Deliverable D9.2

Intermediate Dissemination, Exploitation and Standardization Planning and Report of Activities

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Abstract

The main objective of this deliverable is to present a list of the most relevant Standard Definition Organizations (SDO) and Open Source Communities (OSC) for the SliceNet project. The purpose is to give a brief description and the relation that each one of these SDO/OSC has with SliceNet. Each SliceNet partner will have different approaches regarding the presented SDO/OSC from follow, align, and use, up to collaborate. The document presents also an updated dissemination plan and activities related with SliceNet project.

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Impressum

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Executive summary

This deliverable first describes the updated dissemination and exploitation plans and related activities. Then, the main Standard Definition Organizations (SDOs) and Open Source Communities (OSCs) are presented, with a brief description and the relation with SliceNet for each one of these selected SDOs/OSCs.

Since there are different involvements from the various partners in the several SDOs/OSCs, the approach that each partner has to each one of these SDOs/OSCs are different. In this regard a definition for the different approaches is given- alternatively: follow, align, use, collaborate - and a proposed approach by each partner is presented for each SDO/OSC.

List of authors

Company	Author	Contribution
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EURES	Anastasius Gavras, Maria Barros Weiss	ITU-T, NGMN, SMEs, dissemination activities and exploitation plans
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UWS	Jose Alcaraz Calero, Qi Wang	NetFPGA, OpenStack, Academia
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Abbreviations

3GPP	3rd Generation Partnership Project
5G	Fifth Generation (mobile/cellular networks)
5G PPP	5G Infrastructure Public Private Partnership
AI	Artificial Intelligence
ARM	Advanced RISC Machine
BMSB	Broadband Multimedia Systems and Broadcasting
CAPEX	Capital Expenditure
CNSM	Conference on Network and Service Management
EPC	Evolved Packet Core
ETSI	European Telecommunications Standards Institute
EuCNC	European Conference on Networks and Communications
E-UTRAN	Evolved-UMTS Terrestrial Radio Access Network
IEEE	Institute of Electrical and Electronic Engineers
IETF	Internet Engineering Task Force
IoT	Internet of Things
IRTF	Internet Research Task Force
ISWCS	International Symposium on Wireless Communication Systems
ITU	International Telecommunication Union
KPI	Key Performance Indicator
M2M	Machine to Machine
MANO	Management and Orchestration
MIX-AI	Multi-disciplinary Innovation eXchange-Artificial Intelligence
ML	Machine Learning
MobiArch	Mobility in the Evolving Internet Architecture
MRO	Maintenance, repair and operations
NFV	Network Function Virtualization
NFVI	Network Function Virtualization Infrastructure
NFVO	Network Function Virtual Orchestrator
NGMN	Next Generation Mobile Networks
OCP	Open Compute Project
OPEX	Operational Expenditure
OSC	Open Source Communities
PoC	Proof Of Concept
PoP	Point of Presence
QoE	Quality of Experience
QoS	Quality of Service
R&D	Research and Development
RAN	Radio Access Network
SDN	Software Defined Networks
SDO	Standard Definition Organizations
SliceNet	End-to-End Cognitive Network Slicing and Slice Management Framework in Virtualised Multi-Domain, Multi-Tenant 5G Networks
SWOT	Strengths, Weaknesses, Opportunities, and Threats analysis
TR	Technical Report
TRL	Technology Readiness Level
TS	Technical Specification
UE	User Equipment
VIM	Virtual Infrastructure Manager

VNF	Virtual Network Function
VNFM	Virtual Network Function Manager

1 Introduction

Dissemination, exploitation and standardization are essential to successfully accomplish the several tasks proposed in the SliceNet project. This document contains the updated dissemination, exploitation plans and standardization guidelines for the SliceNet project. The document has the following structure:

- Section 2 provides the updated dissemination plans and activities for the project partners
- Section 3 provides the most relevant Standard Definition Organizations for the project. For each SDO a brief description, the relation with SliceNet and the type of approach is given
- Section 4 provides the most relevant Open Source Communities for the project, also for each OSC a brief description, the relation with SliceNet and the type of approach is given
- Section 5 provides the updated exploitation plans and activities for the project
- Section 6 provides the conclusion of the document

2 Updated Dissemination Plans and Activities

2.1 Past events

As reported in D9.1 Dissemination and Exploitation Plan, submitted on 02 February 2018, SliceNet has set up and has continuous updates to its website [1], with content such as the project overview, partners' overview, deliverables and publications, news, contacts, videos, project leaflet, social media and newsletters.

A total of 12 news posts have been uploaded since the delivery of D9.1 with 8 of these created by SliceNet and the others reused from other sources.

7 future events are anticipated relevant to the SliceNet project including the huge participation in EuCNC 2018 as per table below.

Past events (talks/scientific papers presentations related to SliceNet concepts and technical achievements) since the D9.1 was submitted, are listed below:

- IEEE International Conference on Bioinformatics and Biomedicine (BIBM 2017), 13-16 November 2017, Kansas City, USA [58]:
  - M. Healy, P. Walsh, "Detecting demeanor for healthcare with machine learning".
- SMART Health Conference at W5 Arena, 17 May 2018, Belfast, Ireland [2]:
  - Mark Roddy (CIT) presented the SliceNet e-Health vertical use case and he talked about "How next generation 5G cellular networks are likely to impact the delivery of pre-hospital Emergency Services."
- 13th Israeli Networking Day 2018, May 24, Herzliya, Israel [3]:
  - Talk from IBM about "Visibility and Analytics for Cloud Networks".
- IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB), 6-8 June 2018, Valencia, Spain [4]:
  - Q. Wang, J. Alcaraz-Calero, M. Barros Weiss, A. Gavras, P. Miguel Neves, R. Calé, G. Bernini, G. Carrozzo, N. Ciulli, G. Celozzi, A. Ciriaco, A. Levin, D. Lorenz, K. Barabash, N. Nikaein, S. Spadaro, D. Morris, I. Chochliouros, Y. Agapiou, C. Patachia, M. Iordache, E. Oproiu, C. Lomba, A. Aleixo, A. Rodrigues, G. Hallissey, Z. Bozakov, K. Koutsopoulos, P. Walsh, "SliceNet: End-to-End Cognitive Network Slicing and Slice Management Framework in Virtualised Multi-Domain, Multi-Tenant 5G Networks"; paper presentation.
- SYSTOR 2018, 11th ACM International Systems and Storage Conference, June 4-6, Haifa, Israel [5]:
  - D. Lorenz, V. Perelman, E. Raichstein, K. Barabash, A. Shribman , "SliceNet – Cognitive Slice Management Framework for Virtual Multi-Domain 5G Networks", poster paper.
- COMM 2018 International Conference, 14-16 June, Bucharest, Romania [59]:
  - E. Oproiu, M. Iordache, C. Costea, C. Brezeanu, C. Patachia, "5G Network Architecture, Functional Model and Business Role for 5G Smart City Use Case: Mobile Operator Perspective"; paper presentation.

2.2 Upcoming events

2.2.1 EuCNC, 18-21 June 2018, Ljubljana, Slovenia

SliceNet has a large and varied participation in this year's EuCNC [7], 18-21 June 2018, Ljubljana, Slovenia. We are running a booth where we will demonstrate the RAN Runtime Slicing System necessary to show the programmability of multi-service per slice. We have several workshops on 5G slicing, cloud, security, network management, poster sessions and much more. The list of activities is summarised in the table here.

Table 1 EuCNC list of activities

	Time/Location	Activity	Description
1	18-21 June	SliceNet Booth	The SliceNet booth will run a demonstration "RAN Runtime Slicing System" using a RAN and CN prototype with a novel plug and play network application to show multi-service programmability on a per slice basis. SliceNet use this in an eHealth application, where QoS supports time-critical video transmission.
2	Monday, 18 June 2018, 09:00-13:00, E1 hall	EuCNC 2018 Workshop 2	Orange are co-organising and Marius Iordache presenting in Session 2 at Workshop 2 "From cloud ready to cloud native transformation: What it means and Why it matters" https://www.eucnc.eu/workshops/workshop-2/
3	Monday, 18 June 2018, 09:00-18:00, M3 hall	EuCNC Workshop 3	SliceNet project presentation by Qi Wang (UWS) in Session 2 of Workshop 3 "Multi-provider, multi-vendor, multi-player orchestration: from distributed cloud to edge and fog environments in 5G" https://www.eucnc.eu/workshops/workshop-3/
4	Monday, 18 June 2018, 09:00-13:00, E3 hall	EuCNC 2018 Workshop 7	Eurescom are co-organising and Anastasius Gavras giving the introduction at Workshop 7 "3rd Network Management and QoS for 5G Networks" (https://www.eucnc.eu/workshops/workshop-7/)
5	Monday, 18 June 2018, 14:00-18:00, E3 hall	EuCNC 2018 Workshop 8	Qi Wang (UWS) presents "Security considerations in 5G network slicing" in Session 1 of Workshop 8 on "Next generation network systems security" (https://www.eucnc.eu/workshops/workshop-8/)
6	Wednesday, 20 june, 14:00-15:30, Room Linhart hall	EuCNC 2018 Panel	Navid Nikaein (Eurecom) will be on a Panel "Network Slicing: Real-world Opportunities with Open Standards and Open Source" https://www.eucnc.eu/panels-2/
7	Wed 20 June 2018, 13:30 - 14:00 (5th paper), Foyer 2	Poster session POS2	Networking, application areas, piloting and testbeds - Poster presented by Anastasius Gavras (Eurescom)
8	Wed 20 June 2018, 13:30 – 14:00 (15th paper), Foyer 2	Poster session POS2	Networking, application areas, piloting and testbeds – Poster presented by Maria Barros Weiss (Eurescom)
9	Tue, June 19, 2018 16:30 until 18:00 (4th paper) in E2 hall	Session NET2	Network function virtualization and orchestration session. Representation by Eurescom. https://www.eucnc.eu/net2/

2.2.2 IEEE BMSB 2018, 6-8 June 2018, Valencia, Spain

The IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB) gathers together experts from areas of multimedia broadcasting, telecommunications, consumer electronics, and networking technologies.

SliceNet (EURES) will present the paper "SliceNet: End-to-End Cognitive Network Slicing and Slice Management Framework in Virtualised Multi-Domain, Multi-Tenant 5G Networks", presenting presents the vision of the SliceNet project, highlighting the gaps in existing work and challenges, the proposed overall architecture, proposed technical approaches, and use cases.

2.2.3 IEEE ICTON 2018, 1-5 July 2018, Bucharest, Romania

The main scope of the IEEE International Conference on Transparent Optical Networks (ICTON) 2018 Conference [41] is focused on the applications of transparent and all-optical technologies in telecommunications, computing and novel applications.

SliceNet (UPC) is going to present the invited paper “End-to-end 5G service deployment and orchestration in optical networks with QoE guarantees”. The paper discusses an architecture enabling end-to-end (E2E) provisioning and monitoring of 5G services over optical network segments. In particular, the scenario considers the coordination of various optical enabled network segments by a higher level E2E Orchestrator, which provides of network slice deployment and is able to guarantee agreed levels of Quality of Service.

2.2.4 International CSCC 2018, July 14-17, Mallorca, Spain

Conference on Circuits, Systems, Communications and Computers (CSCC) [6] is a World Forum on Circuits, Systems, Communications and Computers.

Orange Romania will contribute with the paper entitled “5G-Connected Virtualized Enterprise Infrastructure for Smart City”. The paper proposing a "all-in-one" solution that could deliver all the services, to every device, everywhere in the network in a viable option, from the Enterprise Network Segment perspective.

2.2.5 CNSM, 5-9 November 2018, Rome, Italy

In the 14th International Conference on Network and Service Management (CNSM 2018) [8], SliceNet is submitting a paper titled ***“SliceNet Control Plane for 5G Network Slicing in Evolving Future Networks”.*** This paper discusses the future 5G network requirements, the high level control plane architecture, plug and play control, Slice QoE optimiser, network segment controllers as well as a comparison with related work.

2.2.6 ICT Event, 4-6 December 2018, Vienna, Austria

At this event [9], SliceNet intend to exhibit alongside a number of other 5GPPP projects in a booth provided by the 5GPPP project. We will run two demonstrations at the booth, the first on eHealthcare emergency use case and the second showing the network slicing concept across different domains including RAN, EDGE, and CORE.

3 Standard Definition Organizations

In this chapter we will address the main SDO activities related with SliceNet.

3.1 Introduction

The SDOs are very important for the SliceNet project. In fact these SDOs will provide the required recommendations/standards for the project implementation.

For these SDOs we will have several approaches with different levels of involvement:

- **Follow** we will be monitoring what is going on in this SDO
- **Align** we must be aligned with what the SDO is proposing
- **Collaborate** we have the ability to influence the decisions that are taking place in the SDO

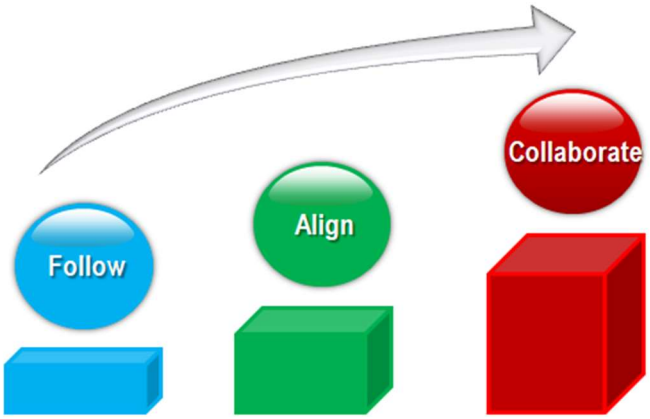

Figure 1: Level of involvement in the SDO

3.2 3GPP

3.2.1 3GPP SA1 Services

3.2.1.1 Brief description

The Technical Specification Groups Service and System Aspects (TSG-SA) is responsible for the overall architecture and service capabilities of systems based on 3GPP specifications.

The first working group (SA-WG1 or SA1) [10] of the TSG-SA is responsible for:

- specification of features (stage 1)
- specification of services (stage 1)
- specification of service capabilities (stage 1)
- Identification of requirements to support service operation
- Identification of requirements for service interworking
- Identification of requirements for service interoperability between networks
- Charging and accounting requirements

The scope of the SA-WG1 is to specify service and feature requirements applicable to mobile and fixed communications technology for:

- 2G, 3G and future communication technologies independent of access technologies based on an evolved GSM/GPRS core network , including the Evolved 3GPP Core Network
- 2G, 3G and future communication access technologies (including GERAN, UTRAN and E-UTRAN)

- an evolved industry-wide IP Multimedia Subsystem (IMS) developed in an access independent manner
- converged fixed-mobile communication technologies, when the involved mobile technologies are those identified above

In the current phase SA1 is active in a number of Work Items (WI) in the form of Features or Studies (1st Level) that influence several ongoing specification activities especially in the next release (Rel-16):

- New Services and Markets Technology Enablers - Phase 2
- Enhancements to IMS for new real time communication services
- Mobile Communication System for Railways 2
- **QoS Monitoring**
- Satellite Access in 5G
- 5G message service for MIoT
- Study on Improvement of V2X Service Handling
- Remote Identification of Unmanned Aerial Systems
- Layer for User Centric Identifiers and Authentication
- Multimedia Priority Service (MPS) Phase 2
- Positioning use cases
- Communication for Automation in Vertical Domains
- **Business Role Models for Network Slicing**
- Maritime Communication Services over 3GPP system

3.2.1.2 Relation with SliceNet

In particular, SliceNet has approached the definition of Business Roles for Slicing [55], which is also under study by an SA1 Work Item [TR 22.830 FS_BMNS]. The Business Roles Discussion within SliceNet produced a model that is somewhat different from the one that had already been proposed by SA5 [TR 28.801], and the project consortium decided that this difference could be an interesting input for the FS_BMNS WI. In the preliminary study for the eventual contribution, it was found that there were significant discrepancies between what had already been defined by SA5 [in TR 28.801] and what is being discussed under SA1 FS_BMNS WI. Contact with the Rapporteur has been established in order to understand the expected work evolution and the convergence with TR 28.801. It was found that there was no such intent in this subject.

This misalignment within the 3GPP seems to have been caused by the general pressure on the SDO for the standardization of 5G, leading to SA1 work to be somehow overcome by other - supposedly later - standardization groups within 3GPP, namely SA5.

3.2.1.3 Approach

SliceNet is continuing to follow the results of this WI [TR 22.830] but chose not to make any proposal/contribution for the moment.

3.2.2 3GPP SA2 Architecture

3.2.2.1 Brief description

The second working group (SA-WG2 or SA2) [11] of the TSG-SA is responsible for the Stage 2 of the 3GPP network based on a system wide view. SA2 addresses service requirements as produced by SA1 and tries to consolidate how these requirements are satisfied by the proper components, the related functionality, the integration approach, including interactions with existing entities, and the exchanged information so as to feed the consolidation of messages that will be performed in Stage 3.

In the current phase SA2 is active in a number of WIs in the form of Features or Studies (1st Level) that influence several ongoing specification activities especially in the next release (Rel-16):

- Single radio voice continuity from 5GS to 3G
- **Enhancements to the Service-Based 5G System Architecture**
- Enhancement of URLLC supporting in 5GC
- Enhancement of systems using EPS for Ultra Reliability and Availability using commodity equipment
- **Enhancement of Network Slicing**
- Application Awareness Interworking between LTE and NR
- Enhancing Topology of SMF and UPF in 5G Networks
- Enhanced IMS to 5GC Integration
- The Wireless and Wireline Convergence for the 5G system architecture
- Enhancement to the 5GC Location Services
- **Enablers for Network Automation for 5G**
- Cellular IoT support and evolution for the 5G System
- **Access Traffic Steering, Switch and Splitting support in the 5G system architecture**
- Encrypted traffic detection and verification
- Architecture enhancements for 3GPP support of advanced V2X services
- EPC support for Mobility with Low Latency Communication

However, more mature WIs in the form of Building Blocks (2nd Level) are already included in Rel-15:

- Stage 2 of 5G System - Phase 1
- Stage 2 of INOBEAR
- Study on Stage 2 of LTE_LIGHT_CON
- Study on Stage 2 for PARLOS

3.2.2.2 Relation with SliceNet

3GPP SA2 is one of the most relevant specification entities with respect to SliceNet. Since most of the output relates with slicing and service based architectures as well as with autonomous management (as highlighted with **bold** in the above lists). The specifications and architecture patterns/principles to be or currently being produced are expected to influence heavily the roadmap with respect to the applicability of the flexibility offered by cloud and software defined/driven practices to future BSS/OSS practices. This aspect is at the centre of SliceNet approach from the first day and it has already influenced control and management plane discussions and decisions so far. Several aspects (especially SBA approaches and Role identification) are already being followed and more of them will be also considered soon by various technical teams in the consortium so that the ongoing and more elaborated designs will adequately aligned with the expected consolidated versions of the specifications.

On the other hand, practices at the technical realization level as early and continuously exercised by SliceNet teams leave ample room for evaluating the concepts in action and potentially either challenge certain aspects or produce useful feedback to be further disseminated and/or even communicated to 3GPP. More specifically, one of the most promising fields is the definition and consolidation of the Role of actors in Sliceable architectures. Additionally, plugability, automation, cognition and abstraction are also aspects to be further tested and elaborated and potentially get influenced or influence SA2 topics.

3.2.2.3 Approach

SliceNet is constantly following the versions of TS 23.501 - “System Architecture for the 5G System” and will try to delve into greater detail the related aspects in order to provide a management plane aligned with the procedures for 5G New Core. Working Items will be also followed to allow for early considerations and adoption of future specifications. Finally, depending on the conclusions and

feedback that can be generated out of the hands-on experience with the SliceNet platform the possibilities for collaborating at a later stage will be seriously considered.

3.2.3 3GPP SA3 Security

3.2.3.1 Brief description

The third working group (SA-WG3 or SA3) [12] of the TSG-SA is responsible for:

- security and privacy in 3GPP systems
- determining the security and privacy requirements
- specifying the security architectures and protocols
- ensuring the availability of cryptographic algorithms which need to be part of the specifications
- further accommodating, as far as is practicable, regional regulatory requirements that are related to the processing of personal data and privacy

The sub-WG SA3-LI provides the requirements and specifications for lawful interception in 3GPP systems.

In the current phase SA3 is active in a number of Work Items (WI) in the form of Features or Studies that influence several ongoing specification activities especially in the next release (Rel-16):

- Security Assurance Specification for 5G
- Security aspects of single radio voice continuity from 5G to UTRAN
- Supporting 256-bit algorithms for 5G

However, more mature WIs in the form of Features, Studies or Building Blocks are included in Rel-15:

- Security aspects of 5G System - Phase 1
- **Security aspects for LTE support of V2X services**
- MC Security Enhancements
- Security aspects of enhancements to ProSe UE-to-Network Relay
- Security aspects of CAPIF
- **Security aspects of 5G Network Slicing Provisioning**
- Long Term Key Update Procedures

3.2.3.2 Relation with SliceNet

3GPP SA3 focuses on security aspects including the 5G security architecture that supports various security features but not limited to:

- access independent authentication framework that supports more than one authentication method
- secondary authentication between the UE and external data networks
- security for access, mobility and session management
- security for untrusted non-3GPP accesses
- subscription and device equipment identifier privacy
- secure storage and processing of subscription credentials, and identifiers
- user data and signalling data integrity and confidentiality
- security visibility and configurability within the UE
- security for roaming with EPS
- security for interworking with and migration from EPS
- security for service based architecture

Also, a set of new specification will describe the 5G System is proposed in TS 33.501 (Security Architecture and Procedures for 5G System), and the security aspects of 5G Network slicing

provisioning are specified in TS 33.811, which expect to influence in Slicenet security management. So far, the discussions on security aspects in Slicenet control and management plane are based on these specifications and some of them will be considered in the designs of security component in Slicenet, e.g., the management interface will need to be secured so that only authorized parties can create, alter, and delete network slice instances, autonomic cognitive security management to study and identify the security threats in different layer (e.g., Management Interface Exposure, NSI, NSST, etc.), and security functions/mitigation solutions in case of threats.

On the other hand, exercises on security management in Slicenet will produce useful feedback to be further disseminated to the 3GPP SA3 WG. The design and demonstration in Slicenet security management will provide PoCs and realisation on the SA3 proposed features.

3.2.3.3 Approach

SliceNet is continuing to follow the results of SA3, specifically WI 750016 (Security aspects of 5G System - Phase 1) and TS 33.811 (Security aspects of 5G Network Slicing Provisioning), but chose not to make any proposal/contribution for the moment.

3.2.4 3GPP SA5 Telecom Management

3.2.4.1 Brief description

The fifth working group (SA-WG5 or SA5) [13] of the TSG-SA is dealing with the requirements, architecture and solutions for provisioning and management of the network elements and network services. Additionally SA5 will define charging solutions in alignment with the related charging requirements developed by the relevant WGs, and will specify the architecture and protocols for charging of the network and its services.

The most relevant 5G studies from the SA5 enabling the first phase in 3GPP Release 15 includes building up a new service-oriented management architecture, network slicing and all the necessary functionalities for management and charging for 5G networks. The current work within SA5 that will influence the next 3GPP Release 16 includes several other work items such as management of QoE measurement collection and new technologies for RESTful management protocols.

3.2.4.2 Relation with SliceNet

Apart of the challenges mentioned in chapter 3.2.1.2 to align the Business Roles for Slicing model from SliceNet [41] **Error! Reference source not found.**with the ones proposed by SA1 Work Item TR 22.830 and SA5 Work Item TR 28.801, there are other synergies between SliceNet and SA5 considering the following components:

- 5G networks and network slicing management concept, architecture and provisioning defined in: TS 28.530, TS 28.531, TS 28.532 and TS 28.533
- Provisioning of network slice instances
- Roles related to 5G networks and network slicing
- Management models for network slicing
- Management architecture
- Network Resource Model (NRM) for 5G networks and network slicing defined in: TS 28.540, TS 28.541, TS 28.542 and TS 28.543
- Fault Supervision of 5G networks and network slicing defined in TS 28.545 and TS 28.546
- Assurance data and Performance Management for 5G networks and network slicing
- Management and virtualization aspects of 5G networks, relying on the findings from TR 32.864
- 5G Charging system architecture and service based interface
- Service Based Interface to deal with the services, operations and procedures of charging that will be defined in TS 32.290 and TS 32.291

- 5G Data connectivity charging to be specified in TS 32.255, TS 32.298 and TS 32.291

3.2.4.3 Approach

SliceNet will liaise with SA5 to anticipate the evolution impact and the potential synergies with the TR 28.801. Moreover, SliceNet is looking to align with the working versions of TR 28.530 - ''Management and orchestration of networks and network slicing; Concepts, use cases and requirements'', TR 28.531 - ''Management and orchestration of networks and network slicing; Provisioning; Stage 1'', TR 28.532 - ''Telecommunication management; Management and orchestration of networks and network slicing; Provisioning; Stage 2 and stage 3 '' and TR 28.533 - ''Management and orchestration of networks and network slicing; Management and orchestration architecture''.

3.3 ETSI

3.3.1 ETSI NFV (Network Functions Virtualization)

3.3.1.1 Brief description

The ETSI NFV ISG (Industry Specification Group) [14] is defining an architectural framework, with reference points and interfaces, for provisioning, operation, management, monitoring and end-to-end orchestration of Network Services (NSs) composed of Virtual Network Functions (VNFs) running in a virtualised infrastructure environment, called Network Function Virtualization Infrastructure (NFVI), and possibly integrating Physical Network Functions (PNFs).

The NFVI is built over physical infrastructures composed of computing, storage and networking resources that are virtualised in order to enable an efficient sharing of the resources. In this context, the physical infrastructures as well as the virtual resources realized on top of them are managed through one or more functional entities called Virtual Infrastructure Managers (VIMs). Such VIMs can operate computing, storage and network resources (e.g. through the OpenStack cloud management platform) or they could be specialized to handle a single type of resources in a specific segment.

The core part of the ETSI NFV architecture relates to the orchestration of Network Services, that is handled through the combined action of an NFV Orchestrator (NFVO) and one or more VNF Managers (VNFMs). In particular, the NFVO manages the lifecycle of NS instances and coordinates the provisioning of their resources interacting with the VIMs, while the VNFMs coordinate the lifecycle of single VNFs, e.g. their instantiation, configuration, scaling up and down, termination, etc. The NFVO, VNFMs and VIMs are the components of the so called NFV MANO (MANagement and Orchestration) platform, which has been specified in the ETSI GS NFV-MAN 001 document [48].

3.3.1.2 Relation with SliceNet

ETSI NFV activities are already in their consolidation phase, and the specifications can currently be considered as mature and pretty stable. Indeed, ETSI NFV is now in its Phase 3, where basically the MANO core concepts, in terms of architecture and high level interfaces are mostly finalized and under a maintenance and consolidation process. Most of the relevant efforts now in ETSI NFV are being spent in the specification of MANO interfaces at the protocol level. Here the SOL Working Group is defining REST based interfaces among the different MANO components (i.e. NFVO, VNFM, VIM), and these are considered as key activities towards NFV multi-vendor interoperability.

In terms of relevance with SliceNet topics, NFV in general can be considered as one of the key reference technology to be leveraged in the project as a way to manage and orchestrate virtualised infrastructures and network functions. More than that, in 2017, ETSI NFV started to analyse and investigate how its principles and architectures could be mapped to network slicing concepts and use cases defined in other standardization bodies. In particular, in the context of the ETSI NFV EVE Working Group, a dedicated document (ETSI NFV GR EVE-012[63]) has been released early 2018 with the aim

of reporting how and if network slicing (as defined mostly within NGMN, 3GPP and ONF) could be supported by the ETSI NFV architecture and MANO concepts. Currently, the ETSI NFV GR EVE-012 work is being continued within a dedicated discussion item under the umbrella of IFA Working Group and called IFA FEAT05.

3.3.1.3 Approach

SliceNet is already following and aligning to what ETSI NFV has specified in terms of management and orchestration approaches, architectures and interfaces. At the moment, SliceNet plans to adopt as much as possible what ETSI NFV has produced. Given the fact that ETSI NFV specification activities are already stable and in their consolidation process, active contributions from the project may be difficult to implement. However, SliceNet plans to carefully follow the evolution of the network slicing related activities and discussions within ETSI NFV EVE Working Group and IFA FEAT05.

3.3.2 ETSI MEC (Multi-access Edge Computing)

3.3.2.1 Brief description

The MEC [15] initiative is an Industry Specification Group (ISG) within ETSI. The purpose of ISG is to create a standardized, open environment which allows the efficient and seamless integration of applications from vendors, service providers, and third-parties across multi-vendor Mobile-edge Computing platforms. The initiative aims to benefit a number of entities including mobile operators, application developers, telecom equipment vendors, Over the Top (OTT) players, Independent Software Vendors (ISVs), IT platform vendors, system integrators and technology providers. All of the former parties are interested in delivering services based on MEC concepts.

The work of MEC aims to unite the telco and IT-cloud worlds, providing IT and cloud-computing capabilities within the RAN. The MEC ISG will specify the elements that are required to enable applications to be hosted in a multi-vendor mobile-edge computing environment. MEC will enable applications and services to be hosted ‘on top’ of the mobile network elements, i.e. above the network layer. These applications and services can benefit from being in close proximity to the customer and from receiving local radio-network contextual information.

3.3.2.2 Relation with SliceNet

The ETSI MEC paradigm is a Slicing and QoS enabler for verticals to deploy their services on the top of a slicing-friendly mobile network infrastructure. Within the context of SliceNet, we will explore MEC so as to meet the challenging requirements in verticals’ use cases by improving the efficiency of slicing and, thus, reducing the slice creation and provisioning time significantly. This entails the revisit of the current existing software-networking based 5G proof-of-concept infrastructure platforms and investigates novel mechanisms to improve the friendliness of slicing in the infrastructure, both virtual and physical.

3.3.2.3 Approach

It is expected to follow, align, and possibly opportunistically collaborate (e.g. PoCs, platforms, and talks) with ETSI SDO.

3.3.3 ETSI ZSM (Zero touch network and Service Management)

3.3.3.1 Brief description

The ETSI “Zero touch network and Service Management Industry Specification Group” (ISG ZSM) [17] is a new specification group that has been kicked off in January 2018. Its main goal is to define a new, future-proof, horizontal and vertical end-to-end operable framework enabling agile, efficient and qualitative management and automation of emerging and future networks and services. While ETSI

ZSM considers horizontal end-to-end as cross-domain, cross-technology aspects, vertical end-to-end is referred to cross-layer aspects, from the resource oriented up to the customer oriented layers.

ETSI ZSM targets a network and service management architecture where all operational processes and tasks (e.g., delivery, deployment, configuration, assurance, and optimization) are executed automatically, ideally with 100% automation.

ETSI ZSM aims to facilitate the coordination and cooperation between relevant standardization bodies and open source projects. Its unique value will be in providing guidance to the implementation of management interfaces as well as coordinating and giving directions to achieve automated end-to-end network and service management solutions and architecture. As part of the end-to-end solution, the necessary management architecture and interfaces to support the end-to-end zero touch network and service management in multi-vendor environment will be identified.

Currently, ETSI ZSM is progressing mostly on two main working items:

- definition of network and service automation use cases and requirements
- initial definition of a reference architecture.

In a second phase, topics like network slicing are also in scope of ETSI ZSM.

3.3.3.2 Relation with SliceNet

ETSI ZSM is considered to be highly relevant to SliceNet, as automation in network and service management in support of network slicing is one of the key objectives of the project. Even if the ETSI ZSM activities have been just started and are at an early stage, SliceNet believes that there are many commonalities in the two roadmaps and objectives, especially for what concerns ZSM plans and targets for defining management interfaces and tackling network slicing aspects.

Moreover, the ETSI ZSM Chairman (Klaus Martiny, from Deutsche Telekom) is a member of the SliceNet Advisory Board, that represents a unique opportunity for the project to have direct collaboration.

3.3.3.3 Approach

SliceNet is already monitoring the ETSI ZSM activities, from mailing list discussions to evolution of new contributions related to use cases and architecture definition. Nextworks is an ETSI ZSM participant, and as non-voting member of the ISG is currently tracking the ETSI ZSM progress and the alignment of the proposed architectures.

Potentially closer collaboration opportunities may arise in the future when ETSI ZSM activities will focus more on network slicing aspects, where SliceNet could play a role of potential contributor at the level of information models and interfaces specification.

3.3.4 ETSI ENI (Experiential Networked Intelligence)

3.3.4.1 Brief description

The purpose of the ETSI ISG ENI [16] is to define a Cognitive Network Management architecture that is based on the “observe-orient-decide-act” control model. It uses AI (Artificial Intelligence) techniques and context-aware policies to adjust offered services based on changes in user needs, environmental conditions and business goals. The system is experiential, in that it learns from its operation and from decisions given to it by operators to improve its knowledge of how to act in the future. This will help operators automate their network configuration and monitoring processes, thereby reducing their OPEX and improving the use and maintenance of their networks.

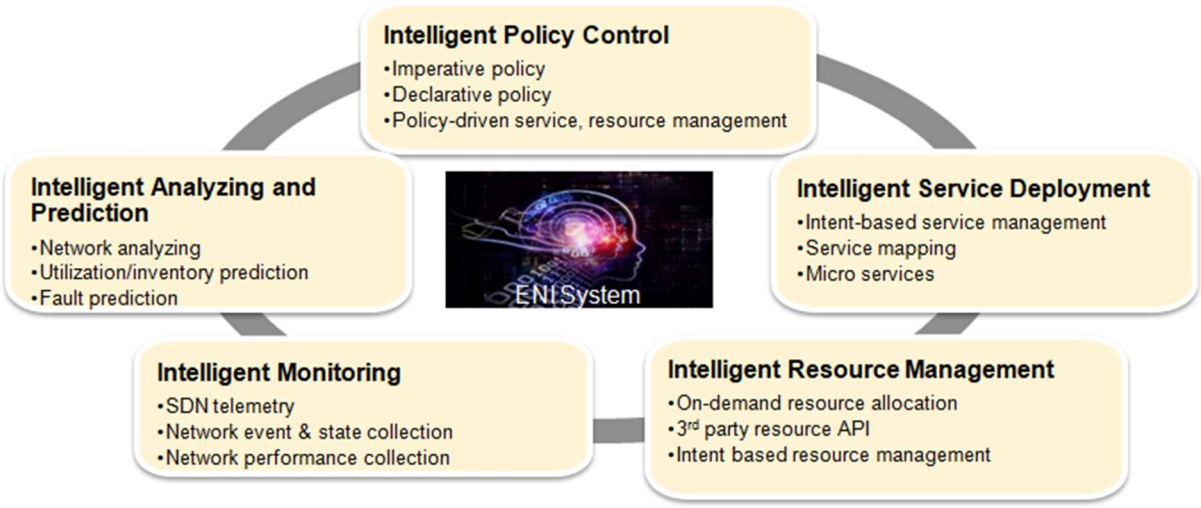

Figure 2: Cognitive Network Management System

3.3.4.2 Relation with SliceNet

Since SliceNet is an "End-to-End Cognitive Network Slicing and Slice Management Framework in Virtualised Multi-Domain, Multi-Tenant 5G Networks" its obvious the strong relationship between ENI and SliceNet, and the benefits that can be obtained with a joint technical cooperation. Some important aspects of this cooperation are cognitive slice management architecture & interfaces/APIs, close cognition control loop, Machine Learning and operator experience metric and optimization.

3.3.4.3 Approach

A workshop has been held in London, UK on 14 Dec 2017, and the desire for cooperation between ETSI ENI-SliceNet was agreed and established. The approach is thus to collaborate with ENI, particularly in this phase with PoCs.

Subsequently to this agreement, ENI has prepared its own structure to support PoCs and - by the end of May 2018 - published the framework for PoC proposals [49]. SliceNet is now preparing a PoC proposal for ETSI ENI.

3.4 IETF

3.4.1 IETF SFC (Service Function Chaining)

3.4.1.1 Brief description

The term "service function chaining" is used by the SFC [18] working groups of IETF to describe the definition and instantiation of an ordered list of instances of such service functions, and the subsequent "steering" of traffic flows through those service functions. The IETF-SFC working groups provide several documents to describe the architecture, encapsulation protocol, use-cases… for the SFC.

The SFC architecture RFC describes an architecture for the specification, creation, and ongoing maintenance of SFCs in a network. It includes architectural concepts, principles, and components used in the construction of composite services through deployment of SFCs, with a focus on those to be standardized in the IETF.

The proposed encapsulation protocol for the SFC was also described in an RFC document. This document describes a Network Service Header (NSH) imposed on packets or frames to realize Service Function Paths (SFPs). The NSH also provides a mechanism for metadata exchange along the

instantiated service paths. The NSH is the SFC encapsulation required to support the SFC architecture. The IETF-SFC working groups present in several documents network function chaining use-cases in, for instance, mobile networks, Fog RAN and data center network.

Recently new documents were published by the SFC working groups to deal with Hierarchical SFC (hSFC) which is a network architecture allowing an organization to decompose a large-scale network into multiple domains of administration. A Method for Service Orchestration in hSFC was also described by the SFC working groups.

3.4.1.2 Relation with SliceNet

The IETF SFC provides the ability to define an ordered list of network services, or service functions (e.g., firewalls, load balancers, DPI) connecting them in a virtual chain. Within the context of SliceNet, we will explore the architectures and recommendations proposed by the IETF-SFC working groups since a network slice in SliceNet can be defined as a set of an ordered/chained network resources. In addition to that the definition of large-scale network into multiple domains of administration defined by IETF-SFC can assist in the decision-making and design of solution for SliceNet.

3.4.1.3 Approach

It is expected to follow the recommendation and architecture of the service function chaining proposed by the IETF working group.

3.4.2 IETF COMS (Common Operations and Management on network Slices)

3.4.2.1 Brief description

IETF COMS [19] is an IETF Birds of Feather (BoF) created early 2018 to progress with the activity started one year earlier in IETF in the context of the discussion group called “netslices”, trying to evaluate the opportunity to create a new dedicated IETF Working Group (WG) or either join existing ones to address network slicing problems and gaps within IETF.

In particular COMS targets a technology-independent and resource-centric management plane for network slices and aims to describe an overall architecture for network slicing, with information models that enable the design of service delivery and customer service interfaces. Also, COMS plans to specify network slicing OAM as well as data plane functionalities required to enable the delivery and operation of network slices as required by industry verticals.

As a general approach, COMS define a network slice as a set of infrastructure resources and service functions with customized and specific attributes designed to address the requirements of an industry vertical or a more generic end to end service. In the COMS view, network slices can span across multiple administrative domains, and may use heterogeneous technologies.

At the time of writing, the next steps from IETF COMS are under discussion within IETF community to properly position the network slicing challenges and problems.

3.4.2.2 Relation with SliceNet

A set of relevant Internet-Drafts (I-Ds) have been released by relevant members of network management industry community, addressing network slicing from several perspectives, from overall management and operation architecture [50] to information models [51] and cross-provider challenges and approaches in multi administrative domain scenarios [52].

The IETF COMS I-Ds produced so far are in general high relevant in the context of SliceNet management and orchestration principles, especially for what concern technology agnostic approaches and network slice information models. In this direction, SliceNet is already considering, in relation with the Plug & Play control plane, the IETF COMS proposal for a technology independent network slice information

model as a reference baseline for modelling how network slices are exposed towards slice consumers, including verticals.

3.4.2.3 Approach

SliceNet is continuously monitoring the IETF COMS activities, from mailing list discussions to new and updated versions of I-Ds from relevant telco operators and vendors. As said, IETF COMS is still in an intermediate and hybride status of non-WG, therefore the minimum level of approach SliceNet is targeting is to follow the next steps and discussions there. Moreover, some of the SliceNet modelling activities are already influenced by IETF COMS approach, therefore where applicable SliceNet will pursue alignment with relevant I-Ds. However, when the next IETF COMS steps and goals will be more clear, SliceNet will evaluate opportunities to actively contribute and collaborate in IETF COMS, e.g. possibly proposing new I-Ds coming out from SliceNet research.

3.5 IRTF NFVRG (Network Function Virtualization Research Group)

3.5.1 Brief description

The main aim of the IRTF NFVRG is to push the growth of the interest of both academia and industry community around the Network Function Virtualization (NFV) concept [20]. This is achieved through the IRTF collaboration tools, the organization of public workshops/seminars co-located with prestigious international conferences and through special issues related to NFV in major journals and magazines.

The NFVRG focuses on research problems associated with NFV-related topics, such as, among others:

- Network architectures based on VNFs
- Network and service function chaining
- Autonomous orchestration and optimization
- Performance modeling
- Real-time big data analytics and data-centric management of virtualised infrastructures

All these topics are strongly related with the SliceNet objectives.

3.5.2 Relation with SliceNet

In 5G networks, the network functions are virtualised and grouped into VNFs. Currently, the research group has an active early internet draft (I-D) about the research challenges still open for network virtualization [53]. It is worth to note that most of such research challenges are aligned with some of the objectives of SliceNet (end-to-end quality of service guarantees, virtualization technologies, 5G network slicing, etc...).

3.5.3 Approach

Since many challenges investigated in the NFVRG are aligned with the SliceNet activities, the progress of the NFVRG activities will be monitored, with special emphasis on those topics/challenges where SliceNet will be very active.

3.6 IEEE Network Intelligence Emerging Technologies Initiatives

3.6.1 Brief description

The scope of the Network Intelligence (NI) [21] sub-committee is to support and endorse researches to embed Artificial Intelligence in the future software and programmable networks.

Future networks need to have built-in (by design) embedded intelligence towards agility, resiliency, faster customization and security. The advent of the future networks is then the opportunity to embed

intelligence while designing those networks and rethinks how to solve problems in the networking space by using AI techniques.

The vision of embedding Intelligence into the network will allow greater level of automation and adaptiveness, enabling:

- Faster deployment (from months down to minutes)
- Dynamic provisioning in line with the dynamic nature of network functions
- End-to-end orchestration to ensure coherent deployment of IT and network infrastructures and service chains
- Ensure resiliency and high availability of networks and services

Network intelligence sub-committee will cover numerous and multidisciplinary topics that are of importance to the ComSoc community including:

- Declarative policies ("intents") for orchestration and management: including Natural Language Processing and Understanding for service deployment, change and assurance
- Learning techniques: supervised, unsupervised and reinforcement Learning (Forecasting, clustering and classification techniques) for resilient network
- Optimal resource allocation and placement and for network action recommendations
- Knowledge base: graph database and advanced data mining techniques to ensure coherency of emerging networks (SDN, NFV, Programmable Forwarding Planes, Cloud, and 5G)
- Autonomic Management for Software-Defined Networks
- Self-configuration, self-optimization, self-healing and self-protection in programmable and software-defined networks
- Self-optimization for dynamic controllers and virtual network functions placement
- Policy-based management, including imperative, declarative (intent), and other paradigms
- Learning and reasoning techniques for programmable networks
- Data analytics and machine learning for autonomic management
- Autonomic based service lifecycle management and orchestration
- Autonomic resource allocation and configuration in virtualised infrastructures
- Adaptive scheduling in cloud computing environments

Indeed, this sub-committee will bring together (cross-fertilization) competences in network and competences in AI towards better, agile and dynamic smart networks that become a must for the foreseen network transformation.

3.6.2 Relation with SliceNet

Orange Labs Networks is leading the Network Intelligence committee and several partners are members of the committee.

3.6.3 Approach

3.6.3.1 Journal participation

We are planning to edit a series of special issues on network intelligence and related topics in the following journals and magazines:

- IEEE Transactions on Network and Service Management (TNSM), which regularly publishes papers in the area of autonomics. We already discussed the possibility of creating the special issue with Raouf Boutaba, the founding Editor-in-Chief (until 2010) and member of the TNSM Advisory Board and with Rolf Stadler, the current editor-in-chief of TNSM.
- IEEE Communications Magazine (COMMAG) series on network and service management, which regularly publish papers on network intelligence related topics like autonomic communications and network management organized in two feature issues per year.

- The International Journal on Network Management technically sponsored by ACM with the editorial board including some NI officers.

3.6.3.2 Standards Activities

NI officers participate on a regular basis to the IRTF Network Management Research Group (NMRG) Meetings and activities. The NMRG held several meetings alternating between co-location with the IETF meetings and Network Management conferences such as IM2017 and NOMS2016.

The NMRG participate to maintain an active liaison and interactions among the various communities (research and standardization) on the topics of network management and has organized special session and workshop dedicated to autonomic networking and collaborative networking, measurement, new management approaches (Intent Based Networking), pushing further the awareness and importance of these topics to the various committees and communities.

NMRG also establishes liaison and cross- IETF working groups / IRTF research groups coordination on the network management and network operation aspects. A recent example is the joint meeting organized by the SDN, NFV and NM research groups at IETF95/Berlin.

Some interactions and liaisons have been exchanged between various groups on autonomic networking standardization such as IETF ANIMA WG and the ETSI NTECH AFI WG.

3.7 ITU-T

3.7.1 Brief description

The Study Groups of ITU's Telecommunication Standardization Sector (ITU-T) assemble experts from around the world to develop international standards known as ITU-T Recommendations which act as defining elements in the global infrastructure of information and communication technologies (ICTs). Standards are critical to the interoperability of ICTs and whether we exchange voice, video or data messages, standards enable global communications by ensuring that countries' ICT networks and devices are speaking the same language.

3.7.2 Relation with SliceNet

The activities of interest within ITU-T are the Focus Groups (FG) that are preparatory activities to establish standardisation work items. In particular the FG IMT-2020, which concluded at the end of 2016, advised its parent study group SG13, and helped formulating the current SG13 questions. FG IMT-2020 formulated the requirements for standardization related to the wireline elements of 5G. It addressed the areas of (i) high level architecture, (ii) network softwarisation, (iii) end-to-end QoS and (iv) front haul/back haul and (v) emerging network technologies.

A new FG on Technologies for Network 2030 (FG NET-2020), which has been established in July 2018, intends to study the capabilities of networks for the year 2030 and beyond, when it is expected to support novel forward-looking scenarios, such as holographic type communications, extremely fast response in critical situations and high-precision communication demands of emerging market verticals. The study aims to answer specific questions on what kinds of network architecture and the enabling mechanisms are suitable for such novel scenarios. SG13 is the parent SG for this FG as well.

In both cases the ongoing work of SG13 resulting from the recommendations of FG IMT-2020 as well as the ongoing work of FG NET-2030 are related to the work of SliceNet.

3.7.3 Approach

The approach of SliceNet in relation to the work of SG13 is to observe and where necessary and possible to align the approach. Direct contributions to the work of SG13 are not envisaged due to the high formal requirements for engagement in ITU-T Study Groups.

In contrast, in relation to FG NET-2030 SliceNet may seek opportunities to collaborate with the FG on future emerging aspects. In the scope of focus Groups the collaboration is easier due to the lower formal requirements for engagement.

3.8 NGMN

3.8.1 Brief description

The NGMN Alliance is an industry grouping devoted to expand the communications experience by providing a truly integrated and cohesively managed delivery platform that brings affordable mobile broadband services to the end user with a particular focus on 5G while accelerating the development of LTE-Advanced and its ecosystem. The alliance is driven by network operators who form the main membership body of the alliance, as well as manufacturers or vendors of mobile technology and network infrastructure.

NGMN is regularly publishing white/position papers advocating important concepts and architecture patterns of relevance to 5G. As an example the slicing concept in 5G has firstly been described by NGMN.

3.8.2 Relation with SliceNet

Most of the contributions of NGMN are of high relevance to SliceNet and serve as a source of advanced concepts that typically are analysed and possibly adopted by SliceNet. A recent example is the document “5G End-to-End Architecture Framework v2.0” that delineates the requirements in terms of entities and functions that characterise the capabilities of an E2E (end-to-end) framework [64].

3.8.3 Approach

SliceNet is following the work of NGMN and analyses its contributions, while evaluating possible alignment with the NGMN concepts.

4 Open Source Communities

In this chapter we will address the main OSC activities that can be of great relevance to SliceNet.

4.1 Introduction

The OSCs are also very important for the SliceNet project. In fact these OSCs will provide solutions/tools that are *de facto* "standards" for telecommunications in a broader sense and thus can be of great value to be used/explored in the SliceNet project.

For these OSCs we will have several approaches with different levels of involvement:

- **Follow** we will be monitoring what is going on in this OSC
- **Align** we must be aligned with what the OSC is proposing
- **Use** we will be using this OSC approach and artefacts in the SliceNet project
- **Collaborate** we have the ability to influence the decisions and potentially contribute to the artefacts development that are taking place in the OSC

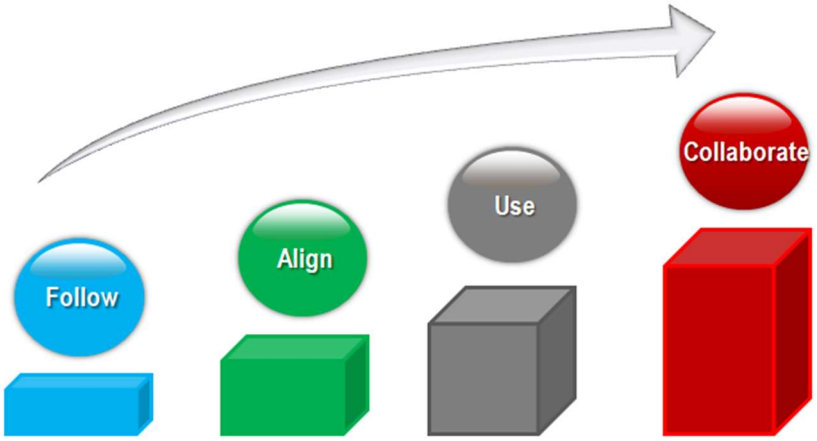

Figure 3: Level of involvement in the OSC

4.2 Central Office Re-architected as a Datacenter (CORD)

4.2.1 Brief description

CORD brings datacenter economics and cloud flexibility to the telco Central Office and its mission is [28]:

"Our mission is to bring datacenter economies and cloud agility to service providers for their residential, enterprise, and mobile customers using an open reference implementation of CORD with an active participation of the community. The reference implementation of CORD will be built from commodity servers, white-box switches, disaggregated access technologies (e.g., vOLT, vBBU, vDOCSIS), and open source software (e.g., OpenStack, ONOS, XOS)."

The main objectives are to become vendor-independent, reduce CAPEX/OPEX and enable agile service creation by applying disaggregation, SDN and NFV to the access network. To accomplish these objectives the network will be deployed using open source hardware and open source software.

The reference implementation of CORD is designed to be a general platform that can be configured for several deployment scenarios, namely R-CORD (Residential), M-CORD (Mobile) and E-CORD (Enterprise):

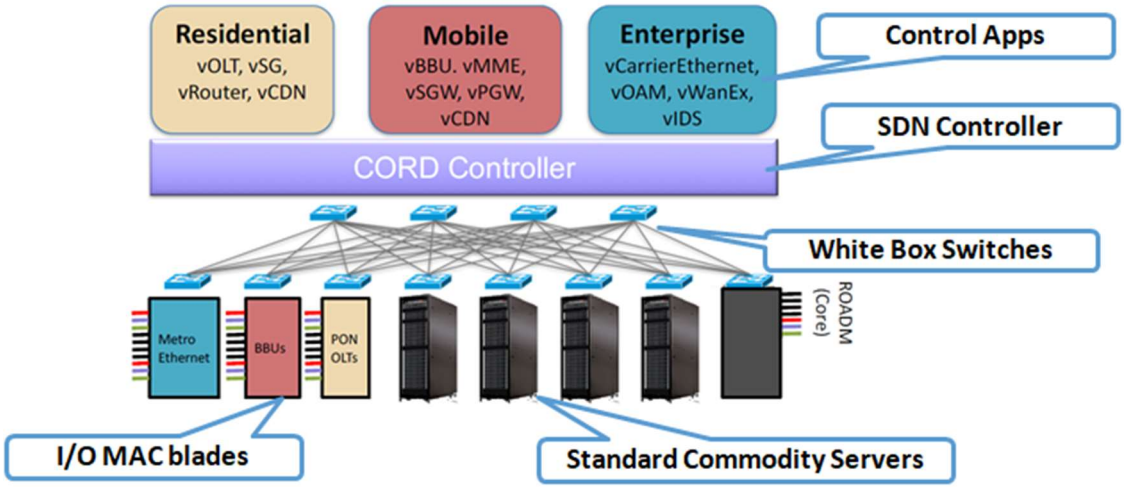

Figure 4: CORD domains of use

4.2.2 Relation with SliceNet

In the scope of the Operator's Central Office, CORD is proposing a valuable approach, based on Virtualization, function Disaggregation and Cloud technologies, across a number of reference scenarios. Recently, the project has been addressing aspects related to Network Slicing in this context, which are worth following by SliceNet.

4.2.3 Approach

The approach will be to follow and use the proposed concepts and artifacts of this project, whenever applicable, in the SliceNet use case implementation scenarios.

4.3 Open Network Automation Platform (ONAP)

4.3.1 Brief description

In February 2017, The Linux Foundation announced the merger of open source ECOMP (Enhanced Control, Orchestration, Management & Policy) and OPEN-O (Open Orchestrator Project) to create the new Open Network Automation Platform (ONAP) project [29]. ONAP is an open source software platform that delivers capabilities for the design, creation, orchestration, monitoring, and life cycle management of:

- Virtual Network Functions (VNFs)
- The carrier-scale Software Defined Networks (SDNs) that contain them
- Higher-level services that combine the above

ONAP has adopted a 6 months Release cadence. The first Release named Amsterdam was delivered in November 2017. The Amsterdam Release provides a unified architecture which includes production-proven code from open source ECOMP and OPEN-O to provide design-time and run-time environments within a single, policy-driven service orchestration platform. The following figure provides a high-level view of the ONAP Amsterdam architecture.

The ONAP Amsterdam architecture includes the following:

- **Portal framework** - The ONAP portal provides access to design, analytics and operational control/administration functions via a shared, role-based menu or dashboard
- **Design-time framework** - This is a comprehensive development environment with tools, techniques, and repositories for defining/describing resources, services, products or offers

- **Run-time framework** - This framework executes the rules and policies distributed by the design-time framework. It includes various modules such as Service Orchestrator (SO), Controllers (SDN-C, APP-C, VF-C), Data Collection Analytics and Events (DCAE), Active and Available Inventory (A&AI). These modules make use of Common Services that support logging, access control and data management
- **ONAP Operations Manager (OOM)** - The OOM is responsible for the end-to-end lifecycle management and monitoring of ONAP platform components

4.3.2 Relation with SliceNet

The orchestration stack on ONAP provides for service delivery/change/scaling controller instantiation and capacity management across both the application and network controllers. These capabilities can be used by the orchestration sub-plane of SliceNet in order to handle the layers of orchestration (i.e. services, slices and resources layers) considered by SliceNet.

In addition, it is expected that ONAP supports in the future the design of 5G specific services that utilize slicing.

4.3.3 Approach

The approach will be to follow the proposed frameworks and architecture of this project and may be communicate with or use it for the orchestration task of SliceNet.

4.4 Open Source MANO (OSM)

4.4.1 Brief description

Open Source MANO [30] is an operator-led ETSI community that is delivering a production-quality open source Management and Orchestration (MANO) stack aligned with ETSI NFV Information Models and that target to meet the requirements of production NFV networks.

OSM has the main objective of being a world-class production ready solution for NFV management and orchestration, and it is engineered, tested and documented to be functionally complete to support to be a key component for internal/lab and external/field trials as well as interoperability and scalability tests for VNFs and Network Services. It allows for rapid installation in VNF vendor, system integrator and operator environments.

OSM provides an integrated solution for NFV management and orchestration, covering both design time (i.e. DevOps) and run time phases of VNFs and Network Services lifecycle management. The design-time scope of OSM includes:

- the capability for Create/Read/Update/Delete (CRUD) operations on the Network Service definition,
- tools for VNF Package Generation,
- Graphical User Interface (GUI) to accelerate the design time phase, VNFs on-boarding and deployment.

On the other hand, the run-time scope of OSM mostly provides:

- an automated Network Service Lifecycle Management environment as the main coordination engine
- plugins for integrating multiple VIMs (including OpenStack, VMWare, Amazon Web Services, OpenVIM)
- plugins for integrating multiple SDN controllers
- an integrated generic VNFM with support for integrating specific VNFMs from VNF vendors
- support to integrate Physical Network Functions into Network Services

4.4.2 Relation with SliceNet

As a full solution for NFV management and orchestration, OSM is considered by SliceNet as an extremely relevant open source tool for Network Services and VNF lifecycle management. It has been proved to be working in many interoperability deployments (including multiple VIMs like OpenStack and VMWare), being it a core participant of the ETSI NFV Plugtests events where NFV solutions providers (from MANOs to VNFs and VIMs) meet together to test and integrate their products.

Moreover, in May 2018, a new OSM Release Four has been made available, with a bunch of new functionalities highly in scope with SliceNet. First, a new cloud-native deployment based on containers has been introduced, providing a much lighter installation and operation of OSM. Moreover, an entire new message bus based (using Kafka technology) integration of the several OSM components has been introduced. This allows an extremely easier integration of customized components and modules into the OSM framework, like those that SliceNet could develop and integrate in support of RAN slicing, specific slice monitoring and cognitive functions.

4.4.3 Approach

SliceNet is already carefully following and monitoring the progress of OSM, both as an NFV tool and as a community at large. Moreover, some of the SliceNet partners already have a solid background and experience with OSM (e.g. Nextworks), and being it an ETSI driven open source initiative with strong involvement and leadership of telco industry (Telefonica, BT, VMWare, Intel among the others) its relevance for the project is very high. Said that, the adoption of OSM as the reference SliceNet NFV management and orchestration framework (possibly with SliceNet custom extensions) is still under discussion in the context of a related evaluation and comparison with open source tools described in this section.

4.5 JOX

4.5.1 Brief description

JOX [31] is a Juju-based orchestrator for the virtualised network that natively supports network slicing. Using JOX, each network slice can be independently optimized with specific configurations on its resources, network functions and service chains. Inside the JOX core, a set of services is used to operate and control each network slice, while at the same time supports the necessary interplay between orchestration, Virtual Network Function Management (VNFM) and Virtual Infrastructure Management (VIMs), as these are defined in the ETSI MANO architecture. From the implementation perspective, JOX is tightly integrated with the Juju VNFM framework and Charm Store provided by Canonical.

Based on the above, JOX can take benefit from a rich Juju API and the Juju Store to not only provide an easy way to deploy but also scale and expose the services to the outside world. For example, a rich set of OAI-based 4G and a subset of 5G VNFs are already available as Juju Charms in the Juju store. However, as the side effect, it may make JOX difficult to work with another VNFM.

4.5.2 Relation with SliceNet

JOX is designed to be a fast and extendable prototyping tool for the mobile network slicing with which new policies such as scaling and placement can be evaluated. All the produced orchestration data and APIs are open to being consumed by 3rd parties through edge open data APIs. On one hand, JOX can be used as a standalone NFVO to work with Juju as a VNFM. On the other hand, JOX can be considered as a part of a complete open-source ecosystem, Mosaic5G [41], for 4G-5G research and development (R&D), with the purpose of building a lightweight 5G service delivery platform across reusable software components.

Therefore, JOX is one of the potential orchestration tools to be used as a NFVO in the SliceNet project, not only for deploying 5G infrastructure (Core and RAN) but also for MEC platform and its application.

It comes from the fact that JOX is designed as a 5G orchestration targeting network slicing, thus, inherently supports lifecycle management of network slices and orchestration for the mobile network.

4.5.3 Approach

It is expected that we follow, align and contribute to this activity under Mosaic5G initiative.

4.6 Openstack/Container Technologies

4.6.1 Brief description

A number of mature virtualization solutions are available and have seen widespread deployment in production environments during the last decade. Today, the two prevalent virtualization approaches can be classified as full virtualization (aka. hypervisor-based virtualization) and OS-level virtualization (aka. container-based virtualization). Full virtualization solutions employ a hypervisor layer allowing the execution of highly isolated Virtual Machines (VM). Each VM executes in its own kernel, with the hypervisor providing isolated access to the host's physical resources. In contrast OS-level virtualization provides virtual environments, known as containers, which share the host's kernel. Each container is assigned a dedicated process and network space and is allocated a share of the available system resources to provide a level of isolation. The associated mechanisms - namespaces and cgroups - are part of the mainline Linux kernel. Container solutions for managing and configuring these kernel features include Docker, LXC, LXD.

In general, full virtualization approaches offer a higher level of isolation between guests. The downside is that the guest Kernel and the host hypervisor layer incur a performance overhead. This can be partially mitigated by using pass-through approaches that grand the guest OS direct access to some hardware components. In contrast, container-based virtualization, which is a lightweight alternative to hypervisor-based virtualization, does not isolate resources as well as hypervisors but it offers higher density of virtualised instances on the same resources and thus offers superior performance and faster deployment.

Openstack [32] is an open source software for managing the virtual infrastructure of private and public clouds, providing the Infrastructure-as-a-service (IaaS) where the virtual resources are made available to users/customers. In the ETSI MANO model, OpenStack can be used as a VIM with a set of functionalities and services to manage the infrastructure effectively. The logical architecture of Openstack mainly consists of functional blocks for Compute, Storage and Networking.

The OpenStack Compute Nova handles the provisioning computer instances (virtual servers), i.e. creating virtual machines, bare metal servers and some support for system containers. It requires additional OpenStack services including Keystone for identity and authentication services, Glance for compute image repository (as all compute instances launch from glance images), and Neutron for provisioning the virtual/physical networks connecting the compute instances. Nova supports a wide variety of compute technologies (hypervisor layer) such as KVM, Xen, LXC, Hyper-V, VMware, XenServer, OpenStack Ironic and PowerVM, which provides the flexibility in choosing a hypervisor(s). The OpenStack storage functionality is provided by three main components: Swift for object storage, Cinder for block storage and Glance for a repository for VM images, which can use storage from Cinder using standard protocols such as Internet Small Computer Systems Interface (iSCSI), Fibre Channel, NFS or object storage from Swift via the Swift API or HTTP protocols with simple PUT/GET commands. Finally, Neutron provides networking functionality between interface devices (e.g. vNICs) managed by other OpenStack services and supports advanced network services like firewall, load balancing, intrusion detection, VPN, etc.

In addition, OpenStack also supports running containers on bare metal or VMs with full storage and networking support. One can easily run containers on top of Nova as it has everything needed to run compute instances. However, in complex environments, it is required to have a container

orchestration solution to ease the task of managing many containers in data centre environments. For this, OpenStack offers the Magnum system that supports multiple container orchestration tools including Docker Swarm, Kubernetes, Mesos, etc.

4.6.2 Relation with SliceNet

Openstack VIM is proposed for NFVI management in SliceNet as its architecture and implementation are fully aligned with ETSI MANO model with a set of functionalities for managing NFVI resources. Also, most of the implementation of other functional blocks in ETSI MANO model, e.g., NFV Manager (Juju) and NFV Orchestrator (Open Baton, Jox, OSM), support the integration of Openstack as a VIM with an Openstack Plugin. In particular, SliceNet has proposed to have Openstack VIMs in virtualised RAN, MEC and CORE infrastructure, each will register with the orchestrator as a PoP where the NFVO sends request to allocate resources and the VIMs will enforce these allocations to create virtual servers to run either VNF or application instances.

Regarding Neutron, it is used to control the data plane of the virtualised infrastructures mainly by providing tenant isolation, traffic filtering, ARP pre-populations and other network optimizations required to control virtualised infrastructures. SliceNet control plane is clearly focused on the programmability of the control plane in order to allow the implementation of slices within the tenant networks. As the future roadmap of Neutron, it is planned that it will provide support for traffic classification, bandwidth control, DSCP and QoS support and Explicit Control Notification in future releases.

4.6.3 Approach

It is expect that SliceNet will follow and use these technologies for reference architecture and for demonstration purposes. Also, SliceNet will keep very close to the further developments of the Neutron QoS support and data plane programmability in order to see where is possible to provide the slicing concept within the tenant networks.

4.7 Open Platform for NFV (OPNFV)

4.7.1 Brief description

OPNFV [35] was created with two main goals, firstly, to promote the developments of NFV services and products. Secondly, to create an open source platform to gather and test NFV elements that are already in use. The first phase of the OPNFV is to build the NFVI and the VIM. Finally, objectives of OPNFV are to contribute at the standardization process of the different open source platforms based on the NFVs elements and to create an ecosystem of industry leaders and end users where they can proactive validate and address the needs of the community.

4.7.2 Relation with SliceNet

OPNFV aims on building NFVI and VIM by adopting open source software such as OpenStack, OVS, OpenDaylight, etc. This allows to make performance, system and functional testing in order to be able to improve the developed components.

4.7.3 Approach

It is expected to follow and align to the OPNFV.

4.8 Open Air Interface (OAI)

4.8.1 Brief description

OAI [40] [36] is a flexible wireless technology platform that enables an open 4G-5G ecosystem. The platform offers an open-source software-based implementation of a subset of the 4G-5G systems spanning the full protocol stack of 3GPP standard in both E-UTRAN and EPC. It can be used to build and customize a base station (e.g. OAI eNB or gNB), a user equipment (OAI UE) and a core network (OAI EPC) in a PC. In a 4G compatible scenario, the OAI eNB can be connected either to a commercial UE or OAI UE to test different configurations and network setups and monitor the network and mobile device in real-time. In addition, OAI UE can be connected to an eNB test equipment (e.g. CMW500) as well as a commercial eNB (e.g. Amarisoft, IP.Access, etc.).

OAI is based on a PC hosted software radio frontend architecture. With OAI, the transceiver functionality is realized via a software radio front end connected to a host computer for processing. OAI is written in standard C for several real-time Linux variants optimized for Intel x86 and ARM processors and released as free software under the OAI License Model. OAI provides a rich development environment with a range of built-in tools such as highly realistic emulation modes, soft monitoring and debugging tools, protocol analyzer, performance profiler, and configurable logging system for all layers and channels.

4.8.2 Relation with SliceNet

The OAI software is used as a reference implementation of 4G and as a subset of 5G mobile cellular systems compliant with 3GPP standards. As such, it is used as the communication platform for a feasibility study, validation and performance evaluation, and proof-of-concept with high Technology Readiness Level (TRL).

4.8.3 Approach

It is expected to follow, align and contribute to the Open Air Interface Software Alliance (OSA).

4.9 OpenDaylight (ODL)

4.9.1 Brief description

The ODL project [37] was born in 2013 as an initiative of the Linux Foundation aiming to develop a flexible and modular SDN-based control platform. After eight releases, ODL is one of the most mature controllers that can be found in the SDN community.

From an architectural perspective, ODL is split in four layers. At the bottom, the southbound interfaces and protocol plugins layer enables the communication with the network infrastructure devices. To this end, ODL implements a number of control and configuration protocols such as different versions os the OpenFlow protocol, NETCONF, SNMP, BGP, PCEP, etc. Above the southbound interfaces layer, the platform one is responsible for modelling and storing the controlled network infrastructure. This is done by means of the Model-Driven Service Abstraction Layer (MD-SAL), which is the core of the ODL controller. The MD-SAL enables the control and operation of the network to the third layer of the architecture, which implements the actual control, network and application functions. Looking for modularity, this layer is composed by a number of software pieces (modules) that interact among them and with the underlying MD-SAL to provide a set of network services such as network connectivity provisioning (L2/L3 network connectivity), routing, network virtualization, etc. Last but not least, the fourth layer implements the northbound interface, which allows third party applications to exploit the controller functionalities to provide ad-hoc services.

4.9.2 Relation with SliceNet

Being one of the most mature and widely used SDN controllers, it is likely that ODL will be found as the control platform in some segments of the network infrastructure that will be under the SliceNet platform control and management responsibility. Hence, the northbound interfaces exposed by ODL will be studied and taken into account when designing and implementing the SliceNet control and management planes.

4.9.3 Approach

It is planned to use ODL as one of the reference architectures to implement SDN control in SliceNet. It is also expected to use ODL as one of the network infrastructure control platforms for testing and demonstration purposes.

4.10 Open Virtual Switch (OVS)

4.10.1 Brief description

OVS [39] is a multilayer software switch which is used in virtual environments and is openflow capable and is used in hypervisors to interconnect VMs between different hosts across networks and provides switching to host-based applications that run as the control stack of hardware switches. OVS is licensed under the open source Apache 2.0 license. The first release was at 2009 and across the years became a quality virtual switch. Now universally available in the linux* kernel and widely used in several SDN/NFV open source projects including OpenDaylight and Openstack.

OVS main capability areas are in:

- security (VLAN isolation, traffic filtering)
- port monitoring (netflow, SPAN/RSPAN)
- QoS (Traffic queuing and shaping)
- tunneling (eg. GRE, VXLAN)
- network automation (openflow, mgmt protocol)

4.10.2 Relation with SliceNet

According to the survey [44], OVS is the virtual switch that is most widely deployed for open source projects such as OpenStack. OVS is essential for any SDN deployment and can be used to tie virtual machines, direct the traffic between different network functions and be used for virtual networking. The SliceNet project is a SDN/NFV oriented project based on virtual deployments, which means that OVS can become an important part of the dataplane infrastructure.

4.10.3 Approach

It is expected to follow and align to the Open VSwitch community.

4.11 NetFPGA

4.11.1 Brief description

NetFPGA [25] is a line-rate, open-source hardware and software networking platform of low cost. The NetFPGA platform can be explored to prototype Data Plane networking devices such as Network Interface Cards (NICs), multiport switches, and firewalls. NetFPGA SUME [26] is the latest NetFPGA platform, based on an FPGA Peripheral Component Interconnect Express (PCIe) board with I/O capabilities for 10 and up to 100 Gbps operation.

4.11.2 Relation with SliceNet

In SliceNet, part of the network slicing-friendly infrastructure has been prototyped based on the NetFPGA platform in order to achieve the Data Plane Programmability capabilities such as traffic classification and lifecycle management (add, delete, clean) of the traffic classification rules, selective traffic mirroring, selective traffic dropping, traffic priority setting etc. The technical details on the preliminary prototyping by using NetFPGA have been reported in SliceNet D3.1 [57]. During the course of the SliceNet project, the progress of the NetFPGA project will be monitored, and technical alignment between the NetFPGA platform and the SliceNet Data Plane will be applied. Moreover, potential collaboration between the two projects is possible. For instance, SliceNet can contribute to NetFPGA through the extension of the Data Plane capabilities being explored in the project.

4.11.3 Approach

It is expected to follow, align and use this open source platform, with the possibilities to collaborate with the NetFPGA team and wider community.

4.12 SkyDive

4.12.1 Brief description

Skydive [54] is an open source real-time network topology and protocols analyzer providing a comprehensive way of understanding what is happening in your network infrastructure. Its capturing capabilities include both topology capture (network topology, interfaces, bridges, namespace attributes, etc.) and flow capture (L2-L4 classifier, GRE, VXLAN, GENEVE, MPLS/GRE, MPLS/UDP, etc.), with the ability to keep the history of the topology modifications. Skydive is distributed and scalable, with an extendable design that supports external SDN controllers and container-based infrastructures (including, OpenStack, OpenContrail, Docker, and Kubernetes).

4.12.2 Relation with SliceNet

Skydive is used as a rich and configurable monitoring system to capture and store multi-layer network information in support of network analytics and cognitive network management. It's dynamic capturing abilities allow it to be utilized for SliceNet's vertically informed sensors. Skydive's application-level capabilities support slice-level modelling, topology viewing, and exploration.

4.12.3 Approach

The approach will be to use Skydive in SliceNet's cognition infrastructure and for SliceNet demonstration; and to collaborate as active contributors to the Skydive open source community.

5 Updated Exploitation Plans and Activities

In this chapter we will address the main exploitation plans and activities related with SliceNet.

5.1 Introduction

SliceNet consortium proposed to address the exploitation dimension, crucial to the Impact of the project, considering the full spectrum of exploitation opportunities and involving the widest possible range of stakeholders (scientific as well as industrial) in the exploitation efforts.

The SliceNet exploitation strategy intends to move along three main streams:

- Individual Exploitation, i.e. the definition by each of the project partners of innovative and clearly market-oriented bundles of SliceNet outcomes with pre-existing background assets, where applicable, to achieve a new impact in the research domain and in the commercial market.
- Internal Exploitation, i.e. the definition by the internal users of quantitative investment and cost/benefit plans on the generalization and extension of the project results to a broader spectrum of business opportunities and collaboration ecosystems;
- and Joint Exploitation, with the option to define and implement an exploitation vehicle which under the norms of a joint exploitation agreement prepares commonly agreed parameters for return on investment plans for all industry partners.

Apart from the more obvious exploitation plans where industry and SMEs will use the results for future product and service design and academic or research institutions will use this to strengthen their scientific standing, there are a number of very specific exploitation plans by the individual partners as listed below. Contributions to standards are key enablers for exploitation aiming to facilitate strategic and long-term exploitation. The focus on shorter-term, more applied exploitation within SliceNet is more appropriately performed on a partner-by-partner basis.

In terms of individual exploitation plans and activities we can identify 6 entities that will play different roles, namely the Coordinator, Telcos, Academia, SMEs, Network telecommunication solutions (HW/SW) and Verticals.

5.2 Coordinator

5.2.1 EURES

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 is of significant interest to EURES and its shareholders and members.

The main expectation from the project results is to deliver a solid architecture for 5G infrastructure management to support the next wave of vertical industry services and applications that emerge in all sectors, and therefore enrich the portfolio of Eurescom's customers (telecom operators and service providers) in this area.

5.3 Telcos

5.3.1 ALB

Altice Labs is a solution provider for telecom operators in several domains, namely providing access network (e.g. GPON, xDSL) hardware and software platforms, service control (e.g. 3GPP PCC) and service delivery functions (e.g. Convergent Voice Service), Business Support Systems / BSS (e.g. Campaign Manager) as well as Operations Support Systems / OSS (e.g. Fulfillment and Assurance solutions).

In order to guarantee its business units' products sustainability, ALB adopted an innovation methodology based on exploratory and planned innovation cycles. On the exploratory innovation side, ALB explores disruptive solutions for its products through national and international R&D projects. Simultaneously, on the planned innovation side, and running in parallel with the R&D projects, in order to apply the obtained R&D knowledge in the company business units, ALB promotes a process based on short-term PoCs to evolve its products and solutions. SliceNet will be an important R&D project for the exploratory innovation in ALB in what concerns the OSSs business unit evolution towards the 5G slice-based paradigm. ALB provides operational management solutions to major telecom operators worldwide for the traditional network, such as fulfillment solutions, including catalogue and inventory solutions, as well as assurance/performance management solutions. ALB intends to evolve both solutions (fulfillment and assurance) in the context of the SliceNet project towards the slice-based paradigm. Additionally, ALB plans to use the SliceNet Cognitive Management Platform as a starting point to create a cognitive-based solution in the company.

5.3.2 OFR

Orange France is working with Orange Romania (ORO) on advancing the smart city use case. All together with the management building blocks as the orchestrators and the analytics in particular. The use case would be a proof of concept of ORO as an Orange group affiliate. Potentially this will be reproduced to other Orange affiliate.

OFR will also plan to work on information model, template towards formal and machine readable definition of the slices. The resources allocation and optimization for the slice management are among the Orange goals. The objective is to enhance the orchestrator tasks to support the smart allocation of slice resources and to provide a better service performance running in the slice.

OFR will also through the Orange delegates push the SliceNet results to SDOs as presented above.

5.3.3 ORO

Orange Romania is interested to identify ways to monetize SliceNet innovative exploitable assets. Therefore, ORO started to assess the market potential with first focus on the Romanian market while in total, 30 Orange countries and territories on 5 continents within the Group's footprint can benefits from SliceNet innovations.

Moreover, ORO will look to capitalize on the synergy with MATILDA (Horizon 2020 No 761898) 5G PPP Phase 2 project, where is also an active member, in order to augment the value of the solutions and services proposed within SliceNet. The vision of MATILDA [47] is to design and implement a holistic 5G end-to-end services operational framework tackling the lifecycle of design, development and orchestration of 5G-ready applications and 5G network services over programmable infrastructure, following a unified programmability model and a set of control abstractions. We target an alignment between MATILDA and SliceNet architectures with synergies for multi-site VIM, multi-site NFVO, with main focus on the use case implementation. In this respect joint virtual meetings to identify and align on common architectural aspects have been performed and other will be planned in order to identify the opportunities for common disseminations and communications activities. It is the aim of both 5G PPP Phase 2 projects to target end-users including the general public such as non-scientific and non-

technical individuals for raising their awareness with regards to the initiatives objectives and achieved results.

Alba Iulia, a small medieval city in Romania, has been selected by ORO to demonstrate the capabilities of the targeted SliceNet smart city use case and high level architecture in dealing with critical smart lighting infrastructure. Alba Iulia enjoys broadband internet access, 4G/4G+/LTE-A, Wi-Fi and LoRaWAN provided by ORO and secured through a Business Internet Security platform. This open infrastructure is based on an open data platform through which applications developed by partner start-ups connect local authorities, citizens, tourists, and entrepreneurs in Alba Iulia. In this way, the digital infrastructure of the city facilitates new opportunities as well as the optimisation of local resources. In Alba Iulia's use case, ORO will build a live testing infrastructure of at least 50 smart lighting controllers that will be deployed on the main roads of the city, in the proximity of Alba Carolina, one of the most spectacular fortresses from Romania. We aim to support the authorities understand the aggregated benefits introduced by SliceNet initiative and to be able to demonstrate to them the full ecosystem benefits comparing with the status quo. On this line but on a wider scale, ORO will look for a collaborative approach addressing public administrations, industrial stakeholders and high tech start-ups, with the aim to deploy and bring closer to adoption in real life the innovative solutions that have been implemented in the context of the project, increasing productivity and generating opportunities for business, jobs and growth.

In order to capitalize on the already formulated ecosystem of stakeholders, ORO is actively introducing 5G concepts, expected benefits and general principle, facilitating discussions about business cases/use cases and the implementation pathways. Some of the impacted communities include:

- Innovation Labs pre-acceleration program
- Orange Fab corporate acceleration program
- TechHub Bucharest
- Orange Educational Program
- The Faculty of Electronics, Telecommunications and Information Technology from POLITEHNICA Bucharest
- Romanian Municipalities Association
- Association of Public Administrators in Romania
- Romanian Association for Smart City and Mobility
- French Chamber of Commerce and Industry in Romania
- Romanian American Foundation

ORO will drive communication and disseminations activities with regards to the MATILDA objectives and results, and through them try to promote the project results and bring the project one step closer to the market, ensuring dialogue with potential tech funders and/or customers. Designing, deploying, operating and monetizing Smart Cities infrastructure and applications as a service represent one strategic pillar for ORO considering the modern digital society we are spending our hyperconnected lives. SliceNet innovations will support ORO efforts to build simple and sustainable products that will first be validated through local demonstrators and then scaled to national and international footprints. Moreover, where possible ORO will work with startups and industrial players to embed SliceNet core technologies, open interfaces and automations within their products and architectures.

We are confident about the feasibility of this plan considering the positive feedback we get following the press conference organized between 9th - 16th Oct 2017 in Alba Iulia, with the occasion of closing the first stage (build phase) of the Smart City pilot by Orange. 1 month following the event we counted 167 media interactions and 200k end-users reached by the communication activities, including general public such as non-scientific and non-technical individuals.

5.3.4 OTE

OTE is planning to explore the main outcomes of SliceNet and build an architecture based on OAI and the other modules provided by the other partners such as the P&P, One stop API and the cognitive engine, so that by building a SliceNet architecture it can implement advanced services and applications in different network domains.

OTE has made recently available a smart house platform to its customers which can be used and incorporated in the SliceNet overlay to show advanced procedures that can help to automate and advance the platform.

5.4 Academia

5.4.1 UWS

By following and further developing the exploitation plan defined in the DoW, UWS can report the following updates:

- The SliceNet UWS team has contributed to the organisation of the first ETSI ENI-SliceNet workshop successfully held in London, UK on 14 Dec 2017, and delivered a presentation entitled “ENI-SliceNet Potential Collaborations” to suggest potential technical contribution areas to be jointly explored by ENI and SliceNet, and a schedule to align both sides especially potential contributions of SliceNet to ENI standardisation. UWS has since then been following this project-wide initiative.
- The institution of UWS recently launched a university-wide project called “Immersive UWS” in Apr 2017. This Immersive UWS project explores virtual reality and 5G technologies to transform how students are taught and how staff conduct their research in higher education. The two professors in the SliceNet UWS team are on the Steering Board of Immersive UWS and they have been leading the technology deployment and planning in the project by leveraging relevant technical experiences being developed in SliceNet, among others.
- UWS has been applying the cutting-edge R&D outcomes from SliceNet to update and enhance the teaching materials for UWS honours year and postgraduate/Master students in the Computer Networking discipline. For instance, 5G technologies related to SliceNet feature a number of modules such as Advanced Wireless Networking Technologies, Emerging Topics in Smart Networks, and Virtual Network & Cloud Computing. The knowledge learnt from SliceNet has also contributed to developing new MSc programmes in UWS, e.g., MSc Information and Network Security.
- In the medium to long term plan, UWS will continue to seek exploitation opportunities with 5G stakeholders nationally and internationally. For example, UWS supports Glasgow’s bid in June 2018 for £100M to become UK’s 5G smart city, and investigate ways to contribute to this and other relevant initiatives including UK innovation centre projects, Knowledge Transfer Partnership (KTP) projects etc. in Scotland and beyond.

5.4.2 UPC

Through the participation to SliceNet project, one of the objectives of the UPC research group is to further expand its expertise on 5G related technologies and concepts, such as network slicing, cognitive slice management, etc.

During the first year of the project, UPC has contributed to the dissemination of the SliceNet concepts and achievements through the active participation in various joint and non-joint scientific publications in international conferences; UPC has leaded some of such publications. This way, besides increasing the visibility of the SliceNet project achievements, also the UPC activities are greatly increased paving the way to exploit the knowledge in future collaborations with both academic and industry leading groups.

On the academic side, the expertise acquired through the participation to the different technical activities/tasks, is intended to be exploited. In particular, UPC is checking if SliceNet concepts can be introduced in both Master Thesis and PhD degrees at UPC. Finally, it is worth to be mentioned that currently 1 PhD student is being performing research activities related to SliceNet.

5.4.3 ECOM

One of the main goals of the ECOM research group via their participation to SliceNet project is to explore 5G related technologies and concepts, particularly with respect to RAN slicing and cognitive slice management, by building upon its current state-of-the art LTE knowledge and the OpenAirInterface (OAI) real-time LTE platform [40]. ECOM is working on evolving the RAN for a multi-service execution environment. Such an exploitation leverages the OAI and FlexRAN [46] platforms to provide the customization and sharing features demanded for each service and at different levels.

In further, ECOM has engaged into the continuous development and dissemination of Mosaic5G [41], an ecosystem of 5G platforms with a pivotal role for SliceNet as the means to transform the radio access and core networks into a agile network service delivery platform across reusable software components. More specifically, three major platforms are provided under the umbrella of the Mosaic-5G ecosystem:

- **FlexRAN:** A platform that abstracts network functions, resources and states of the underlying disaggregated RAN nodes for each service, employing a RTC that can provide slice-specific information and an SDK to enable the development of real-time control applications.
- **LL-MEC:** Following the ETSI MEC standards, LL-MEC is an edge-service platform that provides the necessary user plane programmability, performing ETSI traffic rule control and providing static or dynamic OpenFlow rules to gather statistics and monitor related radio information.
- **JOX:** JOX (further explained in sec. 4.5.1.) provides a multi-service orchestration platform with several JoX plug-in frameworks (e.g., RAN, CN, MEC).

In further, ECOM has contributed to the dissemination of SliceNet concepts and achievements through three demo events:

- Mosaic 5G LL-MEC [45] demo in MobiCom, Snowbird, Utah, USA, 2017, October 16;
- Mosaic 5G demo in EuCNC 2018, Ljubljana, Slovenia, June 18-21;
- Mosaic 5G demo in the 3rd annual ITU IMT-2020/5G Workshop and Demo Day 2018, Geneva, Switzerland, July 18.

Finally, the following papers have been published:

- JOX: An event-driven orchestrator for 5g network slicing, by Kostas Katsalis, Navid Nikaein and Anta Huang, in the IEEE Network Operations and Management Symposium, 2018,

with further plans for publishing papers and articles at top-level conferences and journals on topics related to the above stated research goals of ECOM within the context of SliceNet.

5.5 SMEs

5.5.1 NXW

Nextworks s.r.l. is a R&D SME located in Pisa (Italy) and created in 2002 as a spin-off company of the Computer Science and Telecommunications Division of the Consorzio Pisa Ricerche (CPR–DITEL). Nextworks operates in the TLC sector, collaborating with some of the major European manufacturers and operators (e.g. long term collaborations with Alcatel-Lucent, Ericsson, Interoute, OpenFiber).

Nextworks has a solid background on design, development and integration of full networking protocol stacks, ranging from the industrial (carrier-grade) to the pure R&D application area. This includes a long experience in the SDN and NFV technical areas, with hands-on expertise on open source SDN

controllers (OpenDaylight, ONOS), cloud platforms (OpenStack), and NFV Management and Orchestration tools (OpenBaton, Open Source MANO). In the context of FP7 and H2020 EU projects like SliceNet, NXW has developed solutions for SDN-based control and orchestration of heterogeneous network technologies and domains, including a relevant set of NFV tools for lifecycle management and orchestration of VNFs, as a strategic investment to accrue and update know-how on key selected topics and areas.

The company is organized in two major groups:

- The *Products Area Group*, which develops products for the advanced and integrated control of entertainment, domotics, control & automation, energy/power systems in residential and yachting markets. These products leverage on the company background and expertise acquired through the research activities of the Knowledge Area Group.
- The *Knowledge Area Group*, dedicated to independent consulting activities on network architectures, 3rd-party software development for emerging SDN and NFV network architectures and technologies, research and prototyping activities. Nextworks has focused in innovative technical areas like SDN, NFV, 5G networks and services, network slicing, network virtualization.

SliceNet maps directly to the 5G, NFV and SDN areas within the Knowledge Area Group activities, and the participation in the project is enabling the Nextworks team to consolidate and improve the know-how related to network slicing and converged cross-domain and cross-technology orchestration solutions for controlling and managing 5G networks leveraging on SDN and NFV.

After the first year of the project, the SliceNet expected impact can be mapped on few directions of the company's offer. First, the current Nextworks ongoing activities related to Plug & Play control are foreseen to produce a software asset to be possibly integrated with the company's existing ETSI NFV Management and Orchestration tools, as a way to improve existing solutions with Plug & Play functionalities to offer dedicated control and management environments to service and slice customers. This should bring more dynamicity and flexibility to the existing company's NFV tools features, while offering a more competitive product targeting integration with 5G service platforms. As a second exploitation route, SliceNet is expected to highly contribute towards the consolidation and enhancement of the consulting portfolio of the company in the area of 5G network slicing, NFV and SDN, mostly concerning cross-domain and cross-technology orchestration aspects. The specialized know-how aligned with the research outcomes obtained from the project is a key factor to differentiate the Nextworks' consulting offer from the competitors, mostly composed by large staff leasing companies that provide relatively unskilled personnel to their customers. Finally, the offer of new consolidated and training courses on SDN and NFV, designed for different targets, from network operators to telco vendors and up to SDN and NFV developers is also an aspect that SliceNet can concretely contribute to realize for Nextworks. Depending on the target audience, the courses are currently focused on SDN and NFV use cases and architectures, including hands-on software tutorials on open source tools. The new know-how and practical experience under development in SliceNet is constituting a key baseline for the enhancement and update of the company's "Expert-level training on SDN/NFV architecture and tools"[1] towards a more comprehensive offer embracing new topics like network slicing and 5G network management architectures and solutions.

5.5.2 CSE

In the context of SliceNet design and system definition in WP2, CSE started more concretely delving into the details of the ongoing 5G new core specification and particularly into the Service Based Architecture approaches (SBA). In this context, CSE has identified that work carried in SELFNET with respect to container based application management can be further aligned with automation practices applicable to some extend in SBA. The existing framework is already considered to be extended as a

[1] http://www.nextworks.it/en/research/knowledge-services

standalone rule based policy framework with policies defined around the outputs (sensing) and the configurations (actuation) of instantiated and managed applications. CSE will try therefore to consolidate this plan, also in the context of WP6 - Management Plane, in order to evaluate more accurately the possibility of pursuing further the exploitation of such a component as enabling toolset for 5G Slicing. Additionally, CSE identifies that the support of layered views and roles by the One-Stop API, as identified by 3GPP, might have a good potential to be exploited for coping with slicing related BSS/OSS tools. This is expected to be analysed in depth during the second year of the project.

5.5.3 RZ

As reported in D9.1 Dissemination and Exploitation Plan, RZ has the VELOX Virtual Path Slice engine being a multi-domain platform that evolved from the EuQoS FP6 project on end-to-end quality of service in heterogeneous networks. The VPS engine was used in the multi-domain trials at the TM Forum. The VELOX engine is an early implementation of a standards based multi-domain controller/orchestrator that evolved prior to the current interest in Software-Defined Networks. SliceNet will enable RZ to significant bring VELOX to the next step being ready to deal with scalability, cognitive management and other critical aspect for enhancing our portfolio of products and services. product to be ready for the novel 5G Networks. We are integrating the paramedic use case using value added video services from CIT in the form of VNFs into a slice on infrastructure provided by Dell. We intend to offer this to interested parties such as equipment vendors, telecoms and ambulance services in the marketplace.

With SliceNet RedZinc is targeting the eHealth use case application. We are demonstrating the benefits of offering the emergency services a way to slice through the network in emergency situations. This gives telecoms companies the ability to provide a prioritised network video call. We are talking to telecoms companies and hospital emergency services in Ireland, UK, Spain, Germany, Portugal about the possibilities for emergency services with the slicing mechanism. We have developed a business plan around the prioritisation mechanism in conjunction with our live streaming wearable video camera BlueEye. We have made a demonstration with CIT for the purposes of showing the local emergency services in Cork and in Dublin. We intend to go to market with this innovation across Europe in the next 3 to 5 years with a launch envisaged in three years time.

5.6 Network telecommunication solutions (HW/SW)

5.6.1 TEI

TEI Dissemination and Exploitation plans as presented in T9.1 are confirmed and namely:

- Demo at Ericsson R&D Italy Innovation Day, an in-house exhibition where customers could take the opportunity to get close up to the latest solutions and listen to Ericsson employees presenting the leading-edge research and developments in next generation network evolution.
- Presentations about slicing concepts and SliceNet functional architecture to Salerno and Naples Universities
- Joint paper on SliceNet control plane functional architecture submitted to 2018 14th International Conference on Network and Service Management (CNSM) (PAPER NAME: SliceNet Control Plane for 5G Network Slicing in Evolving Future Networks ; STATUS: Proposed)

The project results will be exploited to enhance product and service offerings and they will be used to improve Ericsson network management, SDN controllers and NFV cloud management/orchestration products. Furthermore, SliceNet innovative orchestration techniques are akin to TEI requirements to orchestrate and manage the lifecycle of virtualised network functions and associated virtual infrastructure in a dynamic, fluid and automated manner. These improvements will allow Ericsson to be ready to offer better 5G telecommunications networks to our customers.

5.6.2 DellEMC

For prototyping purposes in SliceNet, DellEMC is planning to use the equipments as follows:

- RAN segment:
  - Edge Gateway 3000 series: An Edge Gateway, with powerful dual-core Intel® Atom™ processors, connects varied wired and wireless devices and systems, aggregates and analyzes the input, and sends it on. Because the Gateway sits close to your devices and sensors, it sends only meaningful data to the cloud or control center, saving you expensive bandwidth.
- MEC/CORE segment:
  - PowerEdge R640 compute servers: Ideal balance of density and scalability. R640 supports scalable computing and storage in a 1U, 2-socket platform with an ideal mix of performance, cost and density for most data centers.
  - PowerEdge R530 management server: Built for versatility. R530 delivers balanced performance and midrange scalability with a powerful 2S/2U rack server.
  - Dell EMC Networking Virtual Edge Platform: Purpose-built open uCPE platform to host VNFs. It is an ideal access platform for SD-WAN.
- Connectivity:
  - S4148F-ON switches: Maximize performance, flexibility and cost-effectiveness with this ToR switch that features 48 x 10GbE SFP+ ports, 2 x 40GbE QSFP+ ports, and 4 x 100GbE QSFP28 ports, and ONIE for zero-touch installation of alternate network operating systems.
  - Dell Networking Z-Series Core and Aggregation switches: Optimize performance for today applications with multi-rate, flexible solutions supporting 10/25/40/50/100GbE throughput.

5.6.3 IBM

IBM's SliceNet participation is integrated with the CogNETive [60] internal research project at IBM Research – Haifa. CogNETive employs cognitive-based methods for visibility, analytics, and troubleshooting of networks for management at scale.

CogNETive utilizes the Skydive opensource project [54] and contributes code to the community, as part of SliceNet. SkyDive is included with IBM Cloud Private CE (Community Edition) [61], an application platform for developing and managing on-premises, containerized applications. The cognition-based aspects of CogNETive (including technologies developed within WP5 of SliceNet) are expected to be added to future releases of IBM Cloud Private.

SliceNet innovation and concepts are being exploited through CogNETive by several internal IBM customers, in various domains. Some features were demoed at the IBM's business and technology conference, IBM Think 2018 [62].

5.7 Verticals

5.7.1 EFA

The overall exploitation plan presented in SliceNet D9.1 reflects the major guidelines to follow and at this intermediate stage of the project there is no additional activity or realization that should be noted. Nevertheless EFACEC reinforces the objective to start with a reference in a renowned client and subsequently proceed with a sustained expansion to other target markets, leveraged by focused actions on marketing, dissemination and technical/functional specialized influence among potential customers, demonstrating the benefits of the advanced self-healing solutions supported on 5G.

5.7.2 CIT

As a research group inside of the technical university, the CIT SIGMA Lab continues to be active in translating the applied research innovation from SliceNet towards meaningful exploitation. As a result of the innovations emerging from the SliceNet connected ambulance use case, the CIT SIGMA Lab has been able to exploit and continues to exploit the project results in the following ways:

- Engagement with industry. Our successful research engagement with leading enterprises, such as DellEMC, allows us to promote and collaborate in initiatives such as our co-sponsored MSc programmes. In addition, our involvement in SliceNet has enabled some of our PhD students to integrate their research into the SliceNet project eHealth use case. For example, one of our students is currently leveraging his facial detection algorithms into a highly innovative MEC-based in-ambulance diagnostic tool. We are currently collaborating with our Technology Transfer Office and an external consultant on an initial commercial viability feasible study.
- Engagement with academics. As the vertical for the eHealth use case, we have been in active discussions with a similar in-ambulance trial using satellite technology that is being coordinated by the University of Aberdeen, in Scotland. We have also been engaged in discussions with the Zebra Academy in Brussels about their trialling of an ambulance tele-stroke assessment diagnostic service that they have developed for 4G. This engagement has helped inform the discussions inside our SliceNet eHealth Working Group, which in turn is resulting in a more meaningful definition of the exploitable business modelling for the SliceNet One-Stop-API.

6 Conclusions

Besides the updated dissemination plan and activities given at the beginning of the deliverable, the next two chapters about the SDOs and OSCs are the main topics of this deliverable. The SDOs are very important because they are the ones that deliver the recommendations/standards for the implementation of the network solutions. For SliceNet the SDOs that play a major role are 3GPP, ETSI, IETF and ITU-T and we are taking different approaches in these SDOs from follow, align up to collaborate. Also the OSCs are very important nowadays to understand trends and adopt the main results of these initiatives to implement in the new network solutions. In this regard some of the main projects are ONAP, CORD, Openstack, OpenDaylight and OSM among others. The SliceNet partners will also take several approaches regarding OSCs from follow, align, use up to collaborate and for sure a lot, if not all of them, will be used in the SliceNet use cases.

This is a non-stop task to all partners of the SliceNet project that should continue the mentioned approach (follow, align, use, collaborate) as the SDOs are constantly delivering/updating recommendations and the OSCs are also very active in pursuing new trends and initiatives in the telecommunications and information technology areas.

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