshop ''From cloud ready to cloud native transformation: What it means and Why it matters'': Future network transformation 5G cloud architectures	- Workshop organisation and chairing	Ljubljana, Slovenia, 2018
15	IEEE Conference on Standards for Communications and Networking 2018	E2E Cognitive Slice Management	- Keynote	Paris, France, 2018
16	EuCNC 2018	Panellist for PANEL 3 Network Slicing: Real-world Opportunities with Open Standards and Open Source	- Panellist	Ljubljana, Slovenia, 2018

17	EuCNC 2017	Panellist for PANEL 3 What is the benefit of Slicing in 5G?	- Panellist	Oulu, Finland, 2017
18	ETSI ENI and SliceNet Workshop in London	Collaboration between ETSI ISG ENI and SliceNet at Workshop in London	- Workshop organisation and chairing	London, UK, 2017
19	Cisco Connect 2017	Systems and networks evolution for the next 5G business services	- Keynote	Bucharest, Romania, 2017

2.11. Brochures and Other Dissemination Materials

Posters were created and printed for the various events at which SliceNet had a booth in order to illustrate the project goals and outcomes. A fact sheet was created and printed for use on the 5GPPP stand and website. A brochure was created for events such as EuCNC and MWC and updated every year of the project as the information emerged. The most recent version of the brochure is shown in Figure 8.

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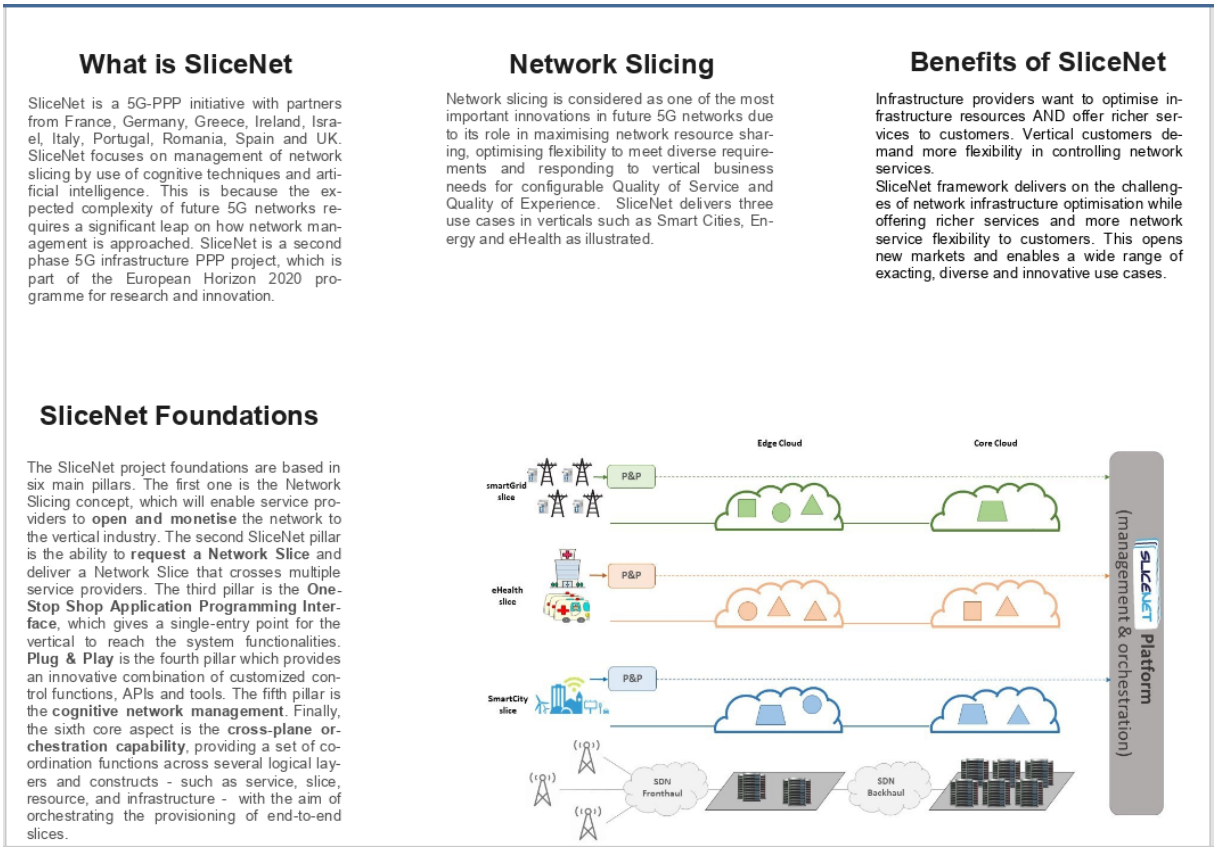

Figure 8 SliceNet Brochure

2.12. Press Releases

Orange Romania Press Release

Orange's first commercial 5G network launched in Romania

05/11/2019, Paris, France

Orange Romania is first within the Orange footprint to launch 5G commercial offer uniquely tied to latest technology innovations and premium services exclusive to Orange Romania 5G launches in three main cities initially: Bucharest, Cluj-Napoca and lasi.

Orange Romania is first within the Orange footprint to launch 5G.

5G commercial offer uniquely tied to latest technology innovations and premium services exclusive to Orange Romania.

5G launches in three main cities initially: Bucharest, Cluj-Napoca and lasi.

See full Press Release here:

https://www.orange.com/en/Press-Room/press-releases/press-releases-2019/Orange-s-first-commercial-5G-network-launched-in-Romania

RedZinc Press Release

SliceNet overlay on 4G network in response to Covid-19 pandemic

11/06/2020, Cork, Ireland

RedZinc, a mobile video telemedicine software company, has responded to the Covid-19 crisis by pivoting technology developed as part of the SliceNet project into a new telemedicine solution for outpatient clinics.

The video platform is currently being used by the Irish Health Service Executive healthcare professionals to provide video consultations to their patients due to the Covid-19 lockdown.

Full press release available on the project website.

2.13. Evaluation of Dissemination Outcomes vs. DoW

Table 9 compares the actual dissemination outcomes with the planned dissemination targets in the Dow. As can be seen, all the planned KPIs have been successfully met, and in most cases the targets have been exceeded significantly. This result shows that the project has performed very successfully in the various dissemination tasks.

Table 9 Dissemination KPIs in the DoW vs. Actual Dissemination Outcomes

Dissemination Activity	Target Value	Actual Value
Participation in EC and 5G-PPP clustering mechanisms	Part. In all meetings	Part. In all meetings
Workshop and Summer School or winter school collocated with Hackathons	1 or twice	**2** ● Cork, Ireland, Sept 2018 ● Barcelona, Spain, Feb 2019
Publications and Presentations in International Conferences (Peer-Reviewed Papers) and Journal Publications (International Refereed Journals)	>=30	**59** ● Journal:15 (14 published, 1 under review); ● Conference: 44
Publications in Magazines and Blogs	>=8	**8** ● Magazines: 6 published, 2 under review
Newsletter Issues	2 per year	**6 published in total**
Participation in Public Exhibitions and Public Demonstrations	>=5	**9**
White Papers and Case Studies	>=4	**13** ● 5G-PPP white papers: 11 ● 5G-PPP brochures: 2
Production of SliceNet leaflets	2	**3 published:** ● 1 leaflet with various versions for EuCNC ● 1 leaflet with various versions for MWC etc. ● 1 fact sheet
Participation in major events outside Europe	>=3	**10** ● IEEE CCNC 2020, USA ● IEEE Globecom 2018, UAE ● IEEE NOMS 2018, China ● etc.
Standardisation meetings participation	1 per year	**7** ● 6 official Work Items or

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		Proof of Concept created in ETSI and ITU (refer to standardisation section for details) ● Organised numerous weekly meetings with ITU/ETSI ● 1 IETF draft

3. Standardisation

This section presents a summary of the contributions, status and plans, and potential impact. Significant achievements have been made, especially in the final year of the project with more technical outcomes becoming available. It is noted that the participating partners have committed to continue collaboration for ongoing standardisation activities, e.g., the work-in-progress technical specification in ETSI GANA.

3.1. Proof-of-Concept Contribution to ETSI ENI

SliceNet has a PoC with ETSI ENI on "Predictive Fault management of E2E Multi-domain Network Slices". The PoC addresses Network Slice Management where an end to end (E2E) Network Slice, composed of several Network Slices (NS) is provided across multiple administrative domains. In this PoC the prediction of a faulty behaviour on one of these NS is performed by making use of AI/ML mechanisms and will trigger policy-based actions that will proactively make the necessary modifications to guarantee the E2E Network Slice availability with the committed SLA.

The PoC (ENI(19)000055) can be download from the SliceNet site at:

https://slicenet.eu/wp-content/uploads/2019/07/PoC_proposal_for_Fault-prediction-and-E2E-Network-Slice-Mngmt-V1.0.pdf

3.2. Contribution to ETSI GANA

This is a new ETSI Technical Report "Autonomic network engineering for the self-managing Future Internet (AFI); Implementing Network and Federated GANA Knowledge Plane for Autonomic Management and control of Slices in 5G E2E Architecture" under ETSI INT work item INT(20)045021.
This technical report presents a plausible approach to implementing Federated GANA Knowledge Planes (KPs) Platforms for E2E Multi-Domain Federated Autonomic Management and Control (AMC) of Slices in NGMN E2E 5G Architecture, using components prototyped and implemented in the European Union (EU) funded SliceNet Project (Grant Agreement N° 761913). The work produces and leverages a mapping of architectural components for autonomic network management & control developed/implemented in the European Union (EU) funded SliceNet Project (Grant Agreement N° 761913) to the ETSI TC INT AFI Generic Autonomic Networking Architecture (GANA) model – an architectural reference model for autonomic networking, cognitive networking and self-management. The mapping identifies the components that were prototyped in SliceNet Project that can be used to implement specific GANA Functional Blocks (FBs) for Autonomics and their associated Reference Points (Rfps), while providing the illustrations that help implementers of GANA autonomics in 5G networks.

It addresses the following subjects:

- Principles for Autonomic Networking and Autonomic Management & Control (AMC), and Enablers
- SliceNet architecture
- Impact of MEC, Network Slicing and Hardware Acceleration to the SliceNet Concepts and Principles
- GANA in ETSI 5G PoC Implementations by the Industry
- Mapping of SliceNet architecture components to GANA Concepts and Architectural Principles
- Addressing the AMC Requirements to 5G E2E Architecture

Working documents:

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https://onlyoffice.eurescom.eu/Products/Files/doceditor.aspx?fileid=31595

3.3. Contribution 1 to ITU-T Focus Group ML5G under SG13

This is a new ITU-T Focus Group ML 5G draft recommendation, under ITU-T SG13. The document is registered under ML5G-I-247 (formerly ML5G-I-230) number with the title – "Machine learning based end-to-end network slice management and orchestration". This Recommendation provides the framework and requirements of machine learning based end-to-end network slice management and orchestration in multi-domain environments. It addresses the following subjects:

- Requirements and challenges analysis of machine learning based end-to-end (E2E) multi-domain network slice management and orchestration
- Framework of ML-based E2E multi-domain network slice management and orchestration
- Cognitive management and security management of ML-based E2E multi-domain network slice management and orchestration
- Security considerations in machine learning based multi-domain end-to-end network slice management and orchestration
- Appendix with an overview of the SliceNet Project, the Smart Grid Vertical Service Use Case and the eHealth Vertical Service Use Case

Working documents:

https://onlyoffice.eurescom.eu/Products/Files/doceditor.aspx?fileid=31772

3.4. Contribution 2 to ITU-T Focus Group ML5G under SG13

The document is registered in ITU-T Focus Group ML5G under ML5G-I-242-R1 (formerly ML5G-I-231) with the title "Vertical-assisted Network Slicing Based on a Cognitive Framework".

This contribution proposes a new framework that enables vertical QoE-aware network slice management empowered by machine learning technologies.

It addresses the following aspects:

- Use Case Requirements
- Overall architecture and API
- Vertical QoE feedback
- QoE/QoS mapping
- One Stop shop Access (OSA) Service
- Control Plane
- eHealth Use Case (described to provide a concrete example of this approach)
- Conclusions
- Appendix with contributions on "Anomaly prediction and integration for eHealth use case based on vertical feedback" and "Noisy neighbour detection and integration in a virtualized infrastructure"

Working documents:

https://onlyoffice.eurescom.eu/Products/Files/doceditor.aspx?fileid=31759

3.5. Contribution 3 to ITU-T Focus Group ML5G under SG13

The document is registered in ITU-T Focus Group ML5G under ML5G-I-198-R1 (formerly ML5G-I-198) with the title "Anomaly prediction and integration for eHealth use case based on vertical feedback".

This contribution presents a ML model that aims to forecast the signal degradation using vertical feedback. Proposed anomaly detection model serves as an intelligent QoE sensor by analysing the data samples related to perceived quality of the service called “quality of perception” (QoP) optimal QoE levels. By forecasting the perceived signal strength degradation, the network maintainers may be alerted in advance and the issue could be solved before it occurs and this will allow maintaining the perceived quality of the slices’ services but also it can allow the vertical to supervise its slice and to interact with the network. This model is integrated in eHealth Use Case.

It addresses the following aspects:

- QoE/ QoS/QoP definitions
- eHealth use case overview
- Architecture for ML-aided network management
- Data and model description
- Experimentation results

Working documents:

https://onlyoffice.eurescom.eu/products/projects/tmdocs.aspx?prjID=79#6513

3.6. Contribution 4 to ITU-T Focus Group ML5G under SG13

The document is registered in ITU-T Focus Group ML5G under ML5G-I-199 with the title “Noisy neighbour detection and integration in a virtualized infrastructure”.

This contribution presents a ML model that aims to detect noisy neighbours in a virtualized infrastructure. Proposed noisy neighbour analytical workflow to determine if a Virtual Network Function (VNF) instance belonging to a slice is being subject to CPU noise coming from another VNF instance collocated into the same physical server or if the VNF is being overloaded due to its internal processes. This model is integrated in Smart City Use Case that implements Intelligent Public Lighting system.

It addresses the following aspects:

- Testbed and data description
- Experimentation results
- Architecture for ML-aided network management
- Noisy neighbour integration within SliceNet architecture

Working documents:

https://onlyoffice.eurescom.eu/Products/Files/doceditor.aspx?fileid=25078

Resilient 5G slices in eHealth and Smart City use cases presentation registered in ITU -T Focus Group ML5G under ML5G-I-204 summarized two contributions ML5G-I-199 and ML5G-I-198.

3.7. Contribution 5 to IETF

SliceNet system architecture and definition of Slice has been discussed with Ericsson representatives at IETF to start and contribute to the Internet-Draft “IETF Definition of Transport Slice”.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). The draft is still active being worked on by the IETF [Teas] Network Slicing Design Team and current live version can be found at V05-draft-nsdt-teas-transport-slice-definition.

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3.8. Per-Partner Standardisation Strategy

Table 10 lists individual partner's standardisation strategy, including both contributions made during the lifetime of the project and also a plan after the project.

Table 10 Per-Partner Standardisation Strategy

Partner	Contributions in the Project (Including contributions to the specific standardisation work items to ETSI, ITU)	Plans beyond the Project
ALB	- Contributed to ETSI ENI POC - Contributed to ETSI INT AFI (GANA) - Contributed to ITU-T FG ML5G Wis 242-R1, 247	- Communicate final project results to ETSI, where Altice is a full member; - Continue collaboration with ETSI by proposing a PoC to recommend, amongst several Network Slices, the most appropriate for a given vertical (AI/ML based recommendations); - Continue collaboration with ITU-T in the 5G, Network Slicing and AI/ML domains
UWS	Participation and actively contributed in all standardisation meetings, and the following contributions: - Contributed to ETSI INT AFI (GANA) - Contributed to ITU-T FG ML5G Wis 242-R1, 247 - Contributed to ETSI ENI and SliceNet workshops	- Continue collaboration with ITU-T especially FG ML5G - Continue collaboration with ETSI especially ENI
OFR	- Contributed to ETSI INT AFI (GANA) - Work item rapporteur in ETSI INT Contributed to ITU-T FG ML5G (198-R1, 199, 242-R1, 247)	- Continue collaboration with Orange standards representatives for AI/ML, QoE, 5G Slicing - Continue collaboration with ETSI INT and ITU-T FG ML5G
UPC	Participation and actively contributed in all standardisation meetings, and the following specific contributions: - Contributed to ETSI INT AFI (GANA) - Contributed to ITU-T FG ML5G 242-R1 and 247 - Supported the ETSI ENI PoC	UPC will continue to collaborate with SliceNet partners to support the work contributed to ITU-T FG ML5G and promoted to SG13. UPC will continue to collaborate with SliceNet partners to support the work contributed to ETSI about mapping between SliceNet and GANA architectures.
NXW	Active contribution and participation to the SliceNet joint standardization activities, with focus on: - Contributed to ETSI INT AFI (GANA) - Contributed to ITU-T FG ML5G 242-	Nextworks plans to continue to support the work contributed to ITU-T FG ML5G

	R1 and 247	
TEI	- Shared results and collaboration with Ericsson IETF representatives for Internet-Draft "IETF Definition of Transport Slice" -Dissemination and collaboration with Ericsson ETSI / 3GPP representatives -Supported the ENI PoC with TEI needed components-integration - Contributed to ETSI GANA - Contributed to ITU-T FG M-I-242-R1	Analyse SliceNet project results and technical achievements with Ericsson standardization representatives to understand possible re-use of SliceNet solutions
IBM	- Continuously shared project's ambition and results with internal IBM representative in ETSI - Evaluated through internal channels IBM's stakes at participating at different workgroups under ETSI - Formally supported consortium's participation in ETSI INT - Provided technical contributions to ETSI INT - Provided technical contributions to ITU-T FG ML5G	- Communicate final project results to IBM's standards representatives, especially in ETSI, where IBM is a full member, to ensure continuation of the standardization effort beyond the project's lifetime.
OTE	Disseminated the project achievements through the internal DT and OTE communication portal. Participation in ETSI ENI Group.	Continued participation in ETSI ENI and possibly other Groups.
ORO	**-** Contributed to ETSI INT AFI (GANA) for Smart City use case - Dissemination and collaboration with slicing concepts in Software Network working group - 5G-PPP active contribution for trials	Continue participation in ETSI and other 5G-PPP groups
DellEMC	- Dissemination and collaboration with Dell O-RAN representatives and the O-RAN WG1 Network Slicing Tasking Group. - Participation and actively contributed in all standardisation meetings - Participation and actively contributed to ETSI INT AFI (GANA) - Participation and actively contributed to ITU-T FG ML5G Wis 242-R1, 247	- Continue collaboration with ITU-T especially FG ML5G - Continue collaboration with ETSI - Continue contribution in the O-RAN WG1 Network Slicing Task

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	- Participation and actively contributed to the 5G Infrastructure PPP Trials & Pilots	
CIT	- A PhD project started in 2019/2020 focussed on the continuation of the SliceNet work on QoE and QoS standardisation funded by the Science Foundation Ireland Centre for Research Training in Advanced Networks for Sustainable Societies led by CIT	- Plan new postdoctoral projects related to SliceNet standardisations at ELITE-S for Future Leadership in ICT and Standardization in Europe where CIT is partner
CSE	- Contributed to the joint activities relating to ETSI INT AFI (GANA) and ITU-T FG ML 5G	CSE will follow the two activities and continue contributing jointly with the other partners. In case future projects emerge that are relevant to these activities, CSE will try to evolve further the concepts as well as adopt and align future developments with the current status of the related standards.

4. Exploitation

This section reports the exploitation outcomes and plans, including project assets beyond open source software, open source software contributions, and per-partner exploitation strategy.

4.1. Project Assets

Table 11 is the list of licensed software developed in the framework of the SliceNet project (other than open source software). In particular, the different software components released are reported, including the component's responsible partner, the license framework and, finally, the link to the code repository.

Table 11 List of Licensed Software Developed in SliceNet

Component	Responsible Partner	License	Source/Binary code
OAI Radio Access Network (OAI-RAN)	ECOM	OAI 5G Public License	https://gitlab.eurecom.fr/oai/openairinterface5g/
OAI Core Network (OAI-CN)	ECOM	Apache 2.0	https://github.com/openairinterface
FlexRAN	ECOM	Apache 2.0	https://gitlab.eurecom.fr/flexran/flexran-rtc
LL-MEC	ECOM	Apache 2.0	https://gitlab.eurecom.fr/mosaic5g/ll-mec
RAN Adapter	ECOM	Apache 2.0	https://gitlab.eurecom.fr/mosaic5g/store/tree/feature-adapter-slicenet
MEC/Core Adapter	ECOM	Apache 2.0	https://gitlab.eurecom.fr/mosaic5g/store/tree/feature-adapter-slicenet
One Stop API (OSA)	CSE	Copyright © CSE Ltd. 2020. All rights reserved.	https://gitlab.com/slicenet/osa
WAN Adapter	RZ	Copyright © Red Zinc Services 2020. All rights reserved.	https://gitlab.com/slicenet/wp4/tree/develop/WAN/WANAdapter
CPSR	TEI	Copyright © Ericsson AB 2019. All rights reserved.	https://gitlab.com/slicenet/wp4/container_registry
QoS Control Service	TEI	Copyright © Ericsson AB 2019. All rights	https://gitlab.com/slicenet/wp4/container_registry

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		reserved.	
IPC Control Service	TEI	Copyright © Ericsson AB 2019. All rights reserved.	https://gitlab.com/slicenet/wp4/container_registry
NF-CONFIG	CSE	Copyright © CSE Ltd. 2020. All rights reserved.	https://gitlab.com/slicenet/wp4/-/tree/develop/NF-CONFIG
BKH Adapter	TEI	Copyright © Ericsson AB 2019. All rights reserved.	https://gitlab.com/slicenet/wp4/container_registry
FMM	TEI	Copyright © Ericsson AB 2019. All rights reserved.	https://gitlab.com/slicenet/wp6-fcaps/container_registry
BCKHL DPP Adapter	UWS	Apache 2.0	https://gitlab.com/slicenet/cp-bkhl-dpp-a
Plug & Play Control (core and plugins)	NXW	Apache 2.0	https://gitlab.com/slicenet/plug-and-play-control
QoE plugin	UPC	Apache 2.0	https://gitlab.com/slicenet/qoe-plugin
Flow Control Agent (FCA)	UWS	Apache 2.0	https://gitlab.com/slicenet/fca
Flow Monitoring Agent (FMA)	UWS	Apache 2.0	https://gitlab.com/slicenet/fm
DP UWS API (DPWA)/FCA	UWS	Apache 2.0	https://gitlab.com/slicenet/fca
QoE REST Client	UPC	Apache 2.0	https://gitlab.com/slicenet/qoe-rest-client
QoE Optimizer	UPC	Apache 2.0	https://gitlab.com/slicenet/qoe-optimizer
Policy Manager	ALB	Apache 2.0	https://github.com/onap/policy-engine
RAN NS Prediction Model	ALB	Apache 2.0	https://gitlab.com/slicenet/cog-model-wrapper
FCAPS-Manager	CSE	Copyright © CSE Ltd. 2020. All rights reserved.	https://gitlab.com/slicenet/wp6-fcaps
FCAPS TAL	CSE	Copyright © CSE Ltd.	https://gitlab.com/slicenet/w

		2020. All rights reserved.	p6-fcaps
P&P Manager	NXW	Apache 2.0	https://gitlab.com/slicenet/plug-and-play-manager
Slice and Service Orchestrator (SSO)	NXW	Apache 2.0	https://github.com/nextworks-it/slicer/tree/slicenet
Network Domain and Resource Orchestrator (NMR-O)	UPC	Apache 2.0	https://gitlab.com/slicenet/nmro; https://gitlab.com/slicenet/nmro-driver
SliceNet TeleStroke application (2020 version)	CIT	Apache 2.0	https://github.com/praveenjoshi01/Slicenet2020_TeleStroke_POC
Anomaly detection Machine learning model	OFR	GNU General Public License	https://gitlab.com/slicenet/anomaly_detection
Noisy 48ransform machine learning model	OFR	Apache 2.0	https://gitlab.com/slicenet/noisy-neighbor
SliceNet TeleStroke application with E2E encryption	DELL	Apache 2.0	https://gitlab.com/slicenet/wp6/-/tree/master/sslconnection-ehealthUC
SliceNet TeleStroke application with SSL connection and archiver with encrypted data	DELL	Apache 2.0	https://gitlab.com/slicenet/wp6/-/tree/master/Archiver-with-EncryptionService
vFirewall supporting REST API calls for NF config	DELL	Apache 2.0	https://gitlab.com/slicenet/wp6/-/tree/master/vFirewall-HttPServer
vEncryption package to support automated deployment in OpenMANO OSM	DELL	Apache 2.0	https://gitlab.com/slicenet/wp6/-/tree/master/vEncryption
Traffic Analysis, Anomaly Detection in Network Traffic	DELL	Apache 2.0	https://gitlab.com/slicenet/wp6/-/tree/master/AnomalyDetection-eHealthUC

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4.2. Open Source Software

Table 12 is the list of open source software developed in the framework of the SliceNet project. In particular, the different software components released are reported, including the name of the component, the responsible partner, the main functionality supported by the component, the deliverables where it has been reported and finally, the link to the code repository.

Table 12 SliceNet Contributions to Open Source Software

#	Name of the Software	Lead Partner	Main Functionality	Deliverable ID	Link to the SW
1	Open vSwitch (OVS)-based 5G traffic	UWS	Enable traffic classification and control in 5G/LTE.	D5.6	https://gitlab.com/slicenet/openvswitch
2	SkyDive	IBM	Skydive is an open source real-time network topology and protocols analyser providing a comprehensive way of understanding what is happening in your network infrastructure. Skydive is used by SliceNet's network traffic and topology monitor.	D5.6, D5.7, D6.6, D6.7, D8.5	https://github.com/skydive-project/skydive
3	OpenWhisk	IBM	Apache OpenWhisk is an open source, distributed Serverless platform that executes functions (fx) in response to events at any scale. In SliceNet, OpenWhisk is used to deploy the RAN Degradation ML Model used in the Smart Grid UC.	D8.5	https://github.com/apache/openwhisk
4	ONAP	ALB	ONAP provides a comprehensive platform for real-time, policy-driven orchestration and automation of physical and virtual network functions.	D5.6 & D5.7, D8.5	https://github.com/onap/policy-engine

For more details of the software contributions, please refer to [7].

4.3. Per-Partner Exploitation Activities and Strategies

The consortium is grouped into Industries, SMEs and Academia. In the following, each partner under their corresponding group presents their own exploitation strategy, activities and/or exploitable outcomes from SliceNet, and exploitation plan beyond the project.

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Industries

ORO

1) Overall exploitation strategy

ORO, apart from using its IP as background for other EU projects, is completely dedicated to commercial activities regarding its results in the SliceNet project. During the project, ORO deployed 56 lamps for the Polytechnics University of Bucharest which will assure the lighting solution for its campus. This will stand as proof of concept for the intelligent lighting solution developed within SliceNet. At the same time, ORO is working closely with over 10 City Halls (including Bucharest) where ORO promotes its capabilities related to smart city solutions, including the intelligent lighting solution. ORO is also present in international conferences/workshops (e.g. Digital Assembly, EuCNC, MWC) presenting its solution and building future partnerships. ORO is considering a SliceNet 5G framework to be used to orchestrate the end to end life cycle of 5G ready applications over ORO programmable infrastructure to be commercially deployed in the next couple of years.

2) Exploitation activities and/or exploitable outcomes

In February 2019 ORO held in Alba Iulia the ''Intelligent lighting solutions workshop'' with Alba Iulia City Manager, his team and with the participation of the Lighting Services Operator that is currently providing services to Alba Iulia Municipality. In April 2020 ORO organized an online seminar on ''Intelligent lighting solutions'' with Iasi City Manager, his team and with the participation of the Lighting Services Operator that is currently providing services to Iasi Municipality. The audience was based on the Municipalities representatives from Iasi and Alba Iulia but also the representatives of the Lighting Services Operator that is providing services to the two municipalities. ORO was represented by the Orange Business Services experts in charge with the IoT Platforms and Services MKT, Sales and Pre-Sales activities and Development & Innovation team in charge with the design, development and engineering activities. In both cases ORO presented its IoT connectivity and platforms solutions with the focus on the Smart City Intelligent Lighting applications. As part of the connectivity we presented the current and future developments starting from LoRaWAN, LTE-M and going towards 5G RAN. On the platforms we highlighted the benefits of the current LoRaWAN based architecture, then we moved to the 5G based programmable infrastructure that is enabling the full set of advantages for the municipalities. More particularly, ORO presented the benefits of using SliceNet – MATILDA based joint infrastructure against the legacy infrastructure currently used by the two cities in RO and that is not at all aware about the real conditions of the lighting services provided to the citizens, is not energy efficient, has a poor SLA in terms of life management, the extensions is very costly for the municipality and citizens and is not flexible to coupe with additional services. The Municipality representatives but also the Lighting Services Operator were interested to understand how the Smart City Intelligent Lighting application components are on boarded in the MATILDA Marketplace, how the application graph is built and orchestrated over the programmable infrastructure using the components developed in the SliceNet project.

The official description of the project ''Rehabilitation, modernization and extension of the public lighting system of the Alba Iulia Municipality'' is presented on the municipality page.

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https://monitoruloficiallocal.apulum.ro/hotararea-nr-49-privind-aprobarea-proiectului-reabilitarea-modernizarea-si-extinderea-sistemului-de-iluminat-public-al-municipiului-alba-iulia-localitati-componente-oarda-de-sus/

The official description of the project ''Rehabilitation, modernization and extension of the public lighting system of the Iasi Municipality'' is presented on the municipality page.

http://www.primaria-iasi.ro/portal-iasi/stiri-si-noutati-din-iasi/iluminatul-public-va-fi-modernizat-cu-fonduri-europene/8509/stiri-din-iasi

In both cases SliceNet documentation has been used to demonstrate the benefits of the solution. Thanks to the live smart lighting demonstrator available in Politehnica University of Bucharest we were able to present relevant statistics and demonstrate the full monitoring of lamps and their power consumptions, the smart dashboard, ticketing and billing modules developed.

In case of Politehnica University of Bucharest the need was to refresh the old, non-managed and power non-efficient lighting solutions from its campus with a modern smart lighting one having also the option to bring new services such as Wi-Fi hotspots and campus entrances video surveillance with analytics option to count and recognize the number of cars entering the perimeter. It was a proactive approach by ORO.

The role of intelligent lighting solutions in the digital transformation of cities has gained momentum in recent years. This development will continue in the years to come through increased connectivity and industrial IoT (IioT) solutions, becoming a key element in most intelligent cities' strategies around the world.

In case of Alba Iulia Municipality there were three objectives that were expressed by the Municipality:

- Decrease Alba Iulia annual energy consumption with the public lighting from 389,636 (kWh/year) – value before project implementation, to 205,501 kWh/year, starting in 2021 through the rehabilitation and modernization of 46,587 ml, i.e. the extension by 5,000 ml of the public lighting system in the area concerned by the project, which also includes installations services and energy efficient equipment.
- Decrease the greenhouse gases due to the current inefficient public lighting system in Alba Iulia from 86 equivalent tons of CO2/year – value before project implementation at 45 equivalent tons of CO2/year from 2021.
- Improving access for persons with disabilities (visually impaired persons, persons with motor disabilities, etc.) to the public lighting service at the level of Alba Iulia through the rehabilitation and modernization of 46,587 ml, i.e. the extension by 5,000 ml of the public lighting system in the area concerned by the project and illumination of 2 pedestrian crossings, including systems based on presence sensors that will control the increase in the light flow of public lighting appliances (at pedestrian crossings) from 2021.

In order to develop vertical intelligent lighting, Iasi City Hall submitted the project ''Rehabilitation / modernization / extension, efficiency of public lighting network in Iasi Municipality''. Smart lighting solutions can play a key role in intelligent urban strategy by serving as the backbone of sensor networks for public safety, environmental quality, traffic monitoring, energy control, and data to improve municipal management. The value created by smart lighting solutions are huge given that 40% of a city's energy budget is consumed by street lighting and intelligent solutions can save up to 50% of these costs.

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Today, most cities that install intelligent lighting solutions choose systems that are already equipped with sensor technology or that can be easily upgraded in order to use the benefits of IoT applications.

Their key benefits are:

- reducing energy and maintenance costs
- enhancing public safety
- safer night traffic due to increased visibility of dangers
- environmental impact due to low energy consumption

The objectives of Iasi Municipality will consist of deploying 4,088 LED lighting fixtures, 4,122 light points, 41 solar panels, 287 ignition points and a remote control system.

The official description of the project ''Rehabilitation, modernization and extension of the public lighting system of the Alba Iulia Municipality'' is presented on the municipality page.

https://monitoruloficiallocal.apulum.ro/hotararea-nr-49-privind-aprobarea-proiectului-reabilitarea-modernizarea-si-extinderea-sistemului-de-iluminat-public-al-municipiului-alba-iulia-localitati-componente-oarda-de-sus/

The official description of the project ''Rehabilitation, modernization and extension of the public lighting system of the Iasi Municipality'' is presented on the municipality page.

http://www.primaria-iasi.ro/portal-iasi/stiri-si-noutati-din-iasi/iluminatul-public-va-fi-modernizat-cu-fonduri-europene/8509/stiri-din-iasi

In both cases SliceNet documentation has been used to demonstrate the benefits of the solution. Thanks to the live smart lighting demonstrator available in Politehnica University of Bucharest we were able to present relevant statistics and demonstrate the full monitoring of lamps and their power consumptions, the smart dashboard, ticketing and billing modules developed.

3) Exploitation plan beyond the project

In case of the Politehnica University of Bucharest ORO will act as a convergent operator, that is, telco and service provider providing the full End-to-End solution consisting of the application components, marketplace, Vertical Application Orchestrator, One Stop API and the programmable infrastructure. As prerequisites for this option, marketplace, Vertical Application Orchestrator and One Stop API should have commercial versions, since, for any component ORO deploys, technical support is needed. In case of Iasi and Alba Iulia Municipalities ORO will commercialize the solution to the Lighting Services Provider that will integrate it within his offering towards the municipalities. Therefore, in this scenario ORO will provide only the application (all or part of the components) standalone without linking it to the programmable infrastructure. This will provide the customer advanced functionalities (e.g. full monitoring of lamps and electricity consumptions, smart dashboards, ticketing, billing) over the lighting solution but without having any automation for deployment or in life management. This means that the application will be deployed manually, the lamps will be connected over the mobile network and all configurations will be performed manually.

This is also the type of the IoT product business model ORO targets for this vertical in the first phase in order to penetrate the market. On the long term ORO is looking to bring with its Intelligent Connected Lighting solutions (1) zero touch network operation for both deployment and in life management, which will reduce significantly the time to market and the cots for both the customers and the providers, (2) friendly environment (Marketplace) for Application Developers to create new 5G applications that can bring new functionalities and can be integrated within the Smart Lighting

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ecosystem. Also, the marketplace stands as a digital collaboration tool among the Application Developers, Service Providers and Infrastructure Providers.

An interesting aspect to be considered is that following the integration of the technical components developed within the two 5G-PPP projects, MATILDA and SliceNet all the tests were performed in a real environment together with the use case beneficiary – Politehnica University of Bucharest. After the end of the two projects, Politehnica University of Bucharest will start using the solution with the support of Orange Romania and will be able to add new functional components that were designed in MATILDA and SliceNet. This is a relevant validation and an expected reference that will help Orange to move in the business monetization stage by going in the field with the solution targeting small cities and campuses with similar requests.

For the commercial integration and operations ORO will involve the relevant partners from both MATILDA and SliceNet consortiums. Depending on the royalty fee ORO will be asked by the MATILDA-SliceNet consortium members we will be able to detail this particular information. However, we do believe that it is an excellent opportunity for SliceNet consortium to monetize some of its developments by a Go To Market approach in RO. The foreseen revenues will be based on monthly fee coming from (1) intelligent connectivity for the lighting poles and ignition points and (2) access to the monitoring of lamps and power consumptions, smart dashboards, ticketing and billing.

ORO Orange Business Services Marketing is working to define the product considering the development performed within MATILDA – SliceNet projects. Prepare presentation materials to be used during the pre-sales activities conducted with RO municipalities.

OFR

1) Overall strategy

Orange S.A is a French multinational telecommunications corporation. In a context of rapid changes in customer uses and expectations, technological breakthroughs, increasing competition from new players and new business models, our mission is to prepare Orange's future with countries and our ecosystems by building differentiating competitive advantages. This mission is based on 4 axes: to support the Group's technological and data strategy, to drive major innovations, to support countries in their innovation process, and to build and operate shared solutions. Our current strategy is to focus on AI Empowered Networks especially in the area of Network Predictive Maintenance. End-to-end AI loop is our target for 5G network besides Forecasting, Anomaly detection, smart network actuations and recommendations are needed. The main goal of the participation in the project has been to develop new partnerships with European research centres, industries and stakeholders to exploit the relevant knowledge and outcomes developed in the framework of SliceNet.

2) Exploitation activities and/or exploitable outcomes

We shared the knowledge gained from SliceNet during internal workshops:

- SliceNet European project outcomes
- SliceNet presentations and discussion about orchestration, monitoring system, policies, slices templates and data models.
- Architecture and Use Cases in SliceNet project with focus on E2E architecture and network slicing.

Orange Labs Research Exhibition (OLRE) is an international event at which the most important achievements of the research area are presented every year. This year, QoE management in 5G slices: Forecast the degradation of QoE in 5G slices for eHealth vertical and proceed for remedial actions demonstration will be presented. This demo will showcase the collect of information from a connected ambulance that is fed towards a monitoring system. The collected information is then transferred to the QoE prediction machine learning model. This model acts as an intelligent sensor that observes the last 5 minutes of the quality of perception metrics in the RAN segment of the network slice supporting the e-Health services. The sensor will predict every 5 seconds if degradation in the communication quality may be perceived by the vertical in the future 5 minutes. Based on the alerts generated by the model, an actuation framework reacts and triggers the necessary remedial actions. Two actuations are considered: either a handover of the ambulance or an increase in the bandwidth.

Our main contributions into the project were mainly focused on design of the QoE Sensor and definition of key pre-processing techniques for QoE sensors, NS ML Model Deployment, E2E Slice ML Algorithm Training, E2E Slice ML Model Running (DSP), Anomaly prediction and integration for eHealth use case based on vertical feedback and Noisy neighbour detection for Smart City Use Case.

3) Exploitation plan beyond the project

The knowledge acquired through SliceNet will be transferred to the contents of

- apprenticeship on the preparation and analysis of quality of service data for anomaly detection to anticipate impacts on the Quality of experience (QoE).
- PhD on Prediction of Vertical feedback (QoE) in 5G slices and recommendation of remedial action.

Continuation of the activity started at SliceNet' s lifetime in the form of internal projects in the AI-Empowered Networks program.

OTE

1) Overall exploitation strategy

OTE has been very much involved in wireless and wireline broadband technologies. As of that, OTE has long ago identified the growing need for investing in 5G technology since this has been proven one of the fields which is very promising for OPEX and CAPEX reduction while, at the same time, offering demanding and advanced services to the end users. Based upon technical and market-led priorities, OTE is expected to gain several advantages by the project results, so that to further increase its market profile. OTE's ultimate goal is to formulate a strategy with respect to the timing for developing and offering 5G enabled end-user/customer services. OTE will exploit the project's results by gaining experience and accessing the maturity of the 5G technology and architectures so as to prepare for the formulation of its commercial strategy. The hands-on experience and the outcome of the preliminary trials will indicate the appropriate time (and perhaps the investment size) for (a) the deployment and rollout of OTE's commercial 5G network, (b) the existing service portfolio that 5G deployment will affect and, most importantly, (c) the New Services that the 5G Network will enable the creation of new revenues streams.

2) Exploitation activities and/or exploitable outcomes

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From the technical point of view, SliceNet has influenced the redesign of the OTE network monitoring. Specifically, a similar approach to the Data Lake concept has been adopted where all monitoring data, analysis and possible actuations are stored into a unifying database. OTE is cooperating with the University of Athens and is training two Erasmus students, Ukiwo Anya and Diana Zhussip, on 5G networks by exploiting main concepts of SliceNet and concepts from the OpenAirInterface software.

3) Exploitation plan beyond the project

SliceNet experience and knowledge acquired will be used for the introduction of predictive analytics by using ML/AI to network performance monitoring. This will be used to identify potential network, service failures and performance issues with greater accuracy and less mean time to repair.

ALB

1) Overall exploitation strategy

ALB is a long-term provider of solutions for communications and digital services industries, either for Altice Group operations or for the external market. In this context, ALB has a portfolio of solutions that addresses several activity domains, including network solutions, service platforms, operations support solutions and business support solutions, exactly the domains where service providers are investing more in data science and AI, going beyond experience and business. More than an opportunity, this context drives a necessity. On the opportunity side, ALB is in a privileged position to leverage its experience and expertise in the areas addressed by its solutions, and thus to extract additional value from managed data and to create new use cases on top of its solutions using AI technology. On the necessity side, not making this investment will create a significant gap in existing solutions in the years to come. Investing on AI infusion into the existing portfolio is one of the most relevant dimensions of ALB current strategy, which by itself drove the company to increasingly invest in data science and AI internal knowledge to define work methodologies and to establish the required infrastructure and toolset. This bet not only unleashes the infusion of AI into existing portfolio but also enables ALB to address AI use cases in functional and data domains previously unexplored and not only on the ones being addressed by existing portfolio, empowering ALB to start positioning itself as an AI competence centre for the Altice Group.

2) Exploitation activities and/or exploitable outcomes

To support the operationalisation of its AI strategy, ALB created the cognitive team. This team is an instrument to catalyst the implementation of AI use cases in the company portfolio in cooperation with all business units, and also to address use cases that flow from within the operations and that can be addressed by the type of knowledge hereby created.

Using agile principles as its workstyle, closely interacting with domain experts and Customer teams allows for a quick-try-fail-fast mentality that keeps the team moving forward into consistent progress that can quickly move into production and produce fast results.

ALB has been researching the AI arena for the past years, and beyond the creation of the cognitive team, several use cases were and still are subject of investigation in collaborative projects with universities and other research institutes. One of the most critical use-cases is the RAN Slice Fault Prediction use-case which was addressed within SliceNet. The available RAN network data from the Altice Portuguese Service Provider was integrated in the project and an end-to-end cognitive process was exercised in the project:

- Data exploration: analysis of the available RAN data and valuable insights creation;
- Dataset transformation: feature engineering and creation of the datasets for training;
- AI Model Training: selection of the most appropriated ML algorithms and training of the ML model;
- AI Model Deployment and Execution: deployment of the trained ML model in a network slice, feeding it with RAN historical data and producing RAN faults predictions.

3) Exploitation plan beyond the project

From now on, since a RAN fault prediction ML model was trained and validated within the project, ALB intends to exploit the project results in several dimensions:

- Integrate the produced RAN faults prediction ML model within the Alarm Manager (AM) product of the Operations Support Systems (OSS) business unit – this is one of the most important exploitation results from the SliceNet project for ALB, which means, promoting the evolution of our existing solutions towards the AI paradigm (AI infusion in ALB solutions);
- Demonstrate (through short-term ML model deployment Proof-Of-Concepts) the enhanced Alarm Management solution (with the RAN faults prediction model produced in SliceNet) to the Altice group service providers worldwide (Portugal/MEO, France/SFR, Israel/HOT, United States of America/AUS, Brasil/Oi);
    - Ongoing ML model deployment is already under way in Altice Portugal Service Provider (named MEO) and validation results should be obtained until the end of Q3'2020;
- Reuse the cognition (or Data Science) cognition pipeline produced in SliceNet to exercise other cognition Ucs that are already in the ALB cognitive team pipeline (e.g. Cognitive Call Centre; STBs – IPTV Set Top Boxes Predictive Maintenance) and thereafter infuse our business units existing solutions with AI-capabilities.

Ericsson TEI

1) Overall exploitation strategy

Ericsson Telecomunicazioni SpA (TEI) is the Italian company in the Ericsson Group (Ericsson). Ericsson is a world-leading provider of communications technology and services in Telecommunication and Information and Communication Technology. Ericsson is the leader in 2G, 3G, 4G and the coming 5G mobile technologies. The world's 10 largest mobile operators are among Ericsson's customers and some 40% of the world's mobile traffic goes through Ericsson networks and Ericsson supports customers' networks servicing more than 2.5 billion subscribers. With 5G standards not yet completely established and commercialized networks started in 2020, Ericsson is already demonstrating fundamental 5G functionality that will be critical to enabling widespread adoption for both consumer and machine-type communications (MTC) with impressive speed test results. In the Ericsson vision 5G networks will be much more than just radio access: 5G networks will be built in a flexible way so that speed, capacity and coverage can be logically allocated to achieve unprecedented performance and adaptive capabilities to meet the specific demands of each use case. Slicing is key technology for 5G networks and TEI participation in the SliceNet project has met the objective of increasing R&D competence and further exploring possible Slice Management system architectures and solutions. Technical results and contributions have been shared with Ericsson internal business and technical stakeholders as well as with cooperating universities in order to strengthen our 5G ecosystem both on international corporate and local country organizations.

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2) Exploitation activities and/or exploitable outcomes

- University of Salerno (Italy) Telecommunication engineering Department: invited talk on SliceNet as H2020 5G slicing project
- Ericsson Learnathon: SliceNet technical results presentation
- Lecturing to Engineering students and professors at Unisannio University of Benevento about 5G Slicing and SliceNet results

3) Exploitation plan beyond the project

The CPSR component has been developed within SliceNet and will be further enhanced and promoted for internal re-use as a good enabler for Service-Based Architectures. The increased competence on Slice Management Systems, Microservices and Containers coupled with Service Based Architecture SW technologies will be extensively re-used for working on Ericsson products and solutions.

DellEMC

1) Overall exploitation strategy

As an infrastructure and service provider for SliceNet project, Dell EMC has contributed to the project the multi-domain network slicing testbed, spanning to three non-collocated sites (CIX, Ovens, Limerick). Two network service providers are built for multi-domain scenarios, supporting E2E network slicing concept in SliceNet. The lab has two separate 5G spectrum licenses to operate the RANs in the two network domains (Ovens and Limerick) and is fitted with Dell Technologies solutions for all hardware components required to build out the telco infrastructure for the two network providers, together with the infrastructure for the Digital Service Provider which also hosts SliceNet software components to demonstrate multiple scenarios in eHealth use-case. The lab was used for prototype developments in the eHealth use-case and was showcased at Mobile World Congress 2019, and other relevant events. The lab also promotes engagement with industry partners and customers and provides technical and commercial feedback to business units. As a technology provider, Dell EMC mainly contributed to the multi-domain FCAPS management, particularly the security aspect where Dell EMC developed multiple plug-ins to allow the information gathering from different sensors (resource sensors, LL-MEC, FlexRAN, SkyDive) to support the FCAPS decision making, and its security design and implementation in different aspects, mainly to support security in the platform and security in a slice.

The main exploitation strategy of Dell EMC in SliceNet project is the 5G technologies with network slicing and E2E security which are of significant interests to Dell EMC and the wider Dell Technologies family of companies and the work that Dell EMC carried out in the project in those areas have been exploited in building the 5G Lab across 3 sites in 2 different premises for multiple showcases with customers as proven use cases for the use of Dell's infrastructure solutions for 5G network slicing. The outcomes of the SliceNet architecture and the 5G Lab have been exploited and disseminated in knowledge transferring and establishing partnerships with internal/external partners (e.g., Vmware, Telenor, Intel, Radisys, etc.). In addition, the knowledge from SliceNet has been used for consulting in Dell's relevant roadmaps for products and service offerings. Stakeholders for exploitation will include Dell's Internal/external partners.

2) Exploitation activities and/or exploitable outcomes

- 5G infrastructure and use-case will be deployed in the customer solution centre for showcasing the Dell 5G devices.
- Multi-domain network slicing testbed will be used for integration with Vmware product, e.g., VeloCloud SD-WAN for a WAN segment and WAN slicing concept for showcasing the 5G technologies and VeloCloud product in E2E slicing.
- Developed Sensor-Monitor plugins and Security Network Functions with Network Anomaly Detection will be used in telemetry and SLA brokering framework in H2020 BRAINE project as a demonstration of the project continuity.

3) Exploitation plan beyond the project

Using 5G and network slicing technologies as a focal point, the lab will be continued to promote engagement with industry partners and customers and to provide technical and commercial feedback to business units. With its capabilities, it is ready to demonstrate current solutions, as well as new use cases, and to engage new business models in the 5G space and beyond. In near-future plan, it will be extended to have 5G Radio and 5G spectrum licenses to extend the engagement with telco partners and customers. In addition, the 5G Lab will be used for further prototype developments for innovations and/or use-cases in H2020 BRAINE and in future research projects.

The virtual security network functions (vEncryption, vFirewall and vAnomalyDetection) that Dell EMC has developed in SliceNet project will be further extended to integrate with a security SLA brokering framework that will be developed in H2020 BRAINE project to allow security SLA negotiation, enforcement and monitoring between the customers and data centre providers to increase the trust and credibility of the providers in delivering their services. In addition, the ML-based Anomaly Detection in Network traffic models will be further improved for faster and better performance and to include classification models for attacker identification to allow the system taking correct actions. The outcomes are possibly to be added or to give feedback and experience to Dell RSA (e.g., RSA orchestrator) and Vmware (e.g., Vmware AppDefense) products.

IBM

1) Overall exploitation strategy

Exploitation strategy is based on continuous communication of project's results to IBM business stakeholders as well as to researchers in other IBM research labs. This allows us to identify synergies with existing IBM offerings and with new initiatives in the company, and to follow up on them.

2) Exploitation activities and/or exploitable outcomes

Specifically, SliceNet outcomes where share as part of internal consultations for the three major initiatives that encompass both Research and business units; all the engagements have identified possible relevance of SliceNet outcomes for IBM:

1. The Research-wide AIOps initiative created to employ advanced data driven methods to operationalize the IBM Cloud infrastructure, in particular the network. SliceNet' s architecture concepts and some realizations of the advanced concepts such as operational data lake and cognitive MAPE loop have had influence to advancements of AIOps research.

2. The company-wide AI-for-IT initiative created to devise new offerings to support clients with operating their IT both on and off the cloud. Lessons learnt in SliceNet were delivered to the project teams and will be taken into account.

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3. The internal 5G-Edge exploration aims at creating a unified operational platform for creating/deploying/operating applications and network functions on the Edge, including 5G.

SliceNet research and its relevance to 5G slicing, along with proven experience of adopting cloud native constructs (OpenWhisk) as part of the orchestration plane will bear relevance to this exploration going forward.

3) Exploitation plan beyond the project

Further exploitation plan is to share the final project outcomes with the already engaged teams (mentioned in the column on the left) and to continue seeking more potential engagements through internal communication channels.

In addition, the research group participating in SliceNet is going to continue exploration started at the project's lifetime in the form of a new internal research project. Giving rise to an internally funded research activity is an unusual and a very valuable outcome of EU participation and one of the most desirable exploitation results for us as researchers. The new project is focused on establishing the best of the breed data-driven pipeline for operational telemetry to feed the AIOps and AI for IT systems, for their various incarnations and use cases.

EFA

1) *Overall exploitation strategy*

Leverage existing partnerships and enable new opportunities in existing clients, by introducing and promoting advanced and innovative solutions that can add value to the currently commercialized products and solutions. Develop new business opportunities for the Distribution Automation portfolio in new clients and markets, by presenting a differentiated solution from other competitors. Potentiate the sales growth of devices for the control and protection of the power grid, such as recloser controllers, since the outcomes of the project contribute to increment the ratio between the economic benefits resulting from enhanced power grid performance indicators (like non-distributed energy or outage duration) and the cost of additional devices installed in the grid.

2) *Exploitation activities and/or exploitable outcomes*

A workshop with several partners, institutions and clients was planned to be held in the second quarter of 2020. Due to the emergency period in the beginning of 2020, this workshop was postponed to a later date. The goal of the workshop is to broadly publicize the results obtained in the project and the new solutions developed for the Automation of the Distribution grid.

Promotional materials, like a video demonstrating the potential and benefits of the new solutions developed and of the advantages of the application of 5G technology, were prepared to support marketing and business development activities.

During 2019 and 2020, some of the algorithmic solutions developed during this project were implemented in a field pilot in a rural area of the Portuguese power grid, with the partnership of the Portuguese DSO. This pilot is based on previous communication infrastructure (4G technology) but the purpose is: first of all, to use it as a benchmark and testbed; secondly, to integrate the project outcomes and enable future upgrades, serving as a demonstration platform for other potential clients and exploit new business opportunities.

EFA has identified the following exploitable outcomes:

- New algorithms for the protection and automation of the distribution grid, integrated in the existing product series for recloser controller applications.
- Innovative flexible and scalable self-healing solution, that can be deployed in mixed distributed / centralized approaches and therefore is adaptable to different specifications and contexts.
- Fine-tuned and reliable Routable-GOOSE (R-GOOSE) messaging system available in field devices, for application in distributed functions where high-performance and reliability are most needed.
- Phasor-measuring unit function developed in FPGA-based hardware platform, enabling future applications for synchronized measurements over the 5G communication network.

3) Exploitation plan beyond the project

EFA plans to work with the following stakeholders to further exploit the outcomes from SliceNet:

- EDP Distribuição, the Portuguese DSO: to explore in the near future opportunities for new pilot projects supported by 5G technologies (extending the scope and upgrading the existing field platform) and to prepare the rollout of the outcomes of the project.
- INESC-TEC, research institute in Portugal: to continue the development of innovative approaches to the automation of the Distribution power grid, based on 5G communication infrastructure, enabling further benefits in terms of increased reliability of the power network operation and enhanced performance indicators for the quality of power supply.
- Several other utilities in different geographies, namely in South America and Europe: to exploit new business opportunities in clients that already use Efacec distribution automation solutions, or in new clients, promoting the results of the project as enablers for the optimization of power grid operation.

EUR

1) Overall exploitation strategy

Eurescom will exploit the project results through the services it provides to its shareholders and members and for the definition of future joint collaborative undertakings and exploiting the acquired knowledge in provision of new services over future services and networks to customers, in particular related to the future 5G infrastructures. Efficient architectures and cost-effective solutions for the management of the future 5G infrastructure is a prerequisite for new services and to sustain the quality of experience of services to customers. Thus, the project results are of significant interest to Eurescom and its shareholders and members.

2) Exploitation activities and/or exploitable outcomes

The main exploitation activities for Eurescom are the transfer of knowledge to consulting services that the company offers, in particular towards its shareholders and members as well as towards commercial contracts. Current commercial contracts exist with the European Space Agency through which the agency endeavours to capture the opportunities for SatCom stakeholders in the 5G value chain. In this context architecture and concepts developed in SliceNet are a valuable pool of knowledge. Further opportunities for Eurescom exist in the development of future programmes and initiatives where the SliceNet results have established the foundation for future explorations.

3) Exploitation plan beyond the project

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Eurescom has been leveraging previous project results in many ways, most prominently during the interaction with its shareholders, members and other stakeholders of the future networks ecosystem in Europe and globally. Global cooperation exists currently with organisations and companies from Japan, Canada, the US and China. Since Eurescom does not develop its own technology, the exploitable result for the company is knowledge. In the case of SliceNet the focus of knowledge is (i) slice management, (ii) actor role model for vertical industries and (iii) AI/ML-based slice management and control. Eurescom plans to use this knowledge in future contracts (e.g. with ESA and other customers) and for ensuring future high-quality research and innovation propositions in the context of the CELTIC Next programme and the next European programme Horizon Europe.

SMEs

CSE

1) Overall exploitation strategy

The main exploitation strategy of CSE regards the enrichment of its solution portfolio and knowledge base with respect to automation, abstraction and self-management practices. Additionally, the company is targeting the adoption and evolution of end-user tailored interfacing approaches.

In this context the company has managed to:

- enhance the existing self-management approaches from phase-1 project SELFNET, by introducing complete and flexible monitoring components with its own catalogue service and limited integration requirements with other components ensuring its transferability and adaptability.
- create from scratch an initial version of the OSA service that aims at serving different roles and business domains in the context business layering.
- contribute to standardisation activities (jointly with other partners) in order to present the above concepts and collect feedback that can allow for further evolution.
- acquire knowledge and hands-on experience through use cases and related scenarios. This was a great feedback for revisiting aspects in the context of future participation in research activities.
- gain significant hands-on experience with respect to monitoring tools (SkyDive, Prometheus) and Data Lake (TICK stack) approaches and deployments as well as familiarity with Machine Learning aspects due to the collaboration with partners that possess expertise in the field.
- improve its front-end development skills by using technologies like NeXtUI, Angular.js, Highcharts, Leaflet which have been integrated with server side components in the context of Node.js libraries and practices.

2) Exploitation activities and/or exploitable outcomes

CSE has contributed to SliceNet platform mainly with two components: the FCAPS framework and the One Stop API service. Both components aim at enabling realisation of technology abstraction strategies that can be utilised in the context of a layered business model. The approach has evolved from earlier concepts implemented and demonstrated in the EU SELFNET project that were focusing on automation and self-management practices. With the additions implemented in SliceNet, the company's toolset became more complete as far as operation automation and service exposure is concerned. Particularly the concepts relating to One Stop API provided ample room for exploitation in the context of Service Based Architectures and futures business practices. In this respect, the

company has contributed to standardisation activities, jointly with other partners, in order to reach, through the collected feedback and evaluation, a more mature state so as to pursue further both the overall design and the developed artefacts. Both service components are subject to utilisation in further research activities through the participation of the company in current and future proposals and consortia. However, part of the technical background is considered to be included in the design of solutions for the company's commercial projects in the field of IoT and Logistics domains.

The segregated and layered business roles, beyond the legacy all in one Telco organisations, and the project's outcomes particularly through the technology abstraction practices seem to be very close to future business and technology approaches. In the following, a related market analysis is attempted to better clarify and present this potential. The following factors should be taken into consideration in potential business plans involving the deployment of SliceNet platform:

- GDPR regulation, Protection and isolation of communications. → Multi domain slicing can be an enabler for creating individual application and networking spaces.
- Cloud based approaches have been the de facto solution for effectiveness. Web based applications are dominant in all aspects of IT. Systems cannot remain centralised at least as far as the evolution of added values services are concerned. → Multi domain slicing can be a driving factor allowing multiple business domains to contribute and share revenues based on usage.
- Societies are already familiar with new technologies and aspects such as easiness and transparency in service provisioning and acquisition are expected to play an important role in the business chain. → Vertical tailored multi domain slicing may allow wider adoption as it will ease the synthesis of services by allowing end users participate in the process of service definition.
- Cloud techniques monopolise the field and as a service approaches are now ubiquitous. M2M and IoT adoption is constantly gaining ground. → Abstraction principles are a key enabler to allow multiple domains and multiple vendors become part of the business ecosystem.

The following analysis should be also part of the plans for exploiting the SliceNet platform so as to drive improvements and additions:

- SliceNet has embraced the layered business model that is in the process of being defined (3GPP TR 22.830) from the beginning. OSA aspects have evolved around abstraction and layering. Therefore, the basic concepts are highly relevant and can drive quite well the vertical tailored multi-domain slicing practices. Abstraction allows existing investments to be reused next to new generation outcomes for serving the same purposes.
- Time, technology availability and cost are barriers for allowing a project to evolve significantly its outcomes from TRL ranking perspective.
- Cloud and as-a-service practices are quite close to the fundamental aspects of the project. It is therefore easier to promote for adoption in new business practices.
- Big players (Google, Facebook, Apple, Microsoft, Amazon) are usually creating their own all in one service platform. This can be potentially extended in the network and communication service domains eliminating all the opportunities stemming from the potential telco business segregation.

3) Exploitation plan beyond the project

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CSE always tries to adopt the gained expertise in the design of solutions for commercial projects, particularly in IoT and Logistics business fields. OSA and monitoring solutions are, in this context, new approaches to be presented (with the appropriate adaptation) to current and new clients. In this respect, CSE plans to present a potential usage of the solutions to its existing client People Group Technology Department (SME, Logistics service provider) as an extension to existing services and solutions. Additionally, the existing toolset will be also subject to be utilised and extended in future projects relating to slicing and self-management networks. There is an ongoing research proposal where part of the abstraction approaches are planned to be evolved.

The study done with respect to 4G slicing (particularly with vEPC and I) is planned to be presented to DANAOS MANAGEMENT CONSULTANTS S.A. to seek potential exploitation of the 4G based slicing for Maritime deployment. This plan with the particular stakeholder is based on older discussions that have to be revisited in the scope of the technical background that can be used initially for consultation. The same aspect of 4G slicing based on I is planned also to be presented to Piraeus Port Authority S.A. (OLP) – Passengers Terminals in the context of a target scenario aiming at seamless mobility for cruise passengers to avoid roaming costs. There is already an open communication channel with the particular stakeholder due a former showcase of indoor location solution from a previous project.

NXW

1) Overall exploitation strategy

Nextworks, as technology provider and software SME active in the ICT and telecommunication sectors, through its research and development activities aims at identifying cutting edge innovative technologies and application scenarios to be turned into company products and knowledge services (e.g. consultancies) for the ICT market. The SliceNet outcomes produced by Nextworks mostly refers to the Service and Slice Orchestrator and the Plug and Play Framework, and substantially contribute to the consolidation and improvement of existing company research oriented network and service management portfolio, which already includes an NFV Orchestrator, an OpenStack-based Virtual Infrastructure Manager (VIM), a multi-NFVO catalogue and a Service Development Kit for designing services. Even if Nextworks does not have direct plans for commercialization of outcomes from European projects, the idea is to build a comprehensive inventory of integrated software tools bound with specific 5G use cases to validate some specific innovative concepts (e.g. slicing, cognitive management, plug & play, etc.). This aims at attracting interest from telco industry players (e.g. through public demonstrations at relevant events, like the MWC) and foster the creation of new research and innovation collaborations, like the one established with Tata Elxsi in 2019, with a joint demo at IBC2019 on open source network slicing solution for 5G media distribution services.

2) Exploitation activities and/or exploitable outcomes

In terms of impact on existing company products, Nextworks actively develops and markets a “digital living” product platform called Symphony, a service-oriented middleware integrating several functional subsystems (media archival and distribution, voice/video communications, home/building automation and management, energy management) into a unified IP-based platform. Nextworks is currently evolving Symphony towards a fully decomposed, virtualized, distributed and generalized platform capable of supporting thousands of interconnected sensing and actuating devices, and of integrating with several vertical applications, including industrial automation and eHealth. In this

context, the Plug & Play framework can be considered in general as a slice customization platform, providing the means to deploy, run and expose per-slice runtime control functions as microservices on top Kubernetes infrastructures. The Plug & Play knowledge has been transferred to the product division of Nextworks to drive an evolution of the Symphony product, with the aim of customizing the control of vertical specific applications in a truly flexible and agile way, with per-service and per-slice functions (e.g. for monitoring, data analytics, etc).

Nextworks has been involved in most of the technical activities for the delivery of the SliceNet vertical-oriented and QoE-driven network slicing framework for cognitive network management and control of end-to-end network slicing operation and slice-based (and slice-enabled) services in 5G networks. However, the main assets delivered by Nextworks are: i) the Service and Slice Orchestrator (SS-O), for end-to-end vertical services and network slices orchestration, and ii) the Plug & Play framework, for the customization of slice runtime control (with per-slice control, management and cognitive functions) and vertical tailored exposure of slice runtime control. These two assets, released as open source software, can be considered as the main relevant Nextworks outcomes from SliceNet, and are tightly integrated to provide an innovative end-to-end network slice orchestration framework capable to customize the runtime slice control and expose it directly to verticals. As an exploitation strategy for these main assets, Nextworks foresees that the work carried out during the project lifetime, starting from their architectural design up to software implementation and integration and validation has consolidated the company expertise in the area of 5G network management, NFV and MEC.

3) Exploitation plan beyond the project

The consolidation of expertise in cutting edge technologies is indeed one of the main objectives for Nextworks when participating in European projects, aiming at translating it into new knowledge services for the ICT national and international market. Nextworks has indeed a wide portfolio of consultancy services, which include training courses, technology support, and third-party software development offers. In this direction, the expertise acquired in SliceNet continuously feed current consultancy activities with ETSI, where Nextworks is participating in several Specialist Task Force (STF) within ETSI NFV and MEC groups (e.g. for the 2018-202' period: ETSI STF 551 on MEC Testing Framework; ETSI STF 569 on MEC API Conformance Test Specification; ETSI STF 557 and 583 on NFV API Conformance Test Specification and ETSI 563 and 586 on OpenAPI Specification for NFV), that are planned to be continued and extended to other ETSI ISGs (e.g. ZSM and ENI). In addition, the expertise acquired in the development of the SliceNet SS-O will allow Nextworks to offer more effective consultancy services in the NFV and network slicing area, specifically targeting customers like service providers or small operators who are interested in delivering custom virtual infrastructure solutions providing simplified tools and interfaces towards a wide range of vertical industries. In this context, contacts with OpenFiber (an Italian wholesale-only operator on the Italian network infrastructures market) have been already established for showcasing the SliceNet based network slicing solution and its integration with the ETSI OSM open source orchestrator, with concrete opportunities to offer OpenFiber either training courses or technology support services.

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RedZinc

1) Overall exploitation strategy

SliceNet has provided RedZinc the opportunity to be part of telemedicine research lab trials and the experiences gained from these trials have been used to feed into their product portfolio design requirements. The extensive insights gained have clearly demonstrated the need for highest quality of user experience from end-to-end of the network service chain. It has been apparent that to make a breakthrough in the telemedicine space, applications are needed that solve the quality of user experience issue, since streaming video applications with poor quality voice and vision has proved to be unacceptable to the healthcare stakeholders.

2) Exploitation activities and/or exploitable outcomes

The RedZinc collaboration with the two other Irish researchers from SliceNet, including DellEMC and Cork Institute of Technology, has provided a deep understanding of the use case requirements and clinical performance indicators from this specialised stakeholder group, and has helped focus the RedZinc research team on the delivery of an end-to-end next generation telemedicine solution that exploits network slicing to solve the problems associated with poor user quality of experience.

The BlueEye products were tested on the project's next generation network slicing testbed in Ireland. The key takeaway was that network slicing had a proven positive impact on the clinical requirements to offer guaranteed end-to-end network support for the delivery of high-quality video streaming and thereby enhance the clinical and patient user's quality of experience.

Central to the provision of telemedicine is the delivery of top-quality next generation telecommunications services that integrate seamlessly with healthcare processes, such as remote access to patients and communities. As part of the Covid-19 response, the Irish national health service provider (the HSE [8]) approached RedZinc to rapidly deploy to the healthcare system their remote video consultation platform, BlueEye Direct, in an attempt to replace the need for face-to-face consultations for Irish healthcare professionals, which would be a key part of a national campaign to help slow down the spread of the infection, and facilitate people in need of non-emergency interventions to remain in their homes during the Irish lockdown.

RedZinc responded by pivoting technology developed as part of the SliceNet project into a new telemedicine solution for outpatient clinics. BlueEye Direct uses real-time web-based video communications technology, so healthcare professionals can see their patients remotely. SliceNet research and innovation enabled the BlueEye platform to be built for rapid scaling using virtualized network functions for flexible deployment of eHealth software services. As such, SliceNet technology has helped healthcare providers to rapidly deploy a much-needed video consultation service in response to the pandemic. The H2020 program has produced concrete benefits for this unexpected healthcare crisis through research investment in 5G slicing technology.

However, what the crisis further highlighted was that a definite need to satisfy quality of experience constraints exists for network slicing enablers in the healthcare space and that deeper relationships need to be built between network and third-party service providers to satisfy and resolve these needs. At a business exploitation level, this would build on the relationships that have grown from the likes of Parlay X (see OneAPI [9]) and other network web service enablers, where clearly defined

service access to the southbound network interface can open up innovative network slicing business models for future network and digital service providers to exploit synergies of interest.

In this regard RedZinc have been able to engage in SliceNet with industry network operators, who ultimately will make the decision to deploy network slicing as an exploitable service. At the same time, a full-scale adoption of these technologies after the pandemic crisis is a work-in-progress, as certain requirements still need to be addressed.

RedZinc' s involvement in 5G network slicing research has contributed to resolving issues such as:

- Quality-of-Experience with audio and video being addressed through guaranteed Quality-of-Service and cognitive management
- Security and privacy are designed-by-default into the network slicing architecture
- End-to-end slicing, coupled with service deployment through an intelligent interface, would mean that future interoperability and integration issues are minimised
- Multi-vendor environments will be centralised, whereby a national healthcare provider designates a single entity as Digital Health Service Provider

3) Exploitation plan beyond the project

RedZinc further envisages using slicing in a 5G environment, enabling network operators to offer end-to-end services, inside a single slice, integrating siloed corporate networks and accelerating deployment. Slicing would allow corporate networks to differentiate services in a more agile way with different traffic types such as data, voice, medical images, real time video, providing appropriate quality of experience to facilitate remote consultations.

Academic Partners

UWS

1) Overall exploitation strategy

UWS has been exploring exploitation in both academic environments and industries. For the former, UWS has exploited selected project outcomes in teaching and research. For the latter, UWS has been leveraging existing and developing new partnerships with UK and EU industries and stakeholders to exploit and further develop the relevant outcomes of the project.

2) Exploitation activities and/or exploitable outcomes

The following PhD students at UWS are associated to this project, and they are currently PhD candidates:

- Ruben Ricart-Sanchez, who has been contributing to the project's R&D in hardware-accelerated data plane programmability for slicing-friendly infrastructure.
- Antonio Matencio, who has been contributing to the project's R&D in OVS-based data plane network slicing and applicable to service function chaining.
- Ignacio Sanchez, who has been contributing to the project's R&D in Topology Awareness for Smart 5G eMBB Network Slicing Virtual Network Function (VNF) Placement.

Moreover, some training and courses at UWS have been enhanced by employing materials from the project:

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- Selected outcomes of the project have been exploited for enlarging the training courses offering of UWS, e.g., one of the training offerings is featured with AI for 5G and has been delivered to a delegation of Chinese for a UWS Enterprise training program.
- Some project demos and presentation materials have been embedded in some BSc honours degree and MSc degree modules such as COMP10023 Wireless Networking, and COMP11058 Advanced Wireless Networking Technologies.

Regarding new directions of research, UWS has extended their research interests from software domain to the hardware domain in this project in FPGA for data plane programmability.

Furthermore, for exploitation with industries and stakeholders, UWS has organised several workshops with the following businesses for exploitation purposes in 2019 and 2020:

1. NATS (existing official UWS-NATS Strategic Partnership)
2. Thales UK (existing collaborator)
3. Police Scotland (existing collaborator)

UWS has started exploring 5G deployment and applications in rural areas, with stakeholders such as Scotland's dairy industries (a recent UK bid sent), and has worked with Thales UK, NATS and ALB on 5G ML-based security (a recent UK fellowship bid sent).

In the project, UWS has developed several exploitable solutions/components, which have been licensed.

1. Flow Control Agent for data path network slicing.
2. Flow Monitoring Agent for flow-level traffic monitoring.
3. OVS-based software switch for data path network slicing.
4. FPGA-based hardware platform for data path network slicing.

3) Exploitation plan beyond the project

UWS plans to investigate further exploitation with the following identified potential collaborators:

1. BT Scotland for deploying 5G use cases in Scotland.
2. Glasgow City Council for exploring 5G smart city.
3. NHS Scotland for exploring 5G use cases for eHealth and beyond.

UPC

1) Overall exploitation strategy

The participation in SliceNet allows to foster the existing and, at the same time, to develop new partnerships with both Spanish and International research centres, industries and stakeholders to exploit the relevant knowledge and outcomes developed. Several technical meetings with local administrations and stakeholders have been performed already during the SliceNet project lifetime that will continue in the next future.

2) Exploitation activities and/or exploitable outcomes

In SliceNet, UPC has contributed (among other technical activities) mostly to the technical activities related to the cognition-based QoE-aware network slicing management framework for 5G networks. UPC also contributed to the resource orchestration in support of the end-to-end network slices, as part of the SliceNet Orchestrator. In particular, the main assets of UPC are:

- The QoE Optimizer, as the entity responsible to manage the end-to-end slices with QoE guarantees. UPC has also developed the related QoE plugin and interfaces with the other SliceNet architectural components.
- The NMRO as part of the SliceNet Orchestrator and the related interfaces.

Regarding the first asset, it worth mentioning the contribution to the definition of the Vertical Feedback from Verticals as an enabling feature to include the Verticals in the process to manage the slices QoE guarantees. Finally, UPC has actively contributed to the integration process of the different software components to run the entire SliceNet architecture.

As part of UPC, the group involved in SliceNet is currently participating in the Public-Private Initiative 5G Barcelona that works towards transforming the metropolitan area of Barcelona into an open and neutral urban laboratory for the validation and adopting of 5G technologies and applications in a real environment. 5G Barcelona is promoted by the Generalitat de Catalunya, Barcelona City Hall, Mobile World Capital Barcelona, i2CAT, CTTC, Atos and the UPC. Actually, 5G Barcelona focuses on different pilot projects for vertical industries: Automotive, Health and Healthcare, Industry, Media and Entertainment, Security and Defence. The UPC group who participated in SliceNet is leading the Working Group on Testbeds and Laboratory of UPC.

In the framework of 5G Barcelona Initiative several meetings with members and potential stakeholders have been carried out in 2019 and 2020, for example with the Catalan Government related to the application of 5G technologies for the health sector and also with the Barcelona City Hall to contribute to deploy a 5G-based field trial covering the Barcelona area.

Moreover, regarding Academic aspects, besides leading and contributing to several dissemination activities, UPC has exploited the participation in SliceNet in the following ways:

- One PhD has been completed during the SliceNet lifetime (Rafael Montero, final defense scheduled in July 2020). Rafael Montero has been involved mainly in the design and implementation of the QoE Optimiser and Orchestrator.
- One Msc degree has been completed during the SliceNet lifetime (Héctor Délas Castellá, final defense of the Msc project, entitled “Study and application of machine learning techniques to the deployment of services on 5G optical networks”, was held in October 2019) in the framework of Master Thesis programme of the Escola d’Enginyeria de Telecomunicació I Aeroespacial de Castelldefels (EETAC) of UPC.
- It has been already promoted in Master degrees at UPC through the inclusion of SliceNet-related technologies in a new subject introduced in the framework of the Master of Telecommunication Engineering and Management (MASTEAM) of the EETAC, one of the schools of UPC. This way, UPC students that will be the future researchers and industrial employees, can be properly educated on advanced technologies for future services.
- In the framework of the 5G Barcelona Initiative, UPC has contributed to a technical training course about 5G technologies (overall duration: 300 hours) offered by UPC to the Servei Català d’Ocupació (SOC). In particular, the contribution was on the management of network slices,including both theoretical and practical lectures in the UPC labs.
- Finally, the UPC group participating in SliceNet organised a workshop entitled “The role of computing in the post 5G-era: Architectures and enabling technologies”, on May 18, 2020 in

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the context of the ONDM 2020 conferences; among the invited speakers, Telefonica, Barcelona SuperComputing Centers, Mellanox, Nokia Bell Labs.

3) Exploitation plan beyond the project

UPC is engaging additional potential stakeholders for further exploitation, and has participated in informal meetings with the following organisations:

- Telefónica
- Vodafone
- Orange Spain
- Aguas de Barcelona
- Local public administrations.

In this context, it has to underline that an agreement between Orange Spain and UPC has been signed to allow the usage of the Orange Spain 5G spectrum inside the UPC campus for vertical oriented experiments. Therefore, UPC will be working on field-trial experiments at a campus level exploiting this way the knowledge and the outcomes from SliceNet (e.g., QoE Optimiser, vEPC automatic deployment of support of end-to-end slices and in general, AI-driven slice management). This will put the UPC group in a significant position towards future research initiatives.

Additionally, several meetings have been set up with the *Institut de Recerca en Energia de Catalunya* (IREC, http://www.irec.cat/es/) about the usage of 5G-based communications systems to guarantee ultra-delay communications among batteries forming the storage systems for power grid ecosystems. Technical discussions and exploration of future cooperation are currently under consideration as well joint projects submission is being evaluated.

CIT

1) Overall exploitation strategy

The main aim of CIT involvement in SliceNet is to explore the application of CIT expertise in Artificial Intelligence and Digital Health in the eHealth 5G Slicing use case, and to develop new partnerships with European research centres and industrial partners.

2) Exploitation activities and/or exploitable outcomes

Two PhD projects were partially funded via SliceNet.

CIT research leaders involved in SliceNet were invited to different national and international events to present some research directions used in the project: Dr Haithem Afli was invited to talk about the application of AI in IoT at Beyond IoT 2020 conference (https://beyondiot.ie/). He was invited, also, in February 2020 to give a talk about the same topic at the CIT seminar series.

A good partnership was established between the CIT team involved in the project and the Dell-EMC and RedZinc teams while leading the Ehealth Use case in SliceNet.

CIT has the following exploitable outcomes**:**

- A PhD project was partially funded via SliceNet project on the topic of 'Machine Learning Vision Recognition for Connected Health'. The student, Michael Healy, who was involved in SliceNet is expected to defend his PhD (supervised by Prof Paul Walsh and Dr Haithem Afli) by the end of 2020.
- A PhD project was partially funded via SliceNet project on the topic of 'A cloud Computing Microservices Architecture for Dataset Mining'. The student, Yanxin Wu, who was involved in SliceNet is expected to defend his PhD (supervised by Prof Paul Walsh and Dr Haithem Afli) by the end of 2021.
- A new PhD project started in 2020 and funded in total by Science Foundation Ireland based on the continuation of CIT research work within SliceNet. The student, Praveen Joshi, who was involved in SliceNet is expected to defend his PhD (supervised by Dr Haithem Afli) by the end of 2023.
- A TeleStroke application was developed within the project by the CIT team that will be improved and applied in other projects such as the H2020 project Health5G (http://health5g.eu/).

3) Exploitation plan beyond the project

CIT plans to investigate further exploitation with the following identified stakeholders:

- Science Foundation Ireland Centre for Research Training in Advanced Networks for Sustainable Societies (ADVANCE CRT, http://advance-crt.cs.ucc.ie/): to fund new PhD scholarships in AI and 5G technologies
- Future Leadership in ICT and Standardization in Europe (ELITE-S, https://elite-fellowship.eu/): to fund new Marie Skłodowska-Curie Postdoctoral fellowships in Ireland (and in CIT) around the application of ML in 5G
- CIT research and industrial partners**:** to explore the new research directions and application of the CIT TeleStroke system developed within SliceNet.

ECOM

1) Overall exploitation strategy

ECOM has exploited a subset of project outcomes to enrich its teaching and research activities. In addition, SliceNet project brought more visibility to ECOM open source and R&D activities, namely OAI and Mosaic5G, which made it possible to further develop new partnerships and collaboration across Europe and also internationally. One of the indicators for the latter is the increase in the number of members in OAI and Mosaic5G.

2) Exploitation activities and/or exploitable outcomes

Three PhD students at Eurecom were associated with this project: Chia-Yu Chang and Robert Schmidt who were contributing to the slicing activity of the project, and Anta Huang on user plane programmability and MEC platform. In addition, three postdocs and one engineer have been contributed to this project: Xenofon Vasilakos and Nassim Ferdosian, were mainly contributing to the WP5 cognitive plane, another postdoc, Osama Araouk was contributing to WP7 in providing orchestration framework for mobile network that support slicing, and Tien-Thinh Nguyen to WP8 on the integration of 4G/5G infrastructure to the considered use-cases. Selected outcomes of the

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project have been exploited for enlarging the training courses offered by ECOM, in particular, some demos and presentation materials have been reused in some BSc programme, in particular, MobAdv. Regarding new directions of research, ECOM has extended its open source activities and software platforms and now not only include 3GPP compliant software but also agile 4G/5G service platforms.

3) Exploitation plan beyond the project

ECOM will exploit the results of SliceNet to enrich their educational offering and research area with the novel concepts of Open and Agile 5G networking and computing. ECOM will promote the usage of open source software for 4G/5G and plans to create an ecosystem of companies and start-ups exploiting commercially the open source software for 4G/5G networking, given that the operators and service providers are more open and even keen to use such technologies to reduce their Capex. ECOM plans to investigate further exploitation with the following identified potential collaborators:

- Orange France, among other partners (e.g., AT&T and China Mobile), to collaborate and contribute to ORAN activities based on the FlexRAN platform.
- Mosaic5G and OAI members to evolve FlexRAN platform to support 5G.

5. 5G-PPP Program-Level Liaison and Collaboration

5.1. 5G-PPP Board and Working Group Activities

SliceNet has been actively participating in all the activities organised by the 5G-PPP WGs that are relevant to the main topics of the project. In some cases, SliceNet partners have been playing leading roles in these WGs or activities. Highlighted examples include KPI Champion in the TB in leading the program-level discussions and definitions of 5G KPIs, Co-chairing the Software Networking WG and the Network Management WG, editing specific sections of a number of 5G-PPP white papers and so on. Table 13 summarises the main activities per WG. It is noted that the primary outcomes of these 5G-PPP WGs have been co-authored white papers, as reported in Section 2.3. As listed there, a total of 10+ white papers have included significant inputs from the project.

Table 13 Summary of SliceNet 5G-PPP Program-Level Activities

Working Group	Main Activities	Main Outcomes	Lead Partner
Steering Board (SB)	SliceNet is represented at Steering Board Level by the project co-ordinator or her deputy. The focus of the activities has been in ensuring flow of information from the different work groups and the technology board to the working level of the project. Further activities include the coordination of 5G PPP programme level exposure at large scale events like trade shows and scientific conferences.	● Ensuring participation of SliceNet experts in the various WGs (see below) ● Description of achievements in annual reports ● Representation of SliceNet in coordinated 5G PPP exposure at events ● Contributions to 5G PPP Programme Monitoring Reports (PMRs)	EUR
Technology Board (TB)	Leading cross-project ad-hoc WG on performance KPIs Represented SliceNet in various TB telcos and workshops such as 5G PPP Technical eWorkshop 2020 Presentation by IBM: SliceNet architecture Cognition Sub-plane, and application use-cases 5G PPP Technical Workshop 2019 in Malaga, Spain https://5g-ppp.eu/newsflash-october-2019/	Contributing to 3 5G-PPP white papers led by TB: ● White paper: Delivery of 5G services indoors – the wireless wire challenge, 2020 ● White paper: Edge Computing for 5G Networks, 2020 ● White paper: Empowering Verticals industries through 5G Networks – Current Status and Future Trends, 2020 Contributed to 5G-PPP program-level documents: ● Phase 2 project SliceNet key	UWS and EUR

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	5G PPP Technical Workshop 2018 in Kista, Sweden https://5g-ppp.eu/feedback-on-ppp-technical-workshop-20-22-11-18-kista/ Produced numerous inputs on behalf of the project	achievements, 2020 • Phase 2 project SliceNet golden nuggets, 2019 • 5G-PPP program-level KPI report as KPI Champion, 2019	
Architecture WG	Represented SliceNet in various WG telcos Presented SliceNet architecture to the WG	Contributed to the 5G-PPP white papers on 5G architecture led by this WG: • White paper: View on 5G Architecture, Version 3.0, 2020	UWS
Software Networks WG	The purpose of the 5G-PPP Software Networks Working Group is to analyse and address unification and applicability of key research topics related to Software Networking including software defined concepts, infrastructures, systems and components for Wire and-Wireless Networks, including Networked Clouds, IoT and Services, i.e. Software Defined Networks (SDN) and Network Function Virtualization (NFV) as developed and promoted by the 5G PPP projects. Since beginning of 2018 Orange Romania is co-chairing this WG where the lead is on Nokia. During the regular WG vphone conferences and projects sharing activities, SLICENET was represented by Orange Romania and UWS. The WG meeting minutes and deliverables are available on https://bscw.5g-ppp.eu. Periodic WG activity reports were submitted to the 5G-PPP Steering Board and Technology Board. During the last 2 years,	The main interventions within SoftNet WG since Jan 2018 are: • 3 white papers with specific SliceNet content, available on the 5G-PPP page https://5g-ppp.eu/white-papers : July 2018, ''From Webscale to Telco, the Cloud Native Journey'', August 2019, ''Cloud-Native and Verticals' services – 5G-PPP projects analysis'' and February 2020, ''Cloud-Native and 5G Verticals' services''; • 34 phone conferences with clear agenda and follow-up minutes that are available on https://bscw.5g-ppp.eu/sec/bscw.cgi/52699; • 3 virtual workshops with presentations from each of the SoftNet WG projects including SLICENET; • 2 EuCNC workshops: 18th June 2018, ''From cloud ready to cloud native transformation: What it means and Why it matters'' and 18th June 2019, '' **From Cloud-ready to Cloud-native transformation'';** • 1 SLICENET paper accepted and presented during EuCNC 2019 SoftNet Workshop: "SliceNet Programmable Data Plane	ORO

	SLICENET had several interventions and contributions within the SoftNet WG, starting with project, use cases and developed tools introduction, proposing content for the 3 published white papers, co-organizing 2 workshops with other 5G-PPP projects and presenting SLICENET concepts and developments during the workshops.	Control in 5G Network Slicing", presenter Pablo Salva-Garcia, UWS, https://www.eucnc.eu/workshops/workshop-2/); ● 2 SliceNet presentations during EuCNC: "Future network 74ransformation. 5G cloud architectures'' (2018, Marius Iordache, https://www.eucnc.eu/2018/www.eucnc.eu/wp-content/uploads/2018/06/EUCNC_2018_program_web.pdf) and ''Cloud native applications design and deployment'' (2019, Marius Iordache, https://www.eucnc.eu/workshops/workshop-2/);	
Security WG	Attending regular meetings and updating the outcomes from the SliceNet project in terms of network slicing and security. Presenting security topic produced in SliceNet. Influencing and contributing to the overall Security KPIs. Leading whitepaper entitled "SDN/NFV virtualisation, 5G Slicing and Security Considerations" with the plan to report in the 5G NS or relevant event. Contributing in the whitepaper entitled "Edge Computing for 5G Networks" led by the 5G IA Verticals Task Force in collaboration with the 5G PPP Security WG.	White paper: SDN/NFV virtualisation, 5G Slicing and Security Considerations, 2020, to be published in 5GPPP Security WG and will be reported in relevant events.	DellEMC

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Trials WG	Leading the work of including the SliceNet eHealth use case at the 5G Public Private Partnership (5G PPP) 2019 showcase called Verticals Cartography. Leading SliceNet contribution at the first 5G PPP Trials & Pilots brochure.	• SliceNet: 5G Smart Health / Connected Ambulance https://global5g.org/slicenet-5g-smart-health-connected-ambulance SliceNet featured as one of the top 10 innovative 5G PPP trials in the 5G Infrastructure PPP Trials & Pilots Brochure https://5g-ppp.eu/wp-content/uploads/2019/09/5GinfraPPP_10TPs_Brochure_FINAL_low_singlepages.pdf • Roadmap Version 5.0 – 10 Phase 2 Projects Trials & Pilots • 5G Pan-European Trials Roadmap Version 4.0 • 5G Trials Roadmap, Observatory and Cartography	CIT/EUR
Communication WG	• EUCNC • MWC • Promotion of SliceNet	• Promotion of SliceNet annually at EUCNC • Promotion of SliceNet through events, website and social media • Promotion of SliceNet annually at MWC	RZ & EUR
Network Management & QoS WG	Co-chaired this WG and led the activities in meetings, telcos, workshops, white papers etc. such as: The 3rd workshop on Network Management and QoS for 5G Networks, EuCNC 2018, Ljubljana, Slovenia Interacted with other 5G PPP WG on various aspects with a focus to ensure consistency of messages by the 5G PPP programme: • 5G Architecture WG • Software Networks WG • Security WG	• Tackling Network Management Challenges for Vertical Sectors Brochure, 2018 **https://5g-ppp.eu/wp-content/uploads/2018/06/NMQ-WG_Brochure_web.pdf**	EUR

	• Vision and Societal challenges WG This WG has concluded.		
SME WG	Participated in all the telcos and discussions of this WG	Contributed to SME Success Stories in the 5GPPP European Annual Journal 2019	NXW

5.2. Cross-Project Collaboration

SliceNet has been collaborating with a number of selected 5G-PPP and other Horizon 2020 projects that are closely related to the project. The collaboration has taken place in various forms including joint development of use case demonstration/trial, and extension, adaptation or reuse of functional components, among others.

SliceNet-MATILDA Collaboration

Lead partner: ORO

Collaboration topic: Smart connected city – intelligent lighting use case

Activities summary: An excellent collaboration between two 5GPPP Phase 2 projects, MATILDA and SLICENET culminated with a technical and coordination meeting hosted by Orange Romania on 12-14th November 2019 in the CAMPUS Research Centre, Politehnica University of Bucharest, where the smart connected city – intelligent lighting application was demonstrated. The collaboration and the clustering technical event brought together 33 partners from 13 countries that exchanged project status and technical details for the 8 use cases. The liaison element between the two 5G-PPP projects was the smart city lighting 5G cloud native application implemented in Romania with Orange Romania leading the way in both projects. The two projects have used both testbed and demonstrator collaboratively to create the Smart City Intelligent Lighting use case showing how street lighting can be monitored and controlled by a central point, helping with lighting issues, saving costs and providing feedback on the system. Amongst other things, MATILDA and SLICENET consortium members had very fruitful discussions on the positioning of both projects and their respective outcomes. In particular, the focus of the clustering workshop was on the practicalities of the application of the results generated from both projects and their alignment with respect to their set objectives. More specifically, the coordination teams of both projects identified areas of interests in some of the implementation results realized within their respective frameworks. As depicted in Figure 9 while MATILDA is focusing more on the end to end framework and on the upper layers related to marketplace and application orchestration, SLICENET is more focused on virtualization/slicing concepts. Orange Romania demonstrator shows how the two frameworks could be integrated in order to automate the deployment and in life management and bringing key benefits in terms of cost and time to market.

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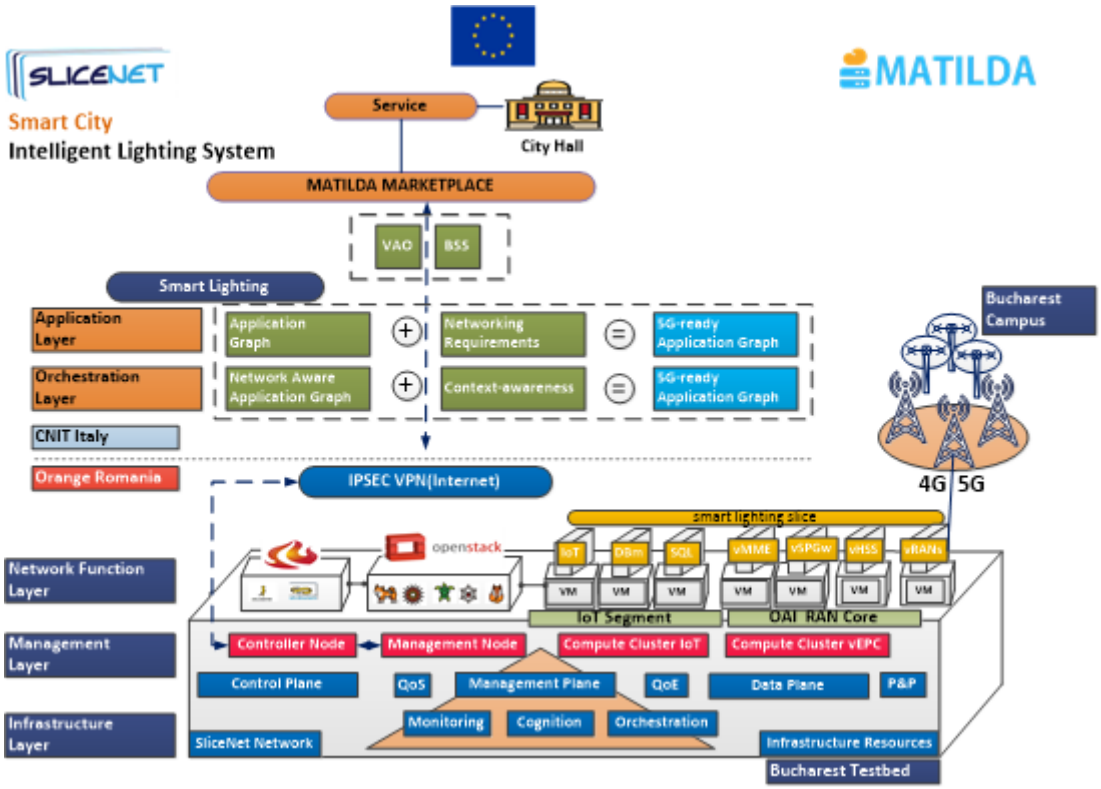

Figure 9 Matilda – SLICENET Smart City Intelligent Lighting System testbed architecture

During the technical workshop, MATILDA presentation highlighted the 5G architectural concepts implemented on Orange Romania testbed, concepts related to the 5G infrastructure developed but also to the specific network components and applications integrated for the end-to-end use case development. Concrete MATILDA experts provided a detailed overview related to key aspects such: (1) integration between MATILDA Marketplace, VAO and OSS components deployed within CNIT infrastructure and ORO programmable infrastructure, (2) application components and graph creation, (3) use of the metamodels for application graph deployments and slice creation and (4) in life management. Orange Romania experts insisted on the Smart City Intelligent Lighting use case that was deployed and demonstrated using this 5G framework developed within MATILDA taking also benefit of the SLICENET collaboration for the development of Orange Romania programmable infrastructure. The integration among the two projects' stands also as proof for the high grade of openness and interoperability of the developed 5G framework. An observation during the workshop sessions was that MATILDA 5G framework can be easily used to orchestrate the end to end life cycle of 5G ready application over programmable infrastructure. SLICENET participants were very interested to understand how the Smart City Intelligent Lighting application components are on boarded in the MATILDA Marketplace, how the application graph is built and orchestrated over the programmable infrastructure using the VAO and OSS. MATILDA participants were questioning more on the management of the end to end dedicated slice supporting the connectivity of the demonstrator, how it is instantiated and managed using the vEPC solution. At the moment of the demonstration from November 2019, all the Smart City Intelligent Lighting application components were available, including the C1 component in its dockerized version. Therefore, a complete MATILDA developed application graph was available and all the functionalities of the platform were shown, including ticketing, alarming or billing. The slicing concepts developed within SLICENET were also demonstrated as the OAI RAN and Core components were available and integrated. The demonstration took place over a live environment of 56 lamps deployed in Politehnica University of Bucharest campus.

Outcomes: Thanks to the follow-up on the exchanges from the MATILDA – SLICENET technical workshop and particularly on the additional development performed within SLICENET, Orange Romania was able to perform a full demo of the use case with all functionalities in place during a MATILDA remote review meeting (due to coronavirus pandemic) held in March 2020. This demonstration took place also in Bucharest in a remote manner and was able to prove on the live environment from Politehnica campus the end to end solution automating the deployment and in life management. The main difference versus the previous demos was achieving the full integration between the VAO, OSS and ORO programmable infrastructure enabling automated deployment of the application graph and slice instantiation. The VAO and OSS were hosted in CNIT infrastructure and fully integrated with the OpenStack and ETSI MANO OSM from ORO programmable infrastructure. An interesting aspect to be considered is that following the integration of the technical components developed within the two projects, all the tests were performed in a real environment together with the use case beneficiary – Politehnica University of Bucharest. After the end of the two projects, Politehnica University of Bucharest will start using the solution with the support of Orange Romania and will be able to add new functional components that were designed in MATILDA and SLICENET. This is a relevant validation and an expected reference that will help Orange to move in the business monetization stage by going in the field with the solution targeting small cities and campuses with similar requests.

The successful collaboration between SLICENET and MATILDA is highlighted in the video created by Orange Romania and available on YouTube: https://www.youtube.com/watch?v=zmxJbxpSTYQ. A screenshot of the video is shown in Figure 10. This video has attracted 2462 and 1000 views in LinkedIn and YouTube respectively by 28 May 2020, as shown in Figure 11.

Figure 10 Video on MATILDA – SLICENET technical workshop available on YouTube

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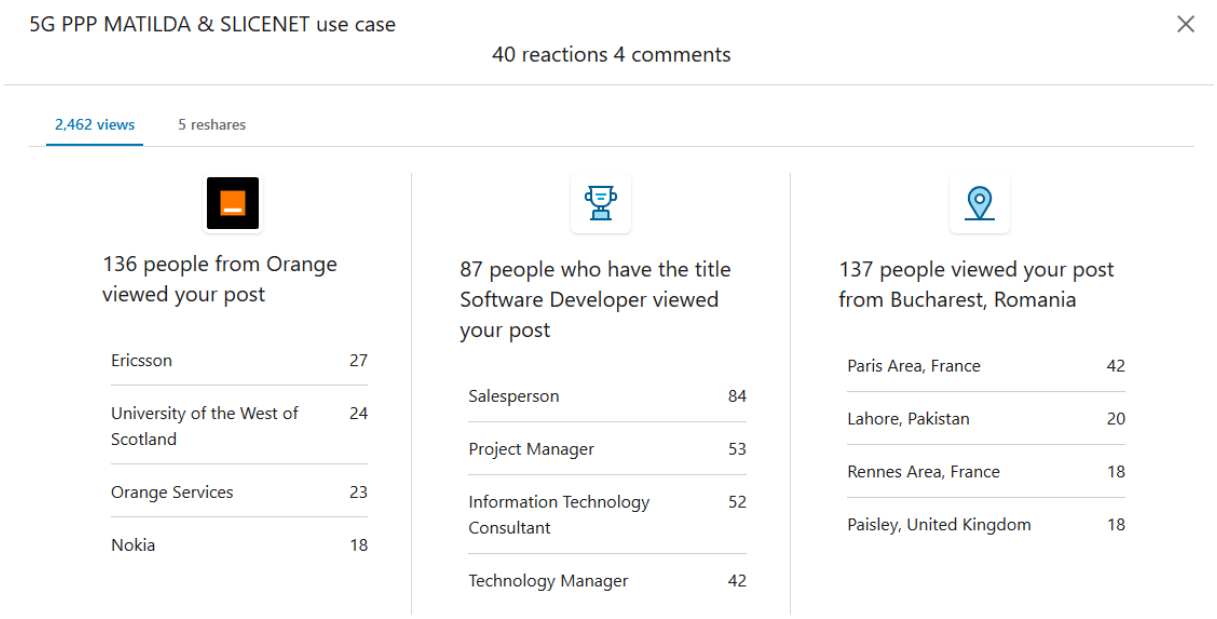

Figure 11 Viewing statistics for the smart city video

Joint publications:

B. Rusti, H. Stefanescu, M. Iordache, J. Ghenta, C. Brezeanu and C. Patachia, "Deploying Smart City components for 5G network slicing," 2019 European Conference on Networks and Communications (EuCNC), Valencia, Spain, 2019, pp. 149-154, doi: 10.1109/EuCNC.2019.8802054.

B. Rusti et al., "5G Smart City Vertical Slice," 2019 IFIP/IEEE Symposium on Integrated Network and Service Management (IM), Arlington, VA, USA, 2019, pp. 13-19.

SliceNet and 5G-PPP Transformer Collaboration

Lead partner: NXW

Collaboration topic: End-to-end vertical services and network slices orchestration

Activities summary: The 5G-Transformer Vertical Slicer component, developed by Nextworks and released as open source software, has been used as the reference baseline for the implementation of the SliceNet Service and Slice Orchestrator (SS-O). While the 5G-Transformer Vertical Slicer aimed at coordinating and arbitrating network slices implemented as a combination of NFV Network Services, it was mostly targeting single administrative domain interactions with NFV MANO orchestrators for the deployment of vertical tailored network slices. SliceNet adopted the 5G-Transformer orchestration approach, especially the vertical service information model and extended it in support of the SliceNet multi-domain principles and DSP-NSP business split. An intermediate layer of 3GPP compliant network slice coordination (including logic and information model) has been introduced to regulate the orchestration of single-domain network slices managed by NSPs and offered to DSPs in the form of Network Slice Templates. These 3GPP compliant network slices include radio slice profile and NFV Network Service information and capabilities. The Vertical Slicer therefore has been extended in its internal software architecture and logic to be deployed in two main flavours: i) an end-to-end vertical service orchestrator at DSP level, exposing end-to-end network slices to verticals, ii) a single-domain network slice orchestrator at NSP level for the coordination of network slice lifecycle and mapping to radio and NFV resources. These two orchestrators (at DSP and NSP levels)

interact to build to the SliceNet End-to-end vertical services and network slices orchestration. Moreover, the innovative Plug & Play features introduced by SliceNet have been fully integrated with the SliceNet SS-O, as an additional functionality on top of those originally provided by 5G-Transformer.

Outcomes: The SliceNet SS-O software component, that can be deployed in the DSP flavour (for orchestrating end-to-end vertical services and network slices) and the NSP flavour (for orchestrating single-domain network slices) is developed on top of the 5G-Transformer Vertical Slicer. It is contributed to the Nextworks company GitHub as an advanced and multi-domain oriented solution of network slices orchestration (https://github.com/nextworks-it/slicer/tree/slicenet)

SliceNet and 5G-PPP PICTURE Collaboration

Lead partner: ECOM

Collaboration topic: Slicing and Orchestration

Activities summary: The collaboration allowed slicing functionality, developed within SliceNet, to be contributed to 5G-PICTURE, and in particular to be used and integrated within a disaggregated RAN deployment. On the other hand, the development of functional splits and corresponding RAN abstractions in 5G-PICTURE allowed to realize a unified slice lifecycle management across different deployment scenarios (monolithic, Cloud-RAN, and disaggregated), which then have been contributed back to the SliceNet. The collaboration also allowed the realization slice orchestration. In particular, the design and development of the orchestrator architecture within 5G-PICTURE allowed to realize all the phases of slice's lifecycle (e.g., preparation subscription, runtime, and decommissioning) with a rich inventory and APIs in SliceNet. On the other hand, the development of slice/service slicing within SliceNet allowed the independence of lifecycles for slices and sub-slices in 5G-PICTURE. As fruit of this collaboration, different scenarios for slicing were demonstrated, like dynamically changing network topology according to user traffic (i.e., dynamic switch between monolithic and disaggregated RAN and vice versa based on the ongoing user traffic).

Outcomes: FlexRAN Slicing system is enhanced and released as a part of use-case evaluation for RAN. JoX orchestrator with slicing support.

SliceNet and 5G-PPP 5G-MEDIA Collaboration

Lead partner: IBM

Collaboration topic: knowledge sharing and component reuse

Activities summary: We leveraged knowledge learned from 5G-Media to employ function as a service (FaaS) technology as part of 5G orchestration stack. We've adopted this knowledge to SliceNet and have deployed FaaS for invoking per-slice Machine Learning models on demand in SliceNet' s Cognition Sub-Plane. Specifically, we reused the OpenWhisk-based component of 5G-Media to deploy the ML model for predicting RAN degradation and RAN failures from alarm data in the Smart Grid Use Case.

Outcomes: OpenWhisk is deployed as part of the Smart Grid Use Case testbed and participates in the Use Case demo to invoke the ML model for predicting RAN degradation and RAN failures, upon arrival of new alarm data.

SliceNet and EU H2020 ANASTACIA Collaboration

Lead partner: UWS

Collaboration topic: 5G-IoT networking and use cases

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Activities summary: UWS has hosted a visiting research fellow from the ANASTACIA project, working with the UWS team for 3 months at UWS in 2019, and the collaboration has been continued since then.

Outcomes: Several joint publications have been produced including one that has been accepted for publication in IEEE Journal on Selected Areas in Communications (J-SAC), a top journal in this field.

Joint publications:

4. *M. Zarca, J. B. Bernabe, A. Skarmeta and J. M. Alcaraz Calero, "Virtual IoT HoneyNets to Mitigate Cyberattacks in SDN/NFV-Enabled IoT Networks," in IEEE Journal on Selected Areas in Communications, vol. 38, no. 6, pp. 1262-1277, June 2020, doi: 10.1109/JSAC.2020.2986621.*

SliceNet and 5G-EVE Project Collaborations/Reuse

Lead partner: ECOM

Collaboration topic: Release and integration of Software platforms

Activities summary: The progress made in the context of SliceNet allowed to enrich the 5G-EVE testbed facility in France, in particular in Sophia with the new functionalities related to RAN and CN control including slicing, monitoring, radio resource management, mobility management.

Outcomes: Enhanced 5G-EVE testbed

https://www.5g-eve.eu/nsf-visit-at-french-5g-eve-site-facility-in-sophia-antipolis/

Collaboration with Phase 1 projects

SELFNET: UWS has extended the Flow Monitoring Agent (FMA) and the Flow Control Agent (FCA) from SELFNET for slice-aware data plane monitoring and control in SliceNet. CSE has evolved the main component (Automation Language Processor) of the TAL Engine to interface directly with Data Lake components and has been used in tasks such integration with cognitive modules, NSP to DSP monitoring data flows, threshold evaluation and simple activation rule resolution. Additionally, the Application Management aspects used in SELFNET through the App Manager component were also extended to provide the FCAPS Framework automation (instantiation and maintenance of Telegraf and proprietary artefacts for monitoring properties)

COHERENT: Led by ECOM, the FlexRAN SD-RAN platform, originally developed in the context of Coherent project, has been reused and extended in the context of SliceNet and used for the use-case validation. In addition, it has been made available to other 5GPPP projects.

5.3. Advisory Board Activities

Meetings Summary

SliceNet had 5 Advisory Board meetings during the official project lifetime, with one additional (6th) Advisory Board meeting scheduled for 2nd July 2020, to be held as an online meeting. Counting this in, SliceNet had 2 in-person meetings and 4 online meetings with the Advisory Board members, which was a good compromise between close in-person discussion and the difficulties of getting a group of busy, highly demanded experts together. The outcomes of each meeting had been very valuable for the work of SliceNet, providing the much-needed external expert perspective, which helped in shaping the SliceNet activities and results to a level of high excellence and scientific and market relevance.

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1st SliceNet Advisory Board Meeting in Sophia Antipolis – 23 January 2018

The 1st SliceNet Advisory Board Meeting in Sophia Antipolis, France aimed to present the plans and results of the project to the Advisory Board members and get their feedback.

The seven participating Advisory Board members included (see photo, from left to right): Michael Fitch, BT; Linus Thrybom, ABB Corporate Research; Toon Norp, TNO; Marco Liebsch, NEC Network Laboratories Europe; Rui Aguiar, University of Aveiro; Jane Zheng, Ulster University; and Klaus Martiny, Deutsche Telekom AG. They brought a wide diversity of expertise and perspectives to the meeting, from network management to vertical sector application in the energy sector and the healthcare domain. The eight other Advisory Board members are: Pål Grønsund, Telenor; Valentin Voinica, City of Alba Lulia Municipality; Dimitra Simeonidou, University of Bristol; Oscar Lazaro, Innovalia Association; Pascal Bisson, Thales Services; Anand R. Prasad, NEC; Jim Leahy, OGCIO; and João Peças Lopes, INESC | FEUP.

2nd Advisory Board Meeting (online) – 27 November 2018

The second meeting mainly focused on an update of the status of the project and current plans and challenges, which led to a productive discussion and useful feedback by Advisory Board members on topics like the network slicing approach and QoS.

3rd Advisory Board Meeting (online) 2 April 2019

The third meeting mainly focused on an update of the status of the project and current plans and challenges, which led to a productive discussion and useful feedback by Advisory Board members on topics like the eHealth use case and demo as well as the architecture in regard to scalability and control aspects.

4th Advisory Board Meeting in Paisley, UK – 12 June 2019

The fourth meeting mainly focused on an update of technical progress and year-2 achievements, which led to a productive discussion and useful feedback by Advisory Board members on topics like cross-domain orchestration of slices, usability for verticals, and control plane functions.

5th Advisory Board Meeting (online) – 22 January 2020

The fifth meeting mainly focused on the presentation of 3 SliceNet use cases and the main achievements of multi-domain FCAPS management, which led to a productive discussion and useful feedback by Advisory Board members on each use case, with recurring themes like usability and control for verticals, standardisation and economic aspects of slice management.

Main Outcomes

The work of the Advisory Board, which consisted mainly of the SliceNet Advisory Board meetings has generated considerable value for the project in three respects:

1. Detailed technical feedback and suggestions by world-class technical and standardization aspects, which helped and confirmed the project in its technical direction and standardization approach.

2. Different perspectives and controversial opinions: The Advisory Board members constantly challenged the project, which helped the SliceNet consortium avoid the trap of just doing what was planned, but always reflecting the relevance and usefulness, sometimes with the effect of making adjustments.

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3. The Advisory Board brought an economic and vertical customer driven perspective into the discussions, which gave the SliceNet consortium valuable hints and practical advice for preparing the successful exploitation of results.

6. Conclusions

Significant achievements have been made in dissemination, exploitation and 5G program liaison activities over the last three years of the project.

For dissemination, among other various activities, over 60 papers have been published or accepted in international journals, magazines or conferences including a number of top-tier journal (e.g., *IEEE Journal on Selected Areas in Communications, IEEE Transactions on Network and Service Management, IEEE Transactions on Broadcasting*) and conference (e.g., *IEEE ICC, Globecom*) publications. The project has also organised a number of events, workshops, webinars, public demos, and produced numerous news/newsletters, videos, social media posts etc. for project dissemination and exploitation.

For exploitation, notable standardisation contributions can be highlighted with several official Work Items and Proof of Concepts created and approved in relevant ITU/ETSI working groups (ITU ML5G, ETSI ENI etc.) and the topics cover various important aspects of the project's technical achievements in network slicing, cognition/ML, network management and orchestration etc. The project also contributes to several open source projects (OAI, Mosaic5G, OVS, SkyDive, OpenWhisk etc.). Per-partner exploitation strategy including future plans to continue working together for standardisation has also been made.

For 5G program liaison and cross-project activities, the project has been actively participating in 5G-PPP meetings and events, and playing leading roles in various cases (e.g., KPI Champion in 5G-PPP TB, Co-chairing 5G-PPP Software Networking WG etc.). The project has contributed to over 10 white papers organised by 5G-PPP. The project has also collaborated with several other 5G/H2020 projects, and the close collaboration with MATILDA (phase 2 project) has been especially fruitful, leading to a joint real-world deployment of Smart City Lighting use case. Regular Advisory Board meetings have also been useful for project progress and collaboration.

To sum up, the outcomes from SliceNet have met or exceeded the target KPIs in the dissemination and exploitation plans in the DoW, and thus successfully achieved the corresponding objective of the project.

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