Small cEllS coordinAtion for Multi-tenancy and Edge services

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Abstract

The purpose of this Deliverable is two-fold:
On the one hand, the aim is to provide a detailed overview of the various activities that took place during the entire lifecycle of SESAME, in order to realize an explicit awareness of the project within an extended variety of sectors, including business areas, the academia, end-users and many more. In this framework, we have identified all performed communication and dissemination activities and, *in particular*, we have focused on the project website, the presence in social networks, related videos, newsletters, interviews press releases, publications in workshops/conferences and journals, leaflets, posters and brochures. SESAME has targeted distinct areas of the market sector and has performed multiple and successful activities in order to broadly "make its specific context known" to any third party.
On the other hand, the present work summarises some of the benefits coming from the SESAME context that have clear and positive impact on various areas, with emphasis given to the societal ones. SESAME promotes a variety of innovative technological features that impact the broader market sector and may have -explicitly and/or implicitly- a significant impact to the end-users, thus affecting social implications. As SESAME introduces suitable and validated solutions to satisfy a certain number of objectives, this can promote the adoption of novel solutions that can offer services of better quality and can enhance various related KPIs, in the dawn of the establishment of 5G. In this framework, we also discuss SESAME's strategic impact and contribution to the related H2020 Work program as well as SESAME's contribution to the improvement of innovation and to the well-identified 5G-PPP KPIs.

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Glossary

Acronym	Explanation
4G	4th Generation of Mobile Communications
5G	5th Generation of Mobile Communications
5G-PPP	5th Generation-Public Private Partnership
ACM	Association for Computer Machinery
AI	Artificial Intelligence
AIAI	Artificial Intelligence Applications and Innovations
API	Application Programming Interface
ARM	Advanced RISC Machine
CAPEX	Capital Expenditure
BS	Base Station
CC	Cloud Computing
CESC	Cloud Enabled Small Cell
CSP	Communications Service Provider
DAE	Digital Agenda for Europe
DC	Data Center
DP	Data Plane
DPACC	Data Plane Acceleration
DPDK	Data Plane Development Kit
EANN	Engineering Applications of Neural Networks
EC	European Commission
EIT	European Institute of Innovation and Technology
ETP	European Technology Platform
ETSI	European Telecommunication Standards Institute
EU	European Union
EuCNC	European Conference on Networks and Communications
FI	Future Internet
FG	Fog Computing
GA	Grant Agreement
GDP	Gross Domestic Product
H2020	Horizon 2020
HD	High Definition
HDTV	High Definition Television
HTTP, http	Hypertext Transfer Protocol
HW	Hardware
IA	Innovation Action
ICT	Information and Communications Technology
IEEE	Institute of Electrical and Electronic Engineers
IF	Impact Factor
IoT	Internet of Things
IT	Information Technology
KIC	Knowledge and Innovation Community
KPI	Key Performance Indicator
LEIT	Leadership in Enabling and Industrial Technologies
LTE	Long Term Evolution
M2M	Machine-to-Machine
MEC	Mobile Edge Computing
MNO	Mobile Network Operator
MVNO	Mobile Virtual Network Operator
MTC	Machine Type Communication
MWC	Mobile World Congress

NFV	Network Function Virtualization
NFVI	NFV Infrastructure
NGMN	Next Generation Mobile Networks
NO	Network Operator
OCCI	Open Cloud Computing Interface
ODL	OpenDaylight
ODP	Open Data Plane
OFP	Open Fast Path
OPEX	Operational Expenditure
OPNFV	Open Platform for NFV
OSS	Operations Support System
OTT	Over-The-Top
PPP	Public Private Partnership
QoE	Quality of Experience
QoS	Quality of Service
R&D	Research and Development
RAN	Radio Access Network
RCIS	Research Challenges in Information Sciences
RIA	Research and Innovation Action
RISC	Reduced Instruction Set Computer
RTD	Research and Development
SB	Steering Board
SC	Small Cell
SCaaS	Small Cell-as-a-Service
SCF	Small Cell Forum
SDN	Software Defined Network
SEP	Standards-Essential Pattern
SLA	Service Level Agreement
SME	Small- and Medium-sized Enterprise
SON	Self-Organising Network
SW	Software
TB	Technology Board
TV	Television
U-HDTV	Ultra High Definition Television
URL	Uniform Resource Locator
TCO	Total Cost of Ownership
VIM	Virtual Infrastructure Manager
VNF	Virtual Network Function
WG	Working Group
WP	Work Package
WWW, www	World Wide Web

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1 Introduction

The ***SESAME Project*** (***Grant Agreement (GA) No.297291***) *-hereinafter the "Project"-* is an active part of the 5G-PPP initiative and targets innovations around three central elements in 5G, as follows:

(i) The placement of network intelligence and applications in the network edge through Network Functions Virtualization (NFV) and Edge Cloud Computing (CC);

(ii) the substantial evolution of the Small Cell (SC) concept, already mainstream in 4G but expected to deliver its full potential in the challenging high dense 5G scenarios, *and*;

(iii) the consolidation of multi-tenancy in communications infrastructures, allowing several operators/service providers to engage in new sharing models of both access capacity and edge computing capabilities.

SESAME proposes the Cloud-Enabled Small Cell (CESC) concept which is a new multi-operator enabled Small Cell that integrates a virtualized execution platform (i.e., the Light DC (*Data Center*)) for deploying Virtual Network Functions (VNFs), supporting powerful "*self-x*" management and executing novel applications and services inside the access network infrastructure. The Light DC features low-power processors and hardware accelerators for time-critical operations and builds a high manageable clustered edge computing infrastructure. This approach allows new stakeholders to "dynamically enter" the value chain by acting as "neutral host providers" in high traffic areas where densification of multiple networks is not practical. The optimal management of a CESC deployment is a "key challenge" of SESAME, for which new orchestration, NFV management, virtualization of management views per tenant, self-x features and radio access management techniques can be developed.

After designing, specifying and developing the architecture and all the involved CESC modules, SESAME culminates with a prototype with all functionalities for proving the concept in relevant use cases. Besides, CESC has been formulated consistently and synergistically with other 5G-PPP components through coordination with the corresponding projects.

The work in this deliverable is organised as follows:

Section 1 of the present deliverable provides a conceptual summary of the SESAME effort, by identifying the major innovative directions.

Section 2 discusses, *in more details*, the related SESAME vision and all corresponding benefits. We analyze the Project's vision and the approach we have followed in order to realize all expected novelties and we discuss benefits coming from the Project outcomes. This section can also stand as an essential "synopsis" of the major

SESAME innovations, towards promoting the way towards an inclusive 5G-*based* society and economy.
Section 3 focuses upon all performed actions aiming to realize SESAME awareness in a variety of "channels" and/or other suitable means, conformant to the practices that have already been outlines in the Project.

Section 4 discusses the context of wider social implications of the SESAME actions, correlated to the actual European policy measures aiming to promote innovation and growth. In particular, we correlate SESAME actions to the well-known 5G-PPP KPIs, in order to better clarify "how our efforts contribute" towards promoting 5G evolution.

Section 5 summarises the work performed in the present document.

2 SESAME's Vision and Benefits

Today, Internet and communication networks are "critical" tools for most areas and sectors of our modern societies and economies as they are transforming our world; actually, these networks constitute fundamental "pillars" for any evolutionary process supporting effort for growth and development. According to recent market trends[1] as well as to actual European policy measures and/or related initiatives[2], it is assessed that the communication networks and the wider modern services/facilities environment of the year 2020 will be *"enormously richer and much more complex than that of today".*

In fact, within the forthcoming years it is expected that the underlying (usually heterogeneous) network infrastructure will be able of "*connecting everything*" according to an extended multiplicity of application-*specific* requirements (thus including users, things, goods, computing centres, content, knowledge, information and processes), in a purely flexible, mobile, and quite powerful way. Living within a fully converged environment, the number of smart terminals, machines, "things" (also including sensors and actuators) attached to current networks is growing exponentially and soon it will be possible to connect and operate an immense diversity of new forms of equipment (e.g., smart home gadgets, vehicles, drones and even robots) as well; this extends our ICT-*based* abilities and concepts far beyond our current experience of tablet and smartphone connectivity.

In order to "face" these major challenges, such innovative aspects not only necessitate but also imply for the proper establishment and the effective operation of a relevant novel kind of infrastructure, able to provide network features and performance characteristics to assure progress and growth in all corresponding domains (i.e., technical, business, financial, regulatory, social, etc.).

In this scope, the simultaneous (occasionally appearing as "gradual") "inclusion" of modern features (such as of virtualisation and of software-*based* network functionalities) in communications infrastructures is expected to support the corresponding transitional process via further strengthening network flexibility and reactivity. Market "actors" (network operators and service providers, manufacturers, SMEs, end-users, etc.) are expected to be strongly involved in such processes; this will "redefine" existing value chains and reform roles and/or relationships between market "players", whilst creating new opportunities for novelty and investments.

These chances are so expected to take place within the forthcoming "fifth generation" -*or 5G*- of telecoms systems, that will be the most critical building block of our "digital society" in the next decade; 5G will not only be an evolution of mobile broadband networks but will bring new unique network and service capabilities, creating a sustainable and scalable technology but also a proper ecosystem for technical and business innovation.

[1] IC Insights, Inc. (2014): *IC Market Drivers, A Study of Emerging and Major End-Use Applications Fueling Demand for Integrated Circuits*. Scottsdale, Arizona: IC Insights, Inc.

[2] European Commission and 5G-PPP (2015): *5G Vision: The 5G-PPP Infrastructure Private Public Partnership: The Next Generation of Communication Network and Services*. Brussels, belgium, European Commission.

2.1 SESAME Vision and Approach

Mobile data traffic and services, fuelled by new demanding personalised applications, radically increase the demand in infrastructure resources so as to "keep" user experience at a satisfactory level. Up to now, this ever-increasing demand has been fulfilled by the continuously evolving technological framework (3G, 4G), which has offered improved coverage and capacity as well as improved resource usage. However, the long anticipated 5G model needs to involve a paradigm shift, that is to establish a next generation network framework achieving reliable, omnipresent, ultra-low latency, broadband connectivity, capable of providing and managing critical and highly demanding applications and services. The fresh, ground-breaking advances in the field are expected to enforce revolutionary changes in network infrastructure and management, offering the power to "align with" a demanding set of diverse use cases and scenarios.

For all these purposes, the 5G scene needs to "couple" fast connectivity and optimised spectrum usage with cloud networking and high processing power, optimally combined in a converged environment. Specifically, one of the envisaged "key" elements of the 5G technological framework is the capability to deliver intelligence directly to network's edge, in the form of virtual network appliances, jointly exploiting the emerging paradigms of Network Functions Virtualisation (NFV) and Edge Cloud Computing (CC).

5G network infrastructures need to offer rich virtualisation and multi-tenant capabilities, not only in term of partitioning network capacity among multiple tenants, but also offering dynamic processing capabilities on-demand, optimally deployed closer to the user. The potential benefits from such an approach "trigger" the interest of Communications Service Providers (CSPs) such as Mobile Network Operators (MNO), Mobile Virtual Network Operators (MVNO) and Over-The-Top (OTT) content and service providers, allowing them to "gain" extra shares in the telecom market by pursuing emerging business models. Following this direction, novel business cases can produce added-value from any kind of infrastructure -or application- that has the potential to be offered "as-a-Service".

While the virtualisation of the communications infrastructure (core/edge segments and access points/macrocells) has been extensively studied by several industry and research initiatives up to now, the applicability of this paradigm to Small Cell (SC) infrastructures has received so far very limited attention[3].
The Small Cell concept has become pivotal in today's 4G access; Small Cells provide improved cellular coverage, capacity and applications for homes and enterprises as well as dense metropolitan and rural public spaces[4]. Without any doubt, their role is "crucial" for providing services in populated areas like stadiums, shopping malls, concert venues, and, *generally*, places with (tactic or sporadic) high end-user density. In such cases, each telecom operator deploys their own infrastructure, acting complementary to the macro-cell network. Normally, SC provisioning requires a number of time and money consuming procedures as, *for example*, provisioning of installation site, power supply and so on.
Operators must also "face" the costs of establishing dedicated, high-capacity backhaul connections, not to mention radio resource management and interference mitigation techniques, all translating to extra costs and efforts (usually of significant order of magnitude). However, this static approach based on the ownership of the physical Small Cell infrastructure not only increases operators' CAPEX and significantly hampers business agility, but also is unable to cope with dynamic scenarios. For example, one should consider the case where sporadic flash crowd events arise not only at predefined venues (e.g., shopping malls, urban areas, stadiums, etc.) but also at arbitrary areas with minor infrastructure in place, resulting in traffic overflow and signal outage. In order to respond to this sort of dynamicity, network operators may wish to deploy for some time a Small Cell network to serve e.g., a sporadic flash crowd event, without really owing the underlying infrastructure. The latter could

[3] Detailed documentation about small cells can be found within the Small Cell Forum (SCF). The Small Cell Forum accelerates small cell adoption to drive the wide-scale adoption of small cells and accelerate the delivery of integrated Heterogeneous networks. SFC is not a standards organization but partner with organizations that inform and determine standards development. SFC can so be assessed as a "carrier-led organization".
For more information, see: *http://scf.io/en/index.php*.

[4] Real Wireless Ltd. (2012, October): An Assessment of the Value of Small Cell Services to Operators (based on Virgin Media Trials) - Version 3.1. Real Wireless Ltd.

even be provided by a third party, i.e., the owner/operator of the venue. Such sharing scenarios are expected to play vital role in 5G networks[5] and to promote market investments.

In order to "address" this need and building upon the pillars of network functions virtualisation, mobile-edge computing (MEC) and cognitive management, SESAME's main goal is the development and demonstration of an innovative architecture, capable of providing Small Cell coverage to multiple operators "as-a-Service" (usually called as "SCaaS" (Small Cell as-a-Service). SESAME envisages the logical partitioning of the localised Small Cell network to multiple isolated slices as well as their provision to several tenants. Moreover, in addition to virtualizing and partitioning Small Cell capacity, SESAME supports enhanced multi-tenant edge cloud services by enriching Small Cells with micro-servers[6].

The SESAME Project is an innovative effort to realize multi-tenant cloud enabled Radio Access Network(s) RAN(s), through a substantial change on the architecture of commercial Small Cells, by evolving them towards the so-called "Cloud-Enabled Small Cell" ("CESC")[7],[8].
This change paves the way towards "placing" network intelligence and applications in the network edge, with the help of virtualization. Through the advanced coordination and orchestration realised within the wider SESAME concept, a new architecture is proposed[9],[10] aiming to attend several operators/service providers and "engage" them in a modern multi-tenant ecosystem[11], to fully serve the broader vision of the 5G.

In particular, SESAME proposes the CESC concept[12]; this is a new multi-operator enabled Small Cell that integrates a virtualised execution platform (i.e.: the Light Data Centre[13] (Light DC) for deploying Virtual Network Functions (VNFs)[14],[15],[16] supporting powerful "self-x" management[17] and executing novel applications and services inside the access network infrastructure[18]. The Light DC features low-power processors and hardware accelerators for time critical operations and builds a high manageable clustered edge computing infrastructure[19].

This approach allows new stakeholders to "dynamically enter" the value chain by acting as "neutral host providers" in high traffic areas where densification of multiple networks is not practical[20]. The optimal management of a CESC deployment is a "key challenge" of the SESAME context, for which new orchestration,

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5 See, *for example*: Small Cell Forum (SCF) Release 7.0: *Document 055.07.01 – Small Cells and 5G Evolution: A Topic brief.* Available at: http://scf.io/en/documents/055_-_Small_cells_and_5G_evolution_a_topic_brief.php.

6 Consider, *for example,* the discussion within the document: Small Cell Forum (SCF) Release 7.0: *Document 056.07.01 – 5G Vision: Defining the future HetNet and its evolution to 5G.* Available at: http://scf.io/en/documents/056_-_5G_Vision_Defining_the_future_HetNet_and_its_evolution_to_5G.php.

7 SESAME Deliverable 3.1: "*CESC Prototype design specifications and initial studies on Self-X and virtualization aspects*". H2020/5G-PPP SESAME Project, June 2016.

8 SESAME Deliverable D3.4: *"CESC Small Cell prototype and PoC"*. H2020/5G-PPP SESAME Project, June 2017.

9 SESAME Deliverable 2.2: "*Overall System architecture and Interfaces – First Iteration*". H2020/5G-PPP SESAME Project, March 2016.

10 SESAME Deliverable 2.5: "*SESAME Final Architecture and PoC Assessment KPIs*". H2020/5G-PPP SESAME Project, December 2016.

11 SESAME Deliverable 2.1: "*System Use Cases and Requirements*". H2020/5G-PPP SESAME Project, December 2015.

12 SESAME Deliverable 2.2: "*Specification of the CESC components – First Iteration*". H2020/5G-PPP SESAME Project, March 2016.

13 SESAME Deliverable 4.1: "*Light DC architecture design*". H2020/5G-PPP SESAME Project, June 2016.

14 SESAME Deliverable 2.3: "*Specification of the Infrastructure Virtualisation, Orchestration and Management – First Iteration*". H2020/5G-PPP SESAME Project, April 2016.

15 SESAME Deliverable 4.3: "*Techniques for efficient VNF Deployment with relevant VIM extensions, Evaluation framework*". H2020/5G-PPP SESAME Project, June 2017.

16 SESAME Deliverable 6.2: "*Service Management and Orchestration functions, including VNF models – Interim*". H2020/5G-PPP SESAME Project, October 2016.

17 SESAME Deliverable 3.2: "*Self-X features and virtualised CESC multi-tenancy techniques evaluation*". H2020/5G-PPP SESAME Project, March 2017.

18 SESAME Deliverable 3.3: "*Framework of a distributed network management system capable to host and run Self-X functionalities*". H2020/5G-PPP SESAME Project, June 2017.

19 SESAME Deliverable 4.4: "*Light DC Prototype*". H2020/5G-PPP SESAME Project, *June 2017*.

20 SESAME Deliverable D8.6: "*Market Analysis, Roadmapping and Business Modelling Report*". H2020 SESAME Project, December 2016.

NFV management[21], virtualisation of management[22] views per tenant, "Self-x" features and radio access management techniques will be developed[23],[24],[25].

Moreover, the SESAME effort -with the related solution(s)- extends the existing and well-known "Small Cell-as-a-Service" ("SCaaS") model[26], which facilitates a third-party provisioning of shared radio access capacity to mobile network operators in various localised areas, together with the provision of Mobile Edge Computing[27] services.

Efficient management of resources, rapid introduction of new network function(s) and/or service(s), ease of upgrades and maintenance, CAPEX/OPEX reduction and encouraging openness within the ecosystem, are only a few -*but quite substantial*- examples of the various benefits that the proposed SESAME-*based* solution(s) can develop and provide for the benefit of the European industry and citizens[28].

After designing, specifying, developing and testing[29],[30] the architecture and all the involved CESC modules[31], SESAME culminates with a prototype[32],[33] with all functionalities for proving the concept in relevant use cases and by applying a dedicated methodology for validation purposes[34].

The development of the 5G ecosystem involves numerous groups of industry stakeholders, research institutions, standard developing organizations, certification bodies and other institutions. Within the broader scope of the current 5G-PPP framework, it is expected to further reinforce the European presence in this field, at the global level.
The main objective -also promoted by the EC- is to design and deliver appropriate solutions, architectures, technologies and standards for the next generation communication infrastructure, via appropriate research projects where the SESAME project is included and is an active part.

By summarizing the above discussion, we could conclude that SESAME introduces, considers, assesses, integrates and validates the **following basic elements**:

- Cloud Enabled Small Cell (CESC).
- Light Data Centre (DC) as geographically distributed NFVI (NFV Infrastructure) within the RAN.
- Multi-tenant over the RAN, exploiting NFV and MEC concepts.

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21 SESAME Deliverable 5.3: "*Techniques and optimization of VNF placement algorithms – Security issues*". H2020/5G-PPP SESAME Project, September 2017.
22 SESAME Deliverable 4.2: "*Virtualisation extensions for Acceleration of Light DC capabilities*". H2020/5G-PPP SESAME Project, December 2016.
23 SESAME Deliverable 6.3: "*Service Management and Orchestration functions, including VNF models – Final*". H2020/5G-PPP SESAME Project, September 2017
24 SESAME Deliverable 6.4: "*Orchestrator Prototype*". H2020/5G-PPP SESAME Project, September 2017.
25 SESAME Deliverable 5.2: "*VIM and CESC Implementation*". H2020/5G-PPP SESAME Project, September 2017.
26 See, *for example*: https://www.ericsson.com/res/thecompany/docs/press/backgrounders/small-cell-as-a-service-press-backgrounder.pdf.
27 Also, see: http://www.etsi.org/technologies-clusters/technologies/mobile-edge-computing.
28 SESAME Deliverable 8.7: "*Techno-Economic Analysis and Commercialisation Plans*". H2020 SESAME project, December 2017.
29 SESAME Deliverable D7.2: "*Integrated CESC Prototype Validation*". H2020/5G-PPP SESAME Project, July 2017.
30 SESAME Deliverable D7.3: "*Experimental Integration results of HW/SW modules of the overall SESAME framework*". H2020/5G-PPP SESAME Project, September 2017.
31 SESAME Deliverable 5.1: "*Description of the CESC Abstraction Model*. H2020/5G-PPP SESAME Project, June 2016
32 SESAME Deliverable D7.4: "*Integrated Pilot and Evaluation Report*". H2020 SESAME Project, December 2017.
33 SESAME Deliverable D7.5: "*Overall Assessment and Roadmap*". H2020/5G-PPP SESAME Project, December 2017.
34 SESAME Deliverable D7.1: "*Proof-of-Concept Integration and Validation Plan*". H2020/5G-PPP SESAME Project, December 2016.

- New business opportunities between the SC infrastructure provider and the Mobile Network Operators (MNOs).
- Use of SDN for managing the connections between VNFs (Virtual Network Functions) within the Light DC.
- Reuse of the current 4G architecture and protocol stack, taking in mind different possible functional splits.
- Evolution of "Self-x" properties for more enhanced network and/or service management.

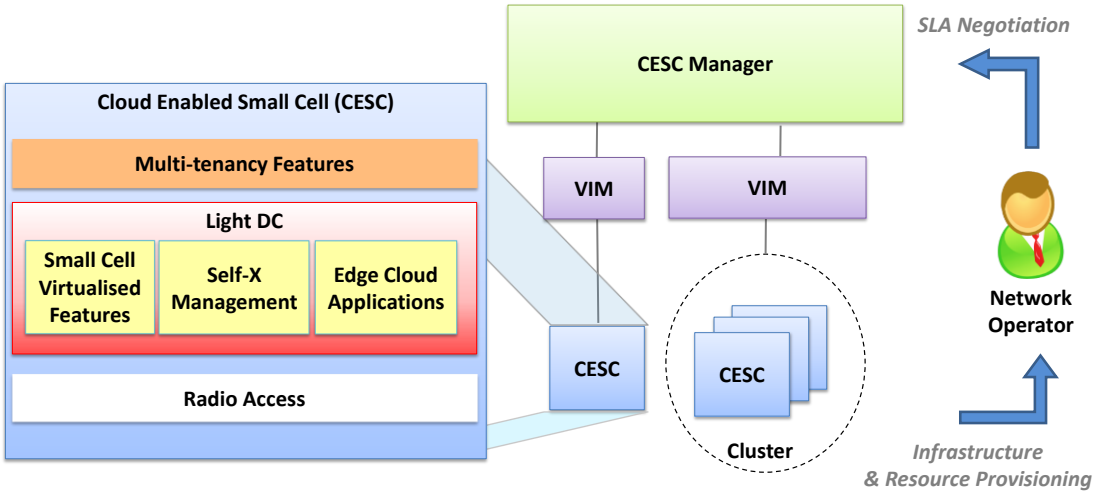

Figure 1: SESAME High-level Architecture and CESC Components

Three initial target scenarios[35] have been already identified during the proposal preparation as "promising fields" for the applicability of the CESC concept:

(i) Enterprise services in multi -tenant large business centres;

(ii) Enhanced service experience on the move, *and*;

(iii) Service provisioning in flash events.

SESAME has been conceived to provide the appropriate framework and solutions for Communications Service Providers (CSPs) to offer reliable, omnipresent, ultra-low latency broadband connectivity to the customers, meeting the highly demanding Future Internet (FI) application and service requirements.
The SESAME proposition to realise micro-scale virtualised execution infrastructure included in the CESC devices (i.e., the Light DC) enables the provision of dynamically repurposed virtual network infrastructures with tailored computing and flexible networking capabilities. This will greatly benefit the CSPs to deploy and offer cutting-edge services to specific customers, with increased cost savings (e.g., energy efficiency thanks to the Light DC design and the portability of functionalities closer to the mobile network edges) and allowing optimal reuse of the deployed virtual infrastructures.
Overall, the SESAME Project provides an appropriate framework for European industry to remain competitive in the 5G systems and technology space, by enabling the flexible densification of networks and services.

The core contribution of SESAME is to create imaginative and concrete opportunities for generating competitive advantages for the European ICT market.

[35] Also, see the description provided in the SESAME Deliverable D2.1: "*System Use Cases and Requirements*". Available at: http://www.sesame-h2020-5g-ppp.eu/Portals/0/Deliverables/SESAME_GA%20No.671596_Deliverable%202.1_v1.0_final.pdf?ver=2016-10-24-162258-900.

SESAME is rooted at the "core" requirement for improving innovation capacity in the European mobile industry by consolidating a very tight convergence of the telecommunications and IT market.
This is the "key differentiator" moving towards 5G technologies where the European ICT market will see the emergence of new vertical business segments and services for consumers and enterprise customers.

2.2 SESAME Beneficial Uses

In order again to "summarize", *somehow*, the discussion and the benefits coming from all performed SESAME-*related* actions and innovative efforts (as mentioned in the previous section) we can mention the following:

- SESAME brings several **competitive advantages** to the Communication Service Providers (CSPs) and service/application providers including, *inter-alia*:
    - Rapid deployment of new services for consumer and enterprise business segments.
    - Adding new revenue streams from innovative services delivered from closer to the user, together with offering the user a better service-oriented QoE, leveraging the Light DC and the CESCM entities, and furthermore, improving revenue opportunities by sharing the infrastructure for specific service providers.
    - Introduction of new applications which are aware of the local context in which they operate (RAN conditions, localised information, density information, etc.) through the integration of the CESC virtual small cells functionalities.
    - Drastic reduction of OPEX costs by offloading signaling and management related functionalities closer to the edge and by developing smarter management techniques, and further limiting the TCO (total cost of ownership) / CAPEX costs by promoting shared infrastructures enabled by the multi-tenancy and related virtualised multi-service management framework (CESCM).
    - Flexible development of market innovative and ground breaking services and applications that take advantage of the contextual information provided by the CESC on the radio network conditions and other information at the edges (e.g., edge caching, critical services).
    - Creation of new market entrants by opening up the shared infrastructures to new software and application providers, infrastructure vendors and other CSPs, thereby increasing revenues and also promoting regulatory support.
- SESAME can provide competitive advantages to equipment vendors and manufacturers so as to greatly enhance their product portfolio and to develop novel offering in the area of virtualised and cloud-*enabled* small cells platforms.
- SESAME offers competitive advantages for IT service providers and solutions suppliers as these can "get" the maximum benefit and advantage out of the SESAME Project by being able to "closely" work with leading mobile market vendors and ICT companies, thus allowing them to strategically "position" and gain an early-entrant advantage within the industry, also keeping in consideration the rapid evolution of the mobile edge computing.
- Involved SMEs can be able to acquire different competitive advantages based on their business and market segments and have opportunities to further extend their offerings and business advantages towards the 5G landscape.
- Once related findings can become applicable by the involved market actors/players, SESAME can offer fast and cost-effective access to a wide variety of new services and applications for the benefit of the end-users through solutions that can directly support either the specific user or broader user communities. This, *among others*, includes residential and business customers as well as public fixed and mobile users who

could ultimately lead companies and business to re-organise their processes, services and practices to increase readiness, productivity and growth, and improve the quality of life of EU citizens.

SESAME targets to contribute to the community societal challenge to "boost" the market opportunities for increased revenues and reduction of CAPEX/OPEX/TCO of telecommunication providers, as well as the market positioning of equipment/solution vendors.

SESAME contributes to the aim of creating and supporting "inclusive societies" by promoting "smart and sustainable growth" and to "strengthening Europe's role as global actor", by bringing innovative solutions to the market validated by industrial partners.

SESAME contributes to the *Europe 2020 strategy*[36] by creating a value-added "Europe-on-the-move" society enabling secure and totally accessible mobility opportunities for end-customers and users.

In particular, SESAME addresses the community societal challenges as follows:

- It strengthens and fosters EU's position as a global actor, by increasing EU's relevance and presence in the 5G context: SESAME creates valuable technical knowledge and innovation that can be reflected in patents, community-*driven* open *de-facto* standards, publications and industry standards. The industry involved in SESAME -and/or using related SESAME-*based* solutions- can take advantage of the Project outcomes to gain strategic positions with respect to 5G technologies applying them on innovation solutions in their products. This can offer unprecedented and novel opportunities towards the industries' ability to "meet" societal challenges such as smarter cities and new environmental awareness.

- Implications for smart and sustainable growth: Exploitation of SESAME's outcomes by the industries will lead to new products and solutions leading to the creation of new jobs opportunities and economic growth. The generation of a new technological field may "trigger" new initiatives leading to the consolidation of entrepreneurship opportunities.

[36] The *Europe 2020 strategy* is in the EU's agenda for growth and jobs of the current decade. It emphasizes smart, sustainable and inclusive growth as a way to overcome the structural weaknesses in Europe's economy, improve its competitiveness and productivity and underpin a sustainable social market economy. Also see: *https://ec.europa.eu/info/business-economy-euro/economic-and-fiscal-policy-coordination/eu-economic-governance-monitoring-prevention-correction/european-semester/framework/europe-2020-strategy_en*.

3 SESAME's Awareness Framework

In order to realize awareness of the Project, the related activities have been performed within the framework of the dedicated WP8. Key achievements in Tasks 8.1, 8.3 and 8.4 are listed as follows[37]:

General public dissemination

- Creation and maintenance of the SESAME website[38] with dedicated created graphics.
- Active presence on the social networks.
- Creation of communication material for SESAME dissemination, such as leaflets, brochures and posters.
- Social Media presence through *LinkedIn*, *Twitter*, *YouTube*, *ResearchGate* and *GitHub*.

Scientific dissemination

- Research results published international journals and conferences: 10 published journals (and 2 under review) of which 5 with open access policy and 6 co-authored between different partners; 52 conference papers (and 2 under review); of which 24 are co-authored papers.
- Organization of 2 SESAME Research Workshops (in EuCNC 2016[39] and EuCNC-2017[40]), plus other 2 SESAME-*related* workshops (i.e.: the 5G-PINE 2016 in AIAI-2016[41] and the 5G-PINE 2017 in EANN-2017[42]), and 2 SESAME research Special Sessions (in EuCNC 2016 and EuCNC 2017) and two SESAME dissemination Sessions (Infocom World 2016[43] and Infocom World 2017[44]).
- Co-organization of 5 Workshops and 1 Summer School in cooperation with other 5G-PPP projects.

Dissemination in industry, standardisation bodies and open source community

- Participation in various international events for raising awareness around the Project.
- Involvement with industry forums and special interest groups.
- Participation with dedicated Booths and demos in 3 internatikonal events (EuCNC-2016, Second Global 5G Event[45] and EuCNC-2017).

Contribution to open source initiatives

- Monitoring of some open source projects and initiatives such as ODP, OFP, Snabb[46], OPNFV, etc.

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[37] For more details see: SESAME Deliverable D8.4: "*Final Report on Dissemination, Communication and Standardisation*". H2020 SESAME Project, December 2017.
[38] SESAME Deliverable D1.1: "*Project Website*". H2020 SESAME Project, September 2015.
[39] For more details about the framework of the EuCNC-16, see: *https://www.eucnc.eu/2016/www.eucnc.eu/*.
[40] For more details about the framework of the EuCNC-17, see: *https://www.eucnc.eu/2017/www.eucnc.eu/*.
[41] See: *https://conferences.cwa.gr/aiai2016/workshops*.
[42] See: *https://conferences.cwa.gr/eann2017/*.
[43] See: *http://www.infocomworld.gr/18th-infocom-world-2016/programma/sesame-and-privacy-flag-projects-based-sessions/*.
[44] See: *https://www.infocomworld.gr/*.
[45] See: *https://5g-ppp.eu/event/second-global-5g-event-on-9-10-november-2016-in-rome-italy/*.

- Supporting Open Source initiatives in the definition of documents, monitoring the development and design activity in the developers' community, providing user support, code reviews and patches.

5G-PPP involvement

- Participation in Steering Board (SB) Meetings and Technology Board (TB) Meetings (both physical and virtual) organised by 5G-PPP and the European Commission.

- Involvement in 5G WG: 5G-PPP[47] Working Groups (WGs): Vision and Societal Challenges, Pre-Standardisation, KPI Management, Architecture, SDN/NFV, Network Management, NetWorld2020[48].

- Participation in events and meetings organised by 5G-PPP Working Groups.

- Collaboration with other 5G-PPP projects achieved through joint organisation of events (e.g. *Soft5G Workshop*[49]) and participation in initiatives organised by other 5G-PPP projects (and *vice versa*).

[46] For more related information see: *https://snabb.co/*.
[47] For more related information on 5G-PPP Working Groups, see: *https://5g-ppp.eu/etp/*.
[48] For more related information see: *http://www.networld2020.eu/*.
[49] For more detail, also see: *http://www.soft5g.org*.

3.1 SESAME Communication Activities

Communication activities include all those actions set by the SESAME partners to "raise awareness" about the Project existence and uptakes as well as about the Project objectives and results achieved during SESAME lifetime, both by individual partners and by the consortium *as a whole*.
The final objective of the communication strategy has been to foster awareness of SESAME through the Project interested value chains. Coordinated communication activities have been performed to reach various audiences promptly and to promote the visibility of SESAME to other related H2020 projects, within the EC, the international fora and the general public.

SESAME has carried out specific actions for enacting its communication strategy, by adapting it with the Project evolution to promote the Project within an audience "*as broad as possible"*, and by changing the transmitted message to maximise the corresponding impact. The target included both specialised and more general audiences, reaching then technical and less technical profiles, adapting the message to the target audience.
A detailed description of the KPIs identified for communication activities are given in the related Deliverable D8.1[50].

The types of communication activities carried on by the SESAME partners are given by the table below (the terminology "Multiple target audiences" includes *Industrial parties, End-users, Academics and researchers and General public*, unless differently specified):

Table 1: Communication activities carried on by SESAME partners during the Project

Type of activity	Target audience	Description	Partners involved
Project awareness and Scientific Knowledge Transfer	Scientific and ICT-*related* research and development community and industries.	Participation or organisation of scientific events, conferences and workshops as well as participation to industry interest groups, venues, associations and standards bodies events.	All partners
Branding, Identity & Logo Design	Functional to communicate/disseminate SESAME to multiple target audiences.	Branding, Identity & Logo Design are important elements for identifying the Project *as a whole*, ensuring immediate identification and uniqueness of the SESAME consortium in all events and through all communication and dissemination channels.	All partners
Marketing Material	Multiple target audiences; managers and researchers in the ICT and related industries.	Brochures, Leaflets, Posters, Press Releases, Videos.	OTE, CNET, and selected partners leading specific actions; All partners to provide support material
Videos	Multiple target audiences.	Videos presented to events or published on SESAME *YouTube* channels.	OTE for coordination; content from all partners

[50] SESAME Deliverable D8.1: "*Plans for Dissemination, Communication, Standardisation and Exploitation, Interaction with 5GPPP*". H2020 SESAME Project, December 2015.

Type of activity	Target audience	Description	Partners involved
Interviews, news/newsletters, press releases and social media coverage	Multiple target audiences.	Regular updates made available to the public through the Project website, partners' communication channels and social media.	OTE, NCSRD, CNET, ITL, IPA, VOSYS
Project Website	The general public, academics and researchers, industrial parties and SESAME partners. Publication pages for the scientific and industrial research communities.	The Project website has multiple functions: to foster Project activities, events and results; to attract and raise awareness of SESAME among specialised users and the general public; to publish facts relevant to the Project, news, upcoming events and disseminate publications.	OTE, CNET for maintenance and update; All partners to provide support material
Presence in social media	ICT community	Continuously release of Project related news on various social media channels including *LinkedIn*, *Twitter*, *YouTube* and *ResearchGate*.	CNET, NCSRD; All partners for participation

The activities for communication pass through actions, identified at the beginning of the Project, which are detailed in the following subsections.

3.1.1 Project website and Project Graphical Identity Design

At the start of the Project, the logo and graphics have been redesigned, starting from those adopted during the submission of the SESAME proposal. The SESAME website and the communication material (i.e. presentation slides, deliverable templates, templates for leaflets and posters) follows the style of the new Project logo and graphics.

The Project website (*http://www.sesame-h2020-5g-ppp.eu/*) was created at the early beginning of the Project in order to foster project activities, events and results to "attract and raise awareness of SESAME" among specialised users and the general public (See Figure 2, below). This task was led by the project coordinator (OTE), who has the responsibility of maintaining the website. Detailed description of the website has been provided in the context of the related SESAME Deliverable D1.1 ("*Project website*").
OTE performed this action in cooperation with CNET and both these two partners took care of all appropriate actions needed for updating information of the public part of the website. The Project website was constantly updated with the latest news, Project outputs and information about events. The Project website is the first point of contact of the Project with the general public, as well as to specialised audiences.

Figure 2: SESAME Project Home Page

The registered domain *http://www.sesame-h2020-5g-ppp.eu/* serves as the single contact point for the online presence of the SESAME Project. The SESAME website contains a public part that is accessible to all Internet users and provides the external community with the current information on the aims and the progress of the Project. It also provides a link to the private section dedicated to the SESAME consortium partners, which is only accessible by using specific credentials (*http://programsection.oteresearch.gr*). OTE, in the context of his duty as project coordinator, is responsible for adequately updating the private part of the website which also serves as a Project repository.

SESAME website organisation (see Figure 3) allows that the general consortium information and contents are easy to retrieve and presented in an easy to understand.

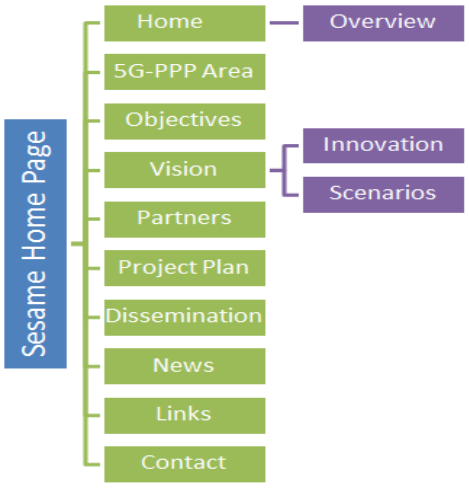

Figure 3: SESAME Website Graph

3.1.2 Leaflets, Posters and Brochures

The SESAME consortium has produced leaflets, posters and brochures to be used to communicate to different audiences, via selecting the "most appropriate means" upon dependence on the specific occasion. They have been created with the goal of raising general awareness around the SESAME "key values", propositions and results. Leaflets and brochures were distributed during international events (e.g. EuCNC 2016, EuCNC 2017, Second Global 5G Event in Rome, Infocom World 2016 and Infocom World 2017). Posters were hanged and presented during conferences and other venues with the purpose to promote SESAME results.

Table 2: Summary of Leaflets, Posters and Brochures Information

Type of material	Motivation	Timing
Leaflet	Initial leaflet of SESAME, distributed at the Mobile World Congress (MWC), Barcelona, Spain, *February 22-25, 2016*	M7
Poster	Presented at ETSI Workshop "*From Research to Standardization*", Sophia Antipolis, France, *May 10-11, 2016*	M9
Poster	Showed in the SESAME's Booth at EuCNC 2016 (updated version), Athens, Greece, *June 27-30, 2016*	M12
Leaflet, Brochure, Poster	Distributed at EuCNC 2016 (updated version), Athens, Greece, *June 27-30 2016*	M12
Leaflet, Brochure, Poster	Infocom World 2016, Athens, Greece, *November 02, 2016*	M17
Leaflet, Brochure, Poster	Second Global 5G Event, Rome, Italy, *November 09-10, 2016*	M17
Leaflet, Brochure	Mobile World Congress 2017 Barcelona, Spain, *February 27 - March 02, 2017*	M20
Leaflet	Distributed at IEEE 11th International Conference on Research Challenges in Information Sciences (RCIS-2017), Brighton, UK,	M23

	May 10-12, 2017	
Leaflet, Brochure, Poster	Distributed at EuCNC 2017 (updated version), Oulu, Finland, *June 12-15, 2017*	M24
Leaflet, Brochure, Poster	Infocom World 2017, Athens, Greece, *October 25, 2017*	M28

3.1.3 Presence in Social Media

For maximizing the Project visibility, the SESAME consortium included social media platforms such as *LinkedIn* and *Twitter* in its communication strategy.

The presence in social media is a suitable and quite effective tool for raising awareness, consensus and generating opinions around the Project, as well as for promoting transparency upon various Project-*related* activities (see Figure 4).

The platforms identified for SESAME's Social Media presence are the following:

- ***LinkedIn group*** (Figure 4): *https://www.linkedin.com/groups/8399017/profile*.
- ***ResearchGate project*** (Figure 5)***:*** *https://www.researchgate.net/project/Small-cEllS-coordinAtion-for-Multi-tenancy-and-Edge-services-SESAME*.
- ***Twitter*** (Figure 6): *https://twitter.com/sesame_h2020.*
- ***YouTube channel*** (Figure 7): *https://www.youtube.com/channel/UCAWdh7dgpmwW4ZuYagViKyg*.
- ***GitHub:*** *https://github.com/H2020-SESAME.*

CNET and NCSRD took care of maintaining updated social media accounts, *and*, together with all other partners, continuously made available SESAME-*related* news and information to reach specialised technical audiences and the general public.

Partners have published SESAME related posts on *LinkedIn* and *Twitter* with the hash tags *#SESAME #H2020 #5GPPP #5G.*

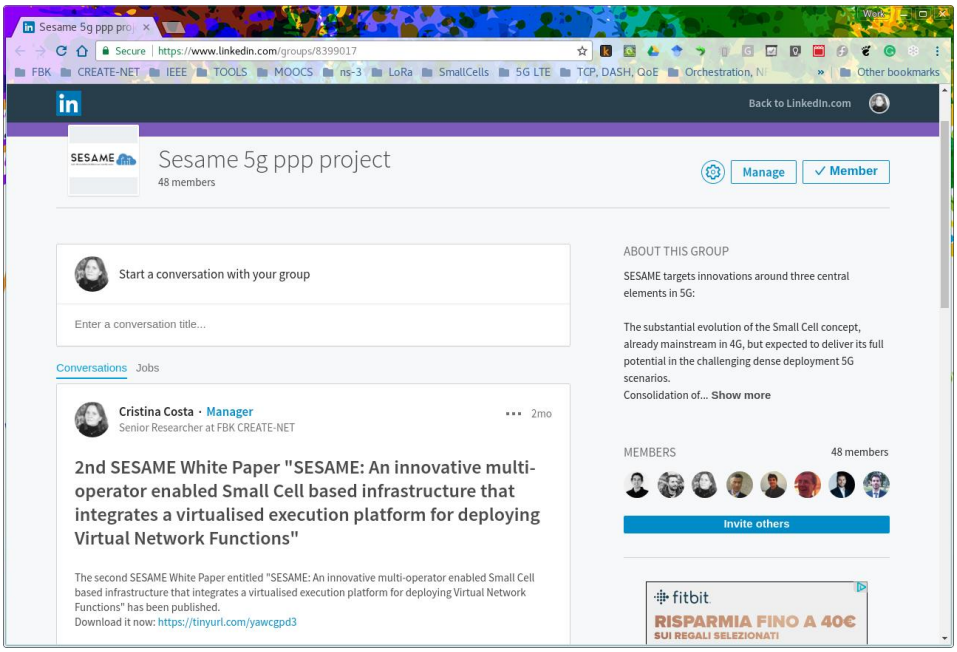

Figure 4: SESAME *LinkedIn* Gate Page

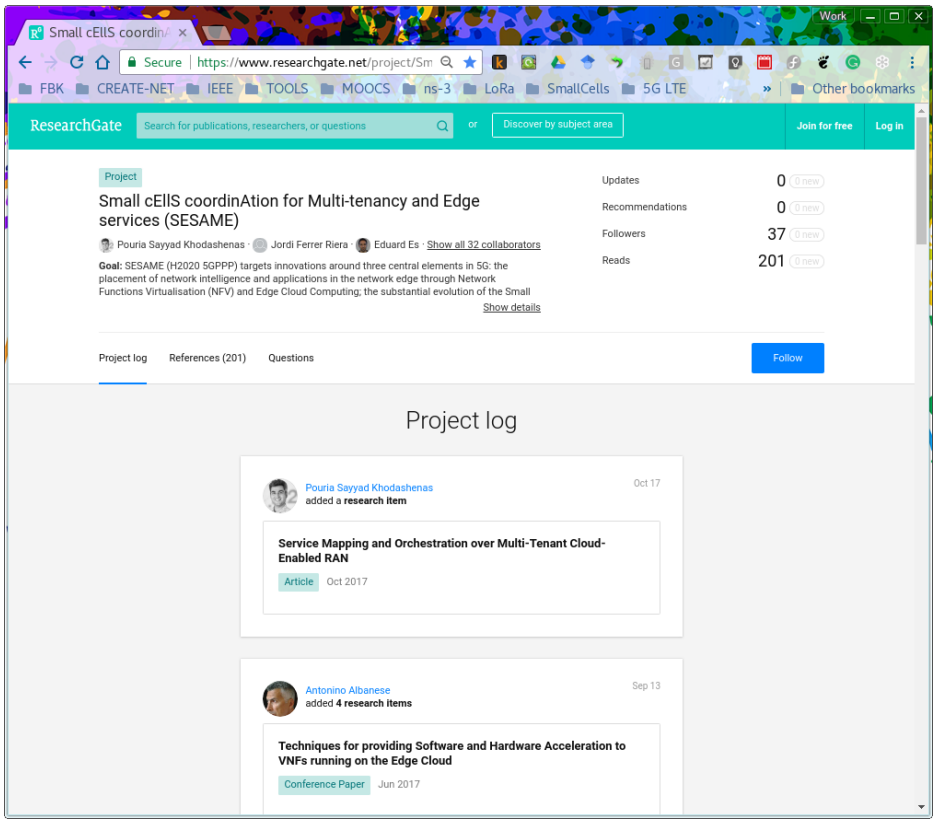

Figure 5: SESAME *ResearchGate* Page

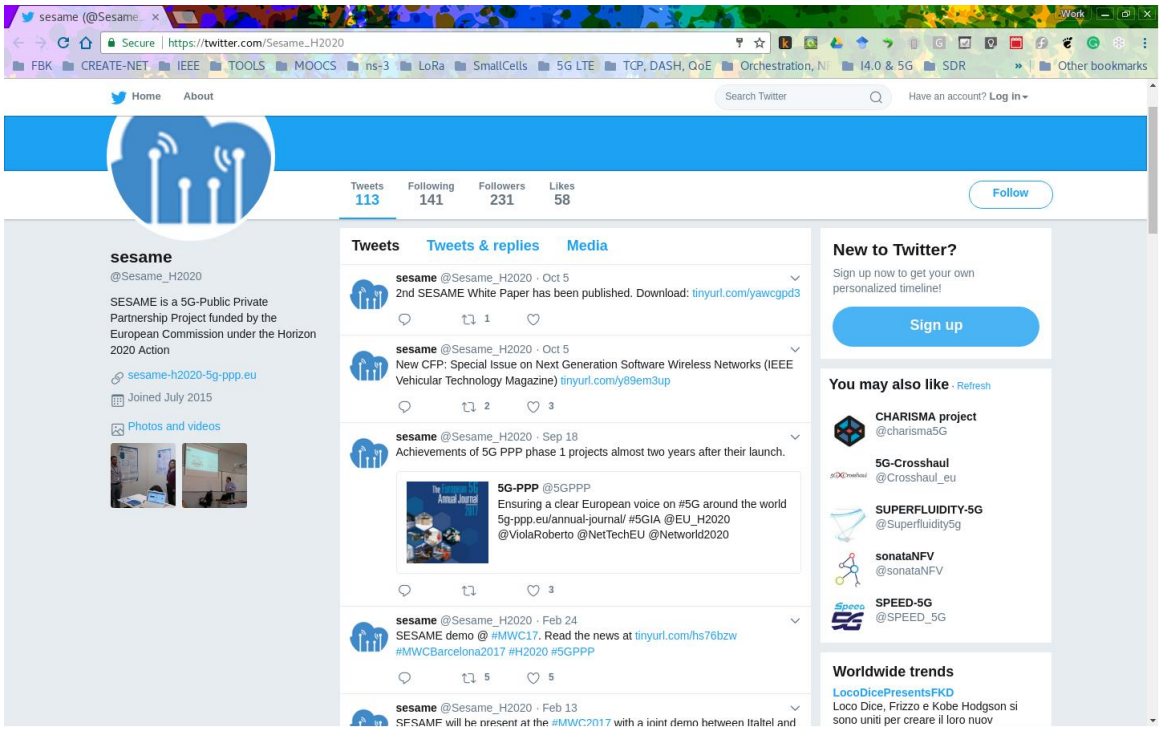

Figure 6: SESAME *Twitter* Page

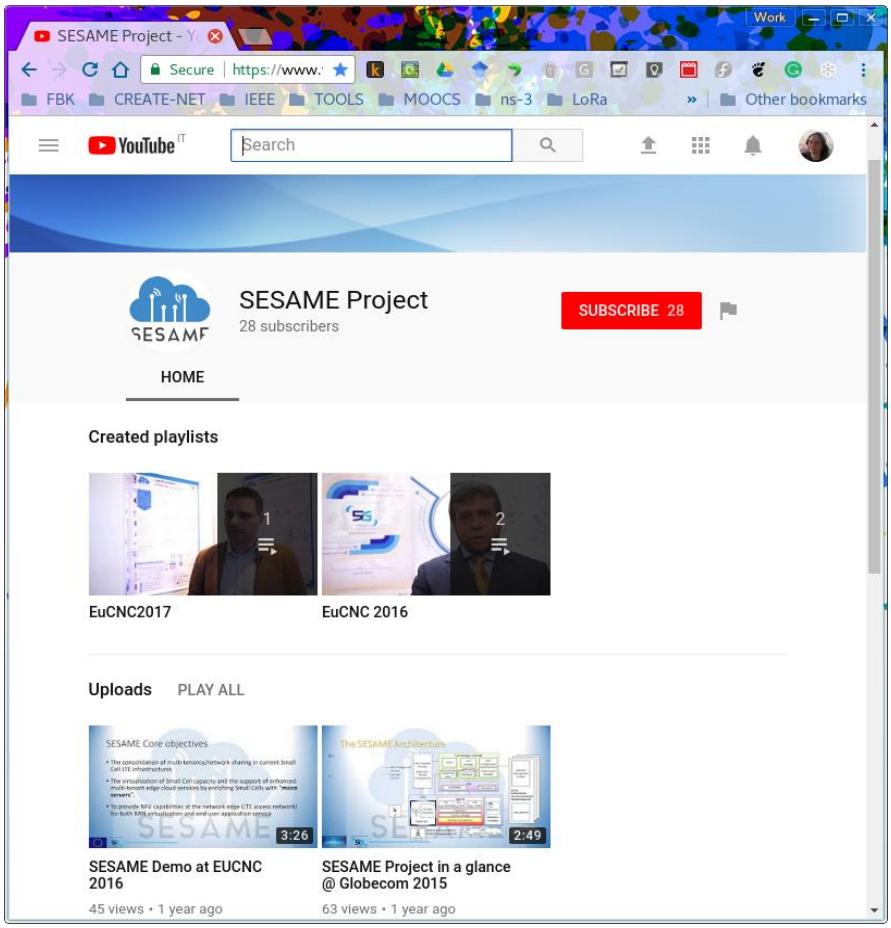

Figure 7: SESAME *YouTube* Channel

3.1.4 Video(s), News/Newsletters, Interviews on Media and Press Releases

Actions were targeted to provide interviews on media (e.g. newspapers, online media and magazines) to widespread the vision and objectives, outcomes and benefits of the SESAME effort to diverse stakeholders.

Related activities successfully performed until today are summarised as follows:

- "*Small cEllS coordination for Multi-tenancy and Edge services*", presentation performed at IEEE Globecom, December 2015 (*http://globecom2015.ieee-globecom.org/*).
- Demo video at EuCNC 2016.
- Video interview on SESAME at EuCNC 2016.
- VOSYS video demo for the Second Global 5G Event in Rome.
- Demo video at EuCNC 2017.
- Video interview on SESAME at EuCNC 2017.
- Interview to the National Institute of Information and Communications Technology (Japan).

SESAME has also set up a *YouTube* Channel where all related videos produced have already been or are to be published (available at the URL: *https://www.youtube.com/channel/UCAWdh7dqpmwW4ZuYaqViKyq*).

Examples of the communications actions from partners are indicatively listed as follows:

- The work related to how to build an NXP image with QEMU[51] and VOSYSwitch[52] has been published on the VOSYS company website[53].
- FLE prepared a SESAME overview for FLE's Quarterly Newsletter which is distributed to Fujitsu managers, worldwide.
- ZHAW, as direct communication activities, has published various blog posts about SESAME on the platform of the University.

[51] For further details also see, *inter alia*: *https://www.qemu.org/*.
[52] See: *http://www.virtualopensystems.com/en/solutions/demos/vosyswitch-perf-openstack-integration/*.
[53] Also see: *http://www.virtualopensystems.com/en/solutions/guides/yocto-qemu-kvm-vswitch-nxp-ls2085a*.

3.1.5 Communications Summary Table

This section aims to detail the plan for communication undertaken during the first year of SESAME by the consortium.

Table 3: Communication Summary Table and KPIs

Type of activity	**Description**
Project awareness and Scientific Knowledge Transfer	Presence of the project in 50 major events (9 in 2015, 20 in 2016 and 21 in 2017) Organization of 5 Workshops and 3 Special Sessions during the Project (KPI min 2)
Marketing Material	Preparation of 4 different Leaflets/ brochures during the Project lifecycle and their distribution at major events, presentation of 8 posters in various international events, >30 press releases or news published in the website, 6 videos/video interviews presented at events or published online.
Social Media	• ***LinkedIn group***: *https://www.linkedin.com/groups/8399017/profile*. • ***Twitter***: *https://twitter.com/sesame_h2020*. • ***YouTube channel***: *https://www.youtube.com/channel/UCAWdh7dgpmwW4ZuYagViKyg*. • ***ResearchGate project:*** *https://www.researchgate.net/project/Small-cEllS-coordinAtion-for-Multi-tenancy-and-Edge-services-SESAME*. • ***GitHub:*** *https://github.com/H2020-SESAME*.

3.2 SESAME Dissemination Activities

The SESAME Project has developed specific actions which compose the dissemination strategy of the consortium. Besides dissemination to the scientific community, SESAME deployed a broad range of activities and different dissemination "channels", aimed to reach the wider RTD and innovation community, as well as industry. This took place with the aim of nurturing a broader understanding and preparing the ground for adoption of the SESAME results.
The dissemination of the results was carried on through the various activities presented in Table 4, below. A detailed list of all SESAME dissemination activities covering the full duration of the Project has been provided in D8.5[54].

Table 4: Summary of dissemination activities carried on by the SESAME partners

Type of activity	Target audience	Description	Partners involved
Scientific articles	Academic and industrial research community	Conferences, Open Access Journals and Peer Reviewed Publications	All partners
White Papers	Industrial decision makers and RTD engineers	Technical documents detailing SESAME features, advances and achievements released at different stages of the Project	All partners
Project showcases	RTD community, wider ICT and Communications Technology interested public	Demonstrations, and Project Booth of SESAME system components	Mainly WP7 with the participation of all Project partners
Events Organization	Graduate level engineers and researchers	Seminars, tutorials and participation of SESAME partners to Summer Schools	All partners
Collaboration with other projects	European ICT research community	Working Groups within the 5G-PPP, as well as direct liaisons with related projects	Individual liaison-contacts
Software Code Release	Developers and research community	Release mature software to the related communities	Individual liaison-contacts

The Project website was used for providing access to public deliverables, white papers, scientific publications, demonstration information, and material explaining SESAME innovations.

[54] See: SESAME Deliverable D8.5: "*Final Report on Dissemination, Communication and Standardisation*". H2020 SESAME Project, December 2017.

3.3 SESAME Contributions to Industry Fora

SESAME focused its contributions to open source initiatives in the area of SDN controllers such as OpenDaylight[55] (ODL) and ONOS[56], cloud management systems such as OpenStack, and NFV platforms and orchestrators[57] such as OPNFV. To this aim, SESAME linked the Project website to the GitHub[58] community-*based* software sharing platform.
In the scope of SESAME, VOSYS monitored a number of open source projects and initiatives such as ODP[59], OFP[60], Snabb[61], OPNFV[62], etc.

During the first year of the project VOSYS submitted several patches to some of those projects, for example:

- More efficient way to parse DPDK command line arguments in ODP-DPDK: *https://git.linaro.org/lng/odp-dpdk.git/commit/2a3b50c210b3efa75bbbfbe5b55367031c1563e4.*
- Fix compilation against the latest version of odp-generic in OPF: *http://www.openfastpath.org/pipermail/openfastpath/2015-December/000001.html*.
- Fix compilation against ODP API 1.5.0 in OPF: *http://www.openfastpath.org/pipermail/openfastpath/2015-December/000002.html*.

Moreover, for what concerns OPNFV, VOSYS actively participated to OPNFV DPACC[63], the project focused on NFV hardware acceleration. In this respect VOSYS contributed to the definition of the "Gap analysis of OpenStack for DPACC"[64] and "DPACC architecture"[65] documents.
In addition, VOSYS is an active contributor of the Snabb NFV open source community. Snabb is the open source project on which is based VOSYSwitch, the virtual switch developed in SESAME by VOSYS. VOSYS monitors the development and design activity in the Snabb community, providing user support and code reviews (e.g., code review of a virtio-net driver proposal *https://github.com/snabbco/snabb/pull/645*). VOSYS SESAME exploitation strategy is focusing on the development of the VOSYSwitch virtual switch.
VOSYSwitch supports x86[66] and ARM servers[67], and provides high performance with an intuitive configuration interface, allowing manual as well as automatic configuration.

Moreover, it supports OpenFlow for integration with SDN controllers (e.g., OpenDaylight) and ODP-*based* plugin system to extend the hardware devices support and leverage hardware accelerators.
Being on an open source project, the VOSYSwitch exploitation is closely related to the Snabb dissemination (scientific papers, open source patches, open source community events, etc.), mostly because telecom operators are looking for enterprise software solution based on successful open source projects that guarantee no vendor lock in.

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55 For further details see: *https://www.opendaylight.org/*.
56 For more related information see: *http://onosproject.org/*.
57 SESAME Deliverable 6.1: "*Orchestrator Architecture Design and Interfaces Specification*". H2020/5G-PPP SESAME Project, June 2016.
58 GitHub is a web-based Git repository hosting service. It offers all of the distributed revision control and source code management (SCM) functionality of Git as well as adding its own features. Unlike Git, which is strictly a command-line tool, GitHub provides a Web-based graphical interface and desktop as well as mobile integration. It also provides access control and several collaboration features such as bug tracking, feature requests, task management and wikis for every project. For more related information see, *for example*: *https://github.com/*.
59 See, *for example*: *https://en.wikipedia.org/wiki/Open_Data_Plane_(ODP)*.
60 See, *for example*: *http://www.openfastpath.org/.*
61 More details can be found at: *https://snabb.co/*.
62 See, *for example*: *https://www.opnfv.org/*.
63 See: *https://wiki.opnfv.org/display/dpacc/DPACC+Home*.
64 GAP Analysis of OpenStack for DPACC: *https://docs.google.com/document/d/1_fOinIQNcPwNODZPzGK5vRMPJQLwL7iLds4NFnjXSms/edit*
65 DPACC Architecture: *https://docs.google.com/document/d/1O4rtCh1vbTOO5cMwmRwfv3UJb_bVWZrqXQS_-QJAk10/edit*.
66 For more information, see: *https://en.wikipedia.org/wiki/X86*.
67 For more information, see: *https://armservers.com/*.

VOSYS has contributed to OpenStack Nomad (now renamed in Cyborg) definition efforts: *https://wiki.openstack.org/wiki/Meetings/CyborgTeamMeeting.*

3.4 Summary of SESAME Communication Activities

This section aims to detail the plan for communication undertaken during the full duration of the SESAME Project, by all members of the consortium.

Table 5: Summary of SESAME Communication activities

Type of publication	Activity	PKI
Journal Papers	10 journal papers published, of which 5 open-access journals and other journal publications compliant with green open-access policy and 6 are joint-authored papers between SESAME partners IEEE Network Magazine (IF 2.899), Transaction on ETT (IF 1.295), ACM Monet, Special Issue (IF 1.045), Elsevier Journal on Computer Standards & Interfaces (IF 1.268), Elsevier Journal on Telecommunications Policy (IF 1.526), IEEE Transactions on Network and Service Management (IF 3.134), IEEE Wireless Communications Journal (IF 8.972), IEEE Communications Letters (IF 1.988), Hindawi Journal on Mobile Information Systems (IF 0.84) 2 papers submitted with pending review	5 open-access journals and other journal publications compliant with green open-access policy 10 journal papers published and 2 submitted with pending review.

Conference Papers	54 conference papers either published or accepted (to appear), 24 are joint-authored papers between SESAME partners: IEEE NFVSDN 2015, MONAMI 2015, MLDM'16, Soft5G 2016, ICC 2016, ICC 2017, EuCNC 2016 (main track & Special Session) and EuCNC 2017 (main track & Special Session), International Symposium on Dynamic Games and Applications 2016, 5G-PINE 2016 (in AIAI 2016) and 5G-PINE 2017 (in EANN 2017), CTTE 2017 23 conference papers were accepted during the first year (M1-M12) 20 conference papers were accepted during the period M13-M30 2 papers submitted with pending review	Of the 52 accepted conference publications, 24 are joint-authored papers between SESAME partners
Whitepapers	3 SESAME Whitepapers were published on the website and publicized through available online channels and during events.	
Booth/Demonstrations	Two main SESAME Booths: 1 organized by OTE/VOSYS/ZHAW/CNET/NCSRD at EuCNC 2016; 1 organized by OTE/VOSYS/NCSRD at the 2nd Global Event (Rome, Italy, November 2016); 1 organized by CNET/OTE at EuCNC 2017 2 minor/specific demos presented in other events	Measurable: number of visits from stakeholders, targeting at least 100; Number of attendees at the hosting event

Invited Talks and Tutorials at international events, seminars or summer schools presenting project achievements	5 talks at international events, 5 summer school participation or tutorials/seminars. 1 SESAME Summer School (2017)	At least 2 tutorials from project partners (one in 2016 and one in 2017) KPI: Number of attendees, including students

Collaboration with other 5G-PPP projects	5G-PPP WGs: Vision and Societal Challenges, Pre-Standardisation, KPI Management, Architecture, SDN/NFV Network Management, NetWorld2020 Collaborations in CHARISMA Summer Schools, Special Sessions, Soft5G Workshop Organization of a SESAME-*based* Special Session[68] in EuCNC-2016 with papers and presentations also coming from three 5G-PPP projects (i.e.: COHERENT[69], CHARISMA[70], SPEED-5G[71]) as well as for the "Privacy-Flag"[72] H2020 project Organization of a SESAME-*based* Special Session (SPS10)[73] in EuCNC-2017 with papers and presentations also coming from three 5G-PPP projects (i.e.: COHERENT, CHARISMA, 5G-XHAUL[74], 5G ESSENCE[75]) as well as for the "Privacy-Flag" H2020 project Organization of a SESAME-*dedicated* Session at Infocom World 2016 Conference with papers and presentations also coming from three 5G-PPP projects (CHARISMA, COHERENT and 5G-XHAUL), in parallel with a Privacy Flag-*based* Session. Organization of a SESAME-*based* and 5G ESSENCE-*based* Session at Infocom World 2017 Conference focused on the usage of Small Cells. Action in parallel with a Privacy Flag-*based* Session and with a broader 5G-oriented Session (with presentations coming from BlueSpace[76], 5G-MEDIA[77], SLICENET[78], 5G-PHOS[79], 5G-PICTURE[80], MATILDA[81], CHARISMA, COHERENT (all 5G-PPP projects) as well as of VICINITY[82], SmarterEMC2[83], CREDENTIAL[84] and CloudPerfect[85] (all H2020 projects).	Participate to at least 4 WG Co-organize at least 1 workshop during the first year

[68] More details can be found at: http://eucnc.eu/?q=node/125.
[69] For more information about the COHERENT H2020/5G-PPP project, see: http://www.ict-coherent.eu/coherent/.
[70] For more information about the CHARISMA H2020/5G-PPP project, see: http://www.charisma5g.eu/.
[71] For more information about the SPEED-5G H2020/5G-PPP project, see: https://speed-5g.eu/.
[72] For more information about the Privacy Flag H2020 project, see: http://privacyflag.eu/.

Software Code Release	Contributions to open source project activities: OPNFV DPACC, Snabb NFV, OpenDayLight, OpenStack Nomad (Cyborg) SESAME GitHub repositories (*https://github.com/H2020-SESAME*): • SESAME_descriptors (VNFD and NSD for SESAME) • NFVO (Repository for T-Nova[86] Orchestrator components)	KPI: at least 4 contributions Link the project website to at least 1 community-*based* software code sharing platform (e.g. GitHub[87])

[73] More details can be found at: *https://www.eucnc.eu/2017/www.eucnc.eu/indexd14f.html?q=node/127*.
[74] For more information about the 5G-XHAUL H2020/5G-PPP project, see: *http://www.5g-xhaul-project.eu/*.
[75] For more information about the 5G ESSENCE H2020/5G-PPP project, see: *http://www.5g-essence-h2020.eu/*.
[76] For more information about the BlueSpace H2020/5G-PPP project, see: *https://bluespace-5gppp.squarespace.com/*.
[77] For more information about the 5G-MEDIA H2020/5G-PPP project, see: *http://www.5gmedia.eu/*.
[78] For more information about the SLICENET H2020/5G-PPP project, see: *https://slicenet.eu/*.
[79] For more information about the 5G-PHOS H2020/5G-PPP project, see: *http://www.5g-phos.eu/*.
[80] For more information about the 5G-PICTURE H2020/5G-PPP project, see: *http://www.5g-picture-project.eu/*.
[81] For more information about the MATILDA H2020/5G-PPP project, see: *http://www.matilda-5g.eu/*.
[82] For more information about the VICINITY H2020 project, see: *http://vicinity2020.eu/vicinity/*.
[83] For more information about the SmarterEMC2 H2020 project, see: *http://www.smarteremc2.eu/*.
[84] For more information about the CREDENTIAL H2020 project, see: *https://credential.eu/*.
[85] For more information about the CloudPerfect H2020 project, see: *https://cloudperfect.eu/*.
[86] For more information about the T-Nova project see: *http://www.t-nova.eu/*.
[87] For more details about GitHub see, *for example*: *https://en.wikipedia.org/wiki/GitHub*.

4 SESAME's Social Implications

In order for the European economy and society to be able not only to "maintain" but also to "fortify" both their roles and influences on the wider international environment, it is important to realize innovative actions and to expand knowledge so that *"to keep a strong position in a strategically important market such as the one of the ICT sector",* as the latter is influenced by the fast Internet penetration[88].

The expected diversity of new (personal and professional) usages results in new requirements on availability, latency, reliability, trustworthiness and security. Therefore, this can lead to new trends and approaches as of networking, with the related features and functionalities much more closely "embedded" within the applications. In addition, users gradually become more and more "demanding" in terms of contents and service requirements, whilst getting increasingly sensitive to privacy and sustainability issues, thus implying for resilient constraints on networks and service platforms[89].

In turn, this imposes for major challenges that can radically affect the entire existing framework of network infrastructures facing, *for example*, a vast majority of issues such as:

(i) Adequate "handling" of the increased network traffic together with the provision of all necessary capacity and/or spectrum available, so that to serve -and to fulfil- *reasonably*, all relevant requests coming from different services, devices and users, in a fully converged environment;

(ii) Suitable accommodation of novel classes of services/facilities (e.g., covering imposed attributes coming from the IoT, M2M communications or content-*based* applications, or by any other future "complex" environment that may potentially appear), while preserving "low" -*or "reasonable"*- CAPEX and OPEX features, supporting economies of scale and avoidance of unnecessary investments;

(iii) Strengthening Internet's penetration in all sectors of our lives and economies, by making it an "indispensable means" for realizing an explicit, ubiquitous and dependable infrastructure in mobile, wireless and fixed communications. In fact, Internet "drivers" are all kind of services and applications from low (sensor and IoT) to high throughput rates (e.g. high quality video streaming) and low to high latency, and for a variety of devices supporting these services and applications;

(iv) Supporting all necessary actions for providing a guaranteed level of Quality of Service/Quality of Experience (QoS/QoE) together with enhancement of privacy and security over the Internet, especially for professional uses and with the aim of offering optimal performance from both network and end user device point of view;

(v) Making the communication critical infrastructures "as resilient as required" by consumers of interconnected critical infrastructures (such as smart grid), *and*;

(vi) Supporting measures for realizing reduced energy consumption.

This imminent wave of innovation will have a tangible exploitation and socio-economic impact by 2020, through the deployment of the so called "*5G infrastructure*". However, 5G will be much more that the next step beyond 4G, as it is expected to be the "*core functional system of our modern digital society and economy*"[90], thus generating a truly converged and tremendously "dense" communication infrastructure, integrating IT systems (e.g., processing and storage) with plentiful network resources.

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[88] European Commission (2010): *Communication on Europe 2020 Flagship Initiative Innovation Union (COM(2010) 546 final, 06.10.2010)*. Brussels, Belgium: European Commission.

[89] NetWorld 2020 ETP (2014): *5G: Challenges, Research Priorities, and Recommendations – Joint White Paper*. European Technology Platform (ETP) for Communications Networks and Services.

[90] European Commission (2012): *Communication on A European strategy for Key-Enabling Technologies – A bridge to growth and jobs (COM(2012) 341 final, 26.06.2012)*. Brussels, Belgium: European Commission.

5G is to become a sort of universal, highly flexible and ultra-low latency virtualized infrastructure, capable of serving immense numbers of smart terminals, devices, machines, things, sensors, cars, drones, etc., with significant processing and storage capabilities that may be exponentially increased, via relevant Cloud-*based* applications[91].

In fact, it is expected that by the year 2020 there will be more than 30 times as much mobile Internet traffic as there was in 2010. However, this will not be the same type of traffic as that of today, due to the enormous growth of the smartphones and tablets being in use globally as well as due to the huge progress in the penetration/use of sensors, actuators, machines and of other IT equipment that use the Internet as the means for communication. 5G is a new network technology and infrastructure that will "*bring the capacities needed to cope with this increased growth in the use of communication – especially wireless – technologies by humans and by machines*"[92].

Assuming the framework previously discussed, it should be expected that future 5G networks will not only be based on transport and routing/switching technologies but will be more "*flexible and open*", able to evolve more easily than today's networks and also to embed sensing, computing and storage resources in a converged and unified infrastructure, able to "orchestrate" the delivery of services in a secure manner[93].
The 5G networks will also provide a significantly higher system capacity than today and solve any anticipated spectrum scarce. In addition, they should also promote -*to the extent possible*- a common network management for mobile and wireless, in terms of constant performance optimisation, fast failure recovery, and fast adaptations to changes in network loads, architecture, infrastructure and technology.

The European vision towards assessing, understanding and then realizing the wide multiplicity of all previous challenges takes place via a dedicated Public-Private Partnership (PPP) Programme[94], able to provide solutions, architectures, technologies and standards for the ubiquitous 5G communication infrastructures of the next decade. The 5G Infrastructure PPP[95] is a unique opportunity for the European ICT industry to compete on the global market for 5G infrastructure deployment, operation and services. 5G-PPP's goal is to sustain as well as to improve the competitiveness of the European ICT industry and to ensure that "*European society can enjoy the economic and societal benefits these future networks will bring*". 5G development is accelerating with progress in standardisation, trials, cooperation between main players and projects.

Furthermore, 5G can also support and enhance the convergence between fixed and mobile networking services with the related development of core and transport networks. 5G can "integrate networking, computing and storage resources into one programmable and unified infrastructure", which can be customized according to the interests of multiple costumers.

5G is also expected to drastically reduce total cost of ownership (TCO) of the infrastructure, *on one hand,* and the service creation and deployment times, *on the other*. Recognizing network traffic patterns proactively is essential to avoid undesired states that can even threaten the operation, performance and disposal of the network. This can be achieved by integrating Self-Organizing Network (SON[96]) features[97], so as to reconfigure resources to attain high QoS and to handle load balancing optimization problems[98].

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91 J.G. Andrews, S. Buzzi, W. Choi, S. Hanly, A. Lozano, A.C.K. Soong, and J.C. Zhang (2014): What Will 5G Be?, *IEEE JSAC, Special Issue on 5G Wireless Communications Systems, 32*(6), pp.1065-1082.

92 See, *for example*, the context discussed in: European Commission (2014, February): *MEMO: What 5G can do for you*. Brussels, Belgium: European Commission. Available at: http://europa.eu/rapid/press-release_MEMO-14-129_en.htm.

93 Horizon 2020 (2013): *Advanced 5G Network Infrastructure for the Future Internet*. Brussels, Belgium: European Commission.

94 5G-PPP framework, [https://5g-ppp.eu/].

95 The 5G Infrastructure PPP, in short "5G-PPP", is a joint initiative between the European Commission and the European ICT industry. The 5G-PPP is aiming at securing Europe's leadership in sectors where Europe is strong or where there is potential for creating new markets (such as smart cities, e-health, intelligent transport, education or entertainment & media). The 5G-PPP initiative will reinforce the European industry so that to successfully compete on global markets as well as on open/new innovation opportunities. Among the priority actions are to deliver solutions, architectures, technologies and standards for the ubiquitous next generation communication infrastructures of the coming decade.

96 Briefly, SON is a collection of procedures (or functions) for automatic configuration, optimization, diagnostication, and healing of cellular networks. It is considered to be a major necessity in future mobile networks and operations mainly due to possible savings in capital expenditure (CAPEX) and operational expenditure (OPEX) by introducing SON.

The main benefits of introducing SON functions in cellular networks are as follows:

(i) Reduced installation time and costs;

(ii) reduced OPEX (operational expenditure) due to reductions in manual efforts in connection with monitoring, optimizing, diagnosing, and healing of the network;

(iii) reduced CAPEX (capital expenditure) due to more optimized use of network elements and spectrum*;*

(iv) improved user experience, *and*;

(v) improved network performance.

Therefore, service/network management should be developed in parallel with suitable advanced automation, with cognitive operations and via developing mechanisms for Big Data to serve both enhanced QoS and QoE independently of the "nature" of the prosumer (i.e.; human or machine or thing).

[97] O. Østerbø, and O. Grøndalen (2012): Benefits of self-organizing networks (SON) for mobile operators. *Journal of Computer Networks and Communications 2012 (Article ID 862527)*, pp.1-16.

[98] Next Generation Mobile Networks (NGMN) (2007, May): Use Cases related to Self Organising Network, Overall Description. Frankfurt, Germany: NGMN. Available at: http://www.ngmn.org/nc/downloads/techdownloads.html.

4.1 SESAME's Strategic Impact and Contributions to the related H2020 Work Program

This section summarises SESAME's impacts listed in the Horizon 2020 – Work Programme 2014-2015 - Leadership in Enabling and Industrial Technologies (LEIT) for ICT in relation to the *"ICT 14 – 2014: Advanced 5G Network Infrastructure for the Future Internet"* challenge within the scope of the *Radio Network Architecture and Technologies Strand* and *Network Management strand*.

Network functions are anticipated to take place over a unified operating system in a number of points of presence (PoPs), especially at the edge of the network for fulfilling specific performance targets. As a result, it will heavily rely on emerging technologies such as Software Defined Networking[99] (SDN), Network Functions Virtualization[100] (NFV), Mobile Edge Computing[101] (MEC) and Fog Computing[102] (FC) to achieve the required performance, scalability and agility.
The above aspects are all essential features within the "core" actions of the full framework of SESAME and have depicted in the related Project deliverables. In the following we discuss per case and in more details, each one these innovative features correlated to fundamental KPIs.

The core challenge in SESAME has been to *develop an ecosystem to sustain network infrastructure openness, through the development of "Cloud-Enabled Small Cells (CESCs)" for 5G* built on the pillars of network virtualization, mobile-edge computing capabilities and cognitive network management that will provide multi-tenancy and flexible cloud-network integration, with highly predictable and flexible end-to-end performance characteristics.
Further, SESAME clearly contributes to the 5G-architecture vision through the development of programmable mobile network infrastructures that allows for continuous innovation by means of key functionalities exposed to CSPs.
A further challenge addressed in SESAME has been to radically decrease network management OPEX through automation, whilst increasing user perceived Quality of Service (QoS), Quality of Experience (QoE) and security.

SESAME proposition has been conceived to provide the appropriate framework and solutions for CSPs to offer reliable, omnipresent, ultra-low latency broadband connectivity to the customers, thus "meeting" the highly demanding Future Internet application and service requirements.
SESAME greatly impacts the manner in which intelligence can be delivered and consumed directly at the network edges, allowing the operators and service providers/Over-The-Top players to harness the benefits of mobile edge computing, with the introduction of novel personalised, content-aware services and business scenarios. Adding new revenue streams from innovative services delivered from nodes which are closer to the user will help the CSPs to remain competitive whilst improving end-user QoE. New applications which are aware of the local context in which they operate (RAN conditions, locality, etc.) thanks to the innovative combination of the CESC infrastructure and the CESC management framework can open-up entire new service categories and enrich the offerings to the end-customers.

The SESAME proposition to realise micro-scale virtualised execution infrastructure included in the CESC devices (i.e., the Light DC) can enable the provision of dynamically repurposed virtual network infrastructures, with tailored computing and flexible networking capabilities. This greatly benefits the CSPs to deploy and offer cutting-edge services to specific customers, with increased cost savings (e.g., energy efficiency thanks to the Light DC design and the portability of functionalities closer to the mobile network edges) and allowing optimal reuse of the deployed virtual infrastructures.

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[99] E. Haleplidis, J.H. Salim, S. Denazis, et *al.* (2015): Towards a Network Abstraction Model for SDN. *Journal of Network and Systems Management, 23*(2), pp.309-327.

[100] N.M. Mosharaf, K. Chowdhury, and R. Boutaba (2010): A Survey of Network Virtualization. *Computer Networks, 54*(5), pp.862-876.

[101] J.O. Fajardo, F. Liberal, et *al.* (2016): Introducing Mobile Edge Computing Capabilities through Distributed 5G Cloud Enabled Small Cells. *Mobile Networks and Applications, 21*(4), pp.564-574).

[102] L.M. Vaquero, L. Rodero-Merino (2014): Finding your Way in the Fog: Towards a Comprehensive Definition of Fog Computing. *ACM SIGCOMM Computer Communication Review, 44*(5), pp.27-32.

Overall, SESAME provides an appropriate framework for European industry to remain competitive in the 5G systems and technology space, enabling the flexible densification of networks and services.

In the following, Table 6 highlights the benefits harnessed by SESAME project within the expected impacts of the *"Horizon 2020 Work programme 2014-15 LEIT ICT-14 – 2014: Advanced 5G Network Infrastructure for the Future Internet"*.
We have selected to "depict" all KPI-*related* information as assessed and achieved in the entire SESAME framework and not only those relevant to societal aspects, with the aim of providing an overview of all SESAME performed progress. In this scope, explicit beneficial uses at macro-level as well as at operational level may also have benefits at societal level.

Table 6: SESAME Contributions towards Expected Impacts and relevant objectives that address the Impact KPIs

Expected impact	**SESAME Contributions towards Expected Impacts and relevant objectives that address to achieve the Impact KPIs**
At Macro Level	
The target impact is to keep and reinforce a strong EU industrial base in the domain of network technologies, which is seen as strategic industry worldwide.	The SESAME Project brings its unique contributions both at technological and market levels. SESAME has introduced several strategic innovations allowing the European technology to "fill the gaps" between current limitations and future 5G systems. This ambitious goal was possible thanks to the blend of the know-how and expertise of each SESAME partner. SESAME included several European industrial partners aiming to be leaders in the 5G-market space, including a mobile network operator (OTE), large European (IPA, ITL, ATOS, STM) and EU-headquartered global (FLE) companies and SMEs, as well as top research and academic institutions. The complementary capabilities of the entire consortium allowed SESAME to produce results that are at the fore of 5G technologies, addressing the concept of cloud-enabled multi-tenant/multi-service small cells. The European market *as a whole* is expected to receive great advantages and thus strategically reinforce the European position worldwide with respect to the development of innovative 5G technologies, services and customer segments.
Retaining at least 35% of the global market share in Europe regarding future network equipment would be a strategic goal.	SESAME has introduced new strategic innovations that represent a significant step forward, towards the goal of retaining at least 35% of the global market share in Europe. However, this could not be possible if SESAME results stemmed only from technical innovations. Indeed, SESAME has proposed a paradigm change, which is in line with recent technological trends of Mobile Edge Computing, Software-Defined Networking and Network Function Virtualization. Thanks to the SESAME approach, new market players such as the third party infrastructure providers are envisaged to enter the market and thanks to the much finer spatial granularity of small cells, users will be able to exploit broadband access to services and applications, thus bringing significant benefits at societal level, as highlighted by the SESAME scenarios. SESAME will be the promoter of a new ecosystem bringing advantages to all involved parties and moving toward the objective of retaining a large share of the global market in Europe.
At operational level	
1000 times higher mobile data volume per geographical area.	SESAME has been prepared to "address" the challenge of 1000 times higher traffic per geographical areas by deploying high-density multi-service virtualised small cell networks, offering several benefits. Clearly, the cells densification process can clearly be beneficial to provision of much higher data rates. However, this is nothing

	new *per se*. SESAME has started from such basic consideration leveraging on the mobile edge computing paradigm applied to the small cell domain to host multiple service providers in multi-tenant fashion. Designing the network architecture in accordance to the principles of virtualised network management and mobile edge computing, SESAME can enable flexible and highly dynamic resources provisioning in the areas and times where they are needed, thus avoiding data congestion and overprovisioning. This can also be realized, thanks to the CESC design and the smart control and management offered by the CESCM and VIM.
10 times to 100 times higher number of connected devices.	SESAME is capable of "meeting" the very tight demand of interconnecting an unprecedented large number of devices by leveraging mobile network and IT convergence offered by the mobile edge computing capabilities of the CESC platform. The flexible design of the CESC platform and the management layers promote shared virtualised infrastructure, allowing multiple services (M2M, Social & Internet data sources, Big Data, Enterprise customers, etc.), permitting a large number of devices to be associated to the network. While SESAME is not innovating in designing new air-interfaces or massive spectrum aggregation techniques, the basic notion of SESAME has been to allow rapid integration of multiple virtual operators sharing the CESC provider's infrastructure, thus allowing isolated and secure provision of vertical services for massive amount of connected devices.
10 times to 100 times higher typical user data rate.	Finally, SESAME manages to provide 10 to 100 times higher user data rate through the realization of dense virtualised small cells network platforms. SESAME has made a much greater step forward on this direction, compared to current approaches, by combining the edge computing paradigm with small cells, through the CESC design, and has managed to provision -where needed- up to 100 times higher user data rate, leveraging on the highly performing CESCM virtual network management system. In this way, network resources can be provisioned and offered where they are needed the most, rebalancing (or repurposing) them from where they are underused to where they are actually needed.
10 times lower energy consumption for low power Machine type communication.	In the view of SESAME, fostering the use of small cells for multi-operator network access and local service delivery helps in reducing energy consumption. In fact, this can be attributed to the lower power consumption of these nodes (by definition) compared to macro-cell base stations (BSs). Improved energy consumption also rises from the energy efficient Light DC, based on ARM processors and exploiting a non-x86 architecture. Furthermore, the use mobile edge computing capabilities and virtual network functions enables the deployment of mobile core network functionalities closer to the edges, thus resulting in the reduction of the signalling overhead and so into energy savings. Further, the edge caching and other advanced service capabilities leveraged in SESAME allows optimising the use of resources in dense network environments, which again will contribute to energy savings. The combination of all these elements adopted by SESAME can allow the radical 10 times lower energy consumption, which can be particularly relevant machine type communications (MTCs).
5 times reduced End-to-End latency (5ms for 4G-LTE).	The technology components of SESAME architecture pursue the objective of severe latency reduction through the adoption of several solutions. It is worth mentioning that the deployment of Small Cell devices combined with edge computing paradigm of the Light DC can have the immediate effect of bringing and managing services much closer to the end-users, which implies for significant latency reduction. This approach allows managing proactively the caching of contents near the edge, thus contributing to further reducing latency in the content delivery, as well as reallocating and provisioning of available resources to CSPs on demand to serve

	customers. All in all, SESAME achieves the goal of lowering the end-to-end latency (at least 5 times reduction at the RAN) by bringing close to the end-users' services, network and computational resources.
Ubiquitous 5G access including in low density areas.	The core goal in SESAME is to offer cloud-*enabled* small cells with "self-x" features supported by a virtualised management and orchestration framework. This allows them to be flexibly deployed and managed for ubiquitous 5G access across multiple operators and multiple services. The SESAME infrastructure can be easily adapted also for low-density areas, though the core small cells concepts are designed with dense penetration and highly localised capacity provisioning in mind. In fact, the multi-tenancy capabilities offered by SESAME also contribute to reduce deployment costs, so the provisioning of services in low density areas will be made more appealing for operators (e.g., the infrastructure owner in such a case could be the municipality interested in ensuring service provision to the users in a small village). The identified SESAME use cases "address" these highly dense/dense/less dense scenarios in a coherent manner, which allow demonstrating the adaptability of the SESAME solutions.
European industry driving the development of 5G standards, at least for the radio part, and to retain control of 5G SEP (standards essential patents), 20% as a minimum. International co-operation with countries having bold R&D initiatives in the field (Korea, Japan, US, China) may be considered on a "win-win" basis.	SESAME had a strategic goal to transform the developed solutions and frameworks into standards as well as to create consensus among global players to use the technologies proposed in the Project. Furthermore, the SESAME partners have contributed to on-going open source initiatives (e.g., OPNFV, OpenDayLight, ONOS, OCCI[103], etc.) which are also considered as *de-facto* standards initiatives. The core industrial driven consortium with several key players who are strong leaders in standards initiatives (e.g., OTE, FLE, IPA, CNET, etc.) has been able to achieve this goal.
Availability of a scalable management framework enabling deployment of novel applications, including sensor based applications, with reduction of network management opex by at least 20%.	One of the core features and innovation of the SESAME architecture is the CESC management framework, which will has so been designed and prototyped in order to manage the multi-tenant SESAME infrastructure, leveraging the novel edge-computing architectures and deploying the "self-x" and optimization procedures directly at the network edge. The management layer comprises of specific VIM and Orchestration mechanisms, to handle the dynamic SLAs between the CESC providers and mobile virtual operators and to orchestrate the network, computing and storage resources in an optimum manner. Remarkably, the introduction of Artificial Intelligence (AI)-*based* mechanisms in the management layer can lead to more efficient autonomous solutions that contribute to management OPEX reductions. The key notion, to combine the CESC management with the virtualised Small Cells realising the clear vision of mobile edge computing capabilities into Small Cell deployments, allows for the introduction of novel applications, and the SESAME consortium believes to achieve a concrete reduction in network and service management OPEX by at least 25% per tenant compared to regular 4G small cells deployments.

[103] For further information, also see: http://occi-wg.org/.

At Societal Level	
The impact is to support an ubiquitous access to a wider spectrum of applications and services offered at lower cost, with increased resilience and continuity, with higher efficiency of resources usage (e.g., spectrum), and to reduce network energy consumption.	As recognised by the "Europe 2020" strategy and its flagship initiative Digital Agenda for Europe (DAE), tomorrow's digital services increasingly rely on fast, effective broadband connections to the extent that a 10% increase in broadband penetration is estimated to bring up the GDP by 1-1.5%. In this context, CESC mobile-edge computing capabilities provide a new ecosystem and value chain for new applications and service delivery at lower costs due to the higher efficiency in resource usage. Software and application providers can serve the new ecosystem by developing and bringing to the market innovative and ground breaking services and applications. SESAME also contributes to achieve higher levels of resilience in service delivery (e.g., critical applications supported at the network edge can run isolated from the rest of the network, while having access to local resources) and reduce energy consumption, as discussed before. In addition, the exploding growth of mobile broadband access to the Internet is introducing significant societal changes. By contributing to the new 5G landscape, SESAME contributes to develop and sustain the new still fragile ecosystem, making easy access to broadband technology at low cost and paying particular attention in environmental friendliness, by adopting during the whole Project lifecycle the approach of making small cells as energy efficient as possible. In this regard, the multi-tenancy capabilities offered by SESAME contribute also to the reduction of deployment costs, thus facilitating the provisioning of services in low density areas or in hard-to-reach areas such as underground facilities. SESAME gives the opportunity to CSPs to provide resources when and their customers demand them, allowing a new set of SLAs for customers to subscribe to. Having such an opportunity, people can just consider access to Internet to be ubiquitous, thus overcoming current limitations. Thanks to this self-awareness, people will just use the new 5G technology in the way they prefer the most to generate new businesses, revenues and advantages for the society as a whole.

4.2 SESAME's Contribution to the Improvement of Innovation and Integration of New Knowledge

The core contribution of SESAME has been to create imaginative and concrete opportunities for generating competitive advantages for the European ICT market. SESAME is rooted at the core requirement for improving innovation capacity in the European mobile industry by consolidating a very tight convergence of the telecommunications and IT market.
This has been the key differentiator moving towards 5G technologies where the European ICT market will see the emergence of new vertical business segments and services for consumers and enterprise customers. Furthermore, such a convergence will be "key" to counter the explosion of data traffic and the ever-increasing introduction of novel applications and cutting edge services by the service providers and OTT players.

A strong indicator and success criteria of SESAME that concretely shows the potential to deliver a substantial improvement in innovation capacity is the perfect mix of multi-dimensional industrial partners coming from the telecommunications and IT sector.
The consortium consisted of a variety of players in the domain of network and IT technologies, including:

- Mobile network operators, (such as OTE (part of the Deutsche Telekom Group, a top European ICT firm) who aims to increase their revenues in the 5G sector).
- Network equipment vendors, (such as IPA which is the market leading small cells vendor in Europe, and SISTEL).
- Global ICT technology companies (such as FLE, who are market leaders in different ranges of technology products, solutions and services (fourth largest IT provider in the world)).
- Manufacturers (such as STM, one of the largest semiconductor and integrated device manufacturer in the world, establishing rapidly as market leader in the low-power electronics domain).
- Network and IT solutions suppliers (such as ITL), and a large IT services provider (such as ATOS), who are leading European players in the telecommunications services sectors.
- Innovative high-tech SMEs focused on complementary business and R&D sectors (such as VOSYS in virtualisation solutions, ATN in flexible mobile core deployments, ORION in virtualised infrastructure management solutions, INC in mobile market analysis and business modelling and SMNET in the development/testing as well as in the provision of advanced solutions and applications in the market).

Figure 8, as below, presents a summary of the SESAME consortium:

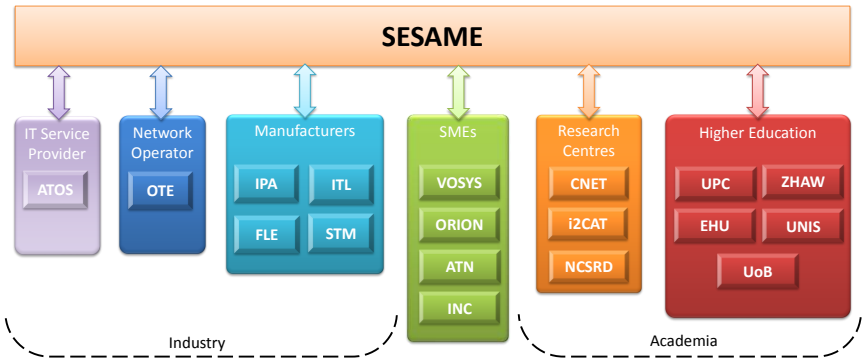

Figure 8: SESAME Consortium Composition

4.3 SESAME's Contribution to the 5G-PPP KPIs

In the following table (Table 7), we discuss how SESAME has contributed to the well-identified 5G-PPP KPIs; these have been separated in three categories (i.e.: business, performance and societal). More details are also given in the SESAME Deliverable D2.1.

We distinguish the following:

Table 7: SESAME Contributions to address 5G-PPP Business, Performance and Societal KPIs

Business KPI	SESAME Contributions
Target SME participation under the 5G-PPP initiative commensurate with an allocation of 20% of the total public funding	The consortium included four high-tech SMEs (VOSYS, ATN, ORION and SMNET), who have contributed to the technical roadmap and objectives in SESAME and have been involved in the "key" technological component development and innovation aspects in the Project from an early stage. The SMEs have been well positioned to leverage the technological expertise to exploit them within the 5G market space either through the consortium or as individual entities. Furthermore, the depth of the industrial participation allowed the SMEs to "work closely" with the large players to gain valuable expertise, and further, the contribution to open standards and open source communities provided the opportunity to the SMEs to have better exploitation plans and commercialization potential from the technologies developed from SESAME. The 5th SME, INC –also working with SMNET and the other partners– has been involved in the business modelling and market analysis aspects, which will give them visibility to collaborate with several CSPs to offer specific consulting services on the 5G virtualised small cells market.
Performance KPI	**SESAME Contributions**
Reducing the average service creation time cycle from 90 hours to 90 minutes (as compared to the equivalent time cycle in 2010)	Clearly, SESAME's management framework exposes the modules that are required for the service deployment by allowing the assembly and optimum coordination of NFV modules. The open architecture adopted by SESAME allows to scale- up/down the services through multi-tenancy and gives the opportunity to network operators and CSPs to explore the optimum assembly of NFV modules in a way that can be exploited in reducing service creation time.
Secure, reliable and dependable Internet with a "zero perceived" downtime for services provision.	The SESAME architecture and functional components have been designed to be adaptive via inherently implemented cognitive intelligence mechanisms that will ensure a reliable and dependable application and service deployment at the edge for the customers, sufficient isolation, and cloud-edge capabilities. These elements will facilitate features such as efficient content caching and, together with load balancing and other re-configurability options, they will allow provisioning services with "zero perceived" downtime.
Societal KPI	**SESAME Contributions**
Reduction of energy consumption per service up to 90%	By allowing CAPEX/OPEX cost reduction through multi-tenancy/multi-service capabilities instilled through CESC infrastructure sharing, SESAME actually provides a key societal contribution towards the reduction of CO_2 from the ICT industry in line with the objectives of many EU member states. Improved energy consumption is also expected to arise from energy efficient Light DC, which is based on ARM processors and exploiting a non-x86 architecture. Further, by leveraging the mobile edge computing capabilities, the CESC management functionalities will leverage the virtual network functions to deploy mobile core network

	functionalities closer to the edges thus reducing the overhead on signalling which will be translated into energy savings. Further, the edge caching and other advanced service capabilities leveraged in SESAME will allow optimising the use of resources, which again will contribute to energy savings.
New economically-viable services of high societal value like U-HDTV and M2M applications	SESAME can greatly improve the capabilities of CSPs and service providers to add new revenue streams for innovative services that have higher societal value and better QoE delivered from closer to the user. Placing relevant applications closer to the edge and slicing the infrastructure to offer multi-tenancy capabilities allows the users to be offered with economically-viable applications, leveraging on the OPEX gains and other service composition and OSS-*related* savings.
Establishment and availability of 5G skills development curricula in partnership with EIT	SESAME partners are active members and contributors of the EIT (the KIC on ICT Labs, where the Madrid, London, Trento node partners have involvement in the project). This allows the Project to create knowledge transfer plans leveraging the EIT framework to develop both education and business related promotion of the SESAME concepts, and further to showcase SESAME prototypes and demonstrations in cooperation with the EIT to potential customers and stakeholders.

5 Conclusion

In this document we have presented a detailed overview of the various activities that took place during the entire lifecycle of SESAME, in order to realize an explicit awareness of the Project within an extended variety of sectors, including business areas, the academia, end-users and many more. In this framework, we have identified all performed communication and dissemination activities and, *in particular*, we have focused on the project website, the presence in social networks, related videos, newsletters, interviews, press releases, publications in workshops/conferences and journals, leaflets, posters and brochures. SESAME has targeted distinct areas of the market sector and has performed multiple and successful activities in order to broadly "make its specific context well and explicitly known" to any third party.

On the other hand, the present work has summarised some among the benefits coming from the original SESAME context that have clear and positive impact on various areas, with emphasis given to the societal ones. SESAME promotes a variety of innovative technological features that can strongly impact the broader market sector and may have -explicitly and/or implicitly- a significant influence to the end-users, thus affecting several social implications. As SESAME introduces suitable and validated solutions to satisfy a certain number of well-defined objectives, this can promote the adoption of novel solutions that offer services of better quality and can enhance various related KPIs, in the dawn of the evolution of 5G. In this framework, we have also discussed SESAME's strategic impact and contribution to the related H2020 Work program as well as SESAME's contribution to the improvement of innovation and to the well-identified 5G-PPP KPIs. This strongly correlates the full scope of SESAME-*based* actions to the related innovative strategic priorities of the European Union.