Satellite and Terrestrial Network for 5G

D6.6
Exploitation Plan

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2G	2nd Generation mobile network
3G	3rd Generation mobile network
3GPP	3rd Generation Partnership Project
4G	4th Generation mobile network
5G	5th Generation mobile network
5G PPP	5G Public-Private Partnership
5GIC	5G Innovation Centre
5GTN	5G Test Network
ABR	Adaptive Bit-Rate
AEEC	Airlines Electronic Engineering Committee
AF	Application Function
AKA	Authentication and Key Agreement
AMF	Access and Mobility Function
API	Application Programming Interface
AR	Augmented Reality
ARPU	Average Revenue Per User
ARTES	Advanced Research in Telecommunications Systems (ESA's Programme)
AT3S	Access Traffic Steering, Switching and Splitting
AUSF	Authentication Server Function
BB	Broadband
BDP	Bandwidth-Delay-Product
BEMES	Business Modelling and Simulation Tool (of IMEC)
BSM	Broadband Satellite Multimedia
BSS	Business Support System
BSS	Broadcast Satellite Services
BUC	Block Up Converter
CAPEX	Capital Expenditure
CBH	Cellular BackHauling
CCN	Content Centric Networking (or else referred to as ICN)
CDN	Content Delivery Network
CDNi	Content Delivery Network Interconnection
CIR	Committed Information Rate
CN	Core Network
COTM	Communications On The Move
COTS	Commercial Off-The-Shelf
CSP	Communication Service Provider
CUPS	Control and User Plane Separation
CWC	Centre for Wireless Communications
DASH	Dynamic Adaptive Streaming over HTTP
DBS	Digital Broadcasting Satellite
DoW	Description of Work (Annex 1 of Grant Agreement)
DPDK	Data Plane Development Kit
DRM	Digital Rights Management
DSL	Digital Subscriber Line
DTH	Direct To Home
DTN	Delay Tolerant Networking
DVB	Digital Video Broadcasting
EAP	Extensible Authentication Protocol
EC	European Commission
ECC	Electronic Communications Committee
ECX	EdgeCentrix
eMBB	Enhanced Mobile Broadband
EMEA	Europe, the Middle East and Africa
EMS	Element Management System

eNB	eNodeB
EPC	Evolved Packet Core
ESA	European Space Agency
ESIM	Earth Station In Motion
ESOA	EMEA Satellite Operator Association
ETSI	European Technical Standards Institute
EU	European Union
EuCNC	European Conference on Networks and Communications
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
FIFO	First In First Out
FOTA	Firmware Over-the-Air
FSS	Fixed Satellite Services
GEO	Geostationary Orbit
GERAN	GSM Edge Radio Access Network
GES	Gateway Earth Stations
GSM	Global System for Mobile communication
GSMA	GSM Association
GW	GateWay
HAPS	High Altitude Platform System
HD	High Definition
HDTV	High Definition TV
HLS	HTTP Live Streaming (Apple)
HSS	HTTP Smooth Streaming (Microsoft)
HTS	High Throughput Satellite
HTTP	Hypertext Transfer Protocol
iDR	iDirect Government Technologies
ICN	Information Centric Networking (or else referred to as CCN)
ICT	Information and Communications Technologies
IEEE	Institute of Electrical and Electronic Engineers
IETF	Internet Engineering Task Force
IFEC	In-Flight Entertainment and Communication
IIoT	Industrial Internet of Things
IMEC	Inter-university Microelectronics Center
IMT	International Mobile Telecommunication
IoE	Internet of Everything
IoT	Internet of Things
IP	Internet Protocol
IPR	Intellectual Property (Rights)
IRR	Internal Rate of Return
ISG	Industry Specification Group
ISP	Internet Service Provider
ITT	Invitation To Tender
ITU	International Telecommunications Union
KPI	Key Performance Indicator
LEO	Low Earth Orbit
LSO	Lifecycle Service Orchestration
LTE	Long Term Evolution
M2M	Machine-to-Machine
M-ABR	Multicast-assisted Adaptive Bit-Rate
MAC	Media Access Control
MANO	Management and Orchestration
MBMS	Multimedia Broadcast Multicast Service
MEC	Mobile Edge Computing (or Multi-access Edge Computing)
MEF	Metro Ethernet Forum
MENDHOSA	Media & ENtertainment Delivery over Hetnet with Optimized Satellite Architecture
MEO	Medium Earth Orbit
MIMO	Multiple-Input Multiple-Output
mIoT	Massive Internet of Things
mMTC	Massive Machine-Type Communications
MNO	Mobile Network Operator

MPEG	Motion Picture Expert Group
MPEG-DASH	MPEG Dynamic Adaptive Streaming over HTTP
MPQUIC	Multipath Quick UDP Internet Connection
MPTCP	MultiPath Transmission Control Protocol
MSS	Mobile Satellite Services
MVNE	Mobile Virtual Network Enabler
MVNO	Mobile Virtual Network Operator
NaaS	Network as a Service
NEO	Network Operation
NF	Network Function
NFV	Network Functions Virtualisation
NFVI	Network Function Virtualisation Infrastructure
NG2	5G Control Plane Interface
NG3	5G User Plane Interface
NGMN	Next Generation Mobile Networks
NIS	Network Infrastructure and Security
NMS	Network Management System
NPV	Net Present Value
NR	New Radio
NS	Network Service
NSSF	Network Slice Selection Function
NTN	Non Terrestrial Network
ODL	OpenDayLight
ONAP	Open Networking Automation Platform
OPEX	Operation Expenditure
OSM	Open-Source MANO
OSS	Operation Support System
OTM/P	On The Move/Pause
OTT	Over The Top
PCF	Policy Control Function
PEP	Performance Enhancement Proxy
PFCP	Packet Forwarding Control Plane
PIMT	Propagation Impairments Mitigation Techniques
PNF	Physical Network Function
POI	Point Of Interest
POP	Point Of Presence
PPP	Public Private Partnership
PSTN	Public Switched Telephone Network
QoE	Quality of Experience
QoS	Quality of Service
QUIC	Quick UDP Internet Connection
R&D	Research & Development
RAN	Radio Access Network
RAN1	(3GPP) Radio Access Network – WG1 (Radio Layer 1 specification)
RDSS	Radio Determination Satellite Service
RIFE	architectuRe for an Internet For Everyone
RNIS	Radio Network Information Service
RoI	Return on Investment
RP	Research Pillar
RRC	Radio Resource Control
RRU	Remote Radio Unit
Rx	Receiver
SA	Service and System Aspects
SA1	(3GPP) Service and System Aspects – WG1 (Services)
SANSA	Shared Access Terrestrial-Satellite Backhaul Network enabled by Smart Antennas
SaT5G	Satellite and Terrestrial Network for 5G
SaT5G	Satellite and Terrestrial Network for 5G
SatCom	Satellite Communications
SATis5	Demonstrator for Satellite-Terrestrial Integration in the 5G Context
SatNaaS	Satellite Network as a Service

SCN	Satellite Communication and Navigation
SDN	Software Defined Network
SDO	Standardisation Organisation
SDR	Software Defined Radio
SES	Satellite Earth Stations and Systems (ETSI TC)
SLA	Service Level Agreement
SMARTER	Services and Markets Technology Enablers (3GPP)
SMB	Server Message Block
SME	Small Medium Enterprise
SMF	Session Management Function
SOHO	Small Office/Home Office
SON	Self-Optimizing Network
SOTA	Software Over-the-Air
SPECSI	Strategic Positioning of the European and Canadian Satcom Industry
SSPA	Solid-State Power Amplifier
STB	Set-Top-Box
SUC	Satellite Use Case
SUCC	Satellite Use Case Category
SVNO	Satellite Virtual Network Operator
SWP	Sub-Work Package
TBC	To Be Confirmed
TC	Technical Committee
TCP	Transmission Control Protocol
TESS	Techno-Economic Software Suite
TM	Technical Module
TN	Transport Network
TR	Technical Report
TS	Technical Specification
TSG	Technical Specification Group
TV	TeleVision
Tx	Transmitter
UAS	Unmanned Aircraft System
UC	Use Case
UDM	User Data Management
UE	User Equipment
UHD	Ultra High Definition
UHDTV	Ultra High Definition TV
UPF	User Plane Function
URLLC	Ultra-Reliable Low-Latency Communications
UTRAN	Universal Terrestrial Radio Access Network
VHTS	Very High Throughput Satellite
VIM	Virtualised Infrastructure Manager
VNF	Virtualised Network Function
VNI	Visual Networking Index
VoD	Video on Demand
VR	Virtual Reality
VSAT	Very Small Aperture Terminal
WCE	Wireless Communication Engineering
WG	Working Group
WP(L)	Work Package (Leader)
WRC	World Radiocommunication Conference
WSN	Wireless Sensors Network
ZDS	Zodiac Data Systems
ZII	Zodiac Inflight Innovations

Executive Summary

This deliverable document corresponds to one of the two outputs of SaT5G WP6.4 “Exploitation Plan”, which defines the plans for exploitation of the research & innovation results and findings from the project. In particular, the present deliverable document D6.6 “Exploitation Plan” defines the strategic plan for SaT5G project results exploitation.

This deliverable document describes the SaT5G exploitation elements on both a thematic and partner specific basis. Thematically four broad areas are considered in terms of SaT5G exploitation elements: Products, Services, R&D, and Standards.

The individual exploitation plans for each SaT5G consortium partner have been independently developed by each party based on its business strategies; however, some of the exploitable opportunities may be developed in conjunction by a subset of the project partners towards and after the completion of the project. Every partner has provided the identification of the exploitable knowledge they have developed so far in the project as well as the opportunities for exploitation coming out from such knowledge.

The SaT5G exploitation activities will be reported into the companion deliverable document of the same WP6.4, which is D6.7 “Exploitation Activity Report” and is due for delivery at the end of the SaT5G project.

1 Introduction

1.1 *Scope of SaT5G*

SaT5G is a European Commission H2020 5G PPP Phase 2 project, kicked-off in June 2017 with 30-month duration, whose vision is to develop cost effective “plug and play” SatCom (Satellite Communication) solutions for 5G to enable telecom operators and service providers to accelerate 5G deployment in all geographies and at the same time create new and growing market opportunities for SatCom industry stakeholders. SaT5G focuses primarily on backhaul via satellite and on enhanced mobile broadband (eMBB) use cases for 5G.

SaT5G aims to deliver the seamless integration of satellite into 5G networks to ensure ubiquitous 5G access everywhere. The six principal SaT5G project objectives are to:

- Leverage relevant ongoing 5G and satellite research activities to assess and define solutions integrating satellite into the 5G network architecture;
- Develop the commercial value propositions for satellite-based network solutions for 5G;
- Define and develop key technical enablers for the identified research challenges;
- Validate key technical enablers in a lab test environment;
- Demonstrate selected features and use cases with in-orbit GEO and MEO HTS satellites;
- Contribute to the standardisation at ETSI and 3GPP of the features enabling the integration of SatCom solutions in 5G.

1.2 *Document Context*

This deliverable document corresponds to one of the two outputs of SaT5G Work Package (WP) #6.4 titled “Exploitation Plan”, which defines the plans for exploitation of the research & innovation results and findings from the project. The WP6.4 activities undertaken are summarized as follows:

- Definition of a strategic plan for the commercial exploitation of the SaT5G concept and project results at national, European and international level.
- Consolidation of individual and joint exploitation plans in line with the common SaT5G roadmap defined.
- Identification of potential joint exploitation of project results by project partners.
- Identification and definition of future roles and responsibilities of all project partners targeting a successful commercial exploitation of the project results.

The present deliverable document D6.6 defines the strategic plan for SaT5G project results exploitation.

As an output document of WP6.4, this deliverable document D6.6 is fed with inputs from all WPs and sub-WPs. As an illustration, WP6.4, as well as WP6 in general, fits in with the surrounding activities as depicted in the figure below.

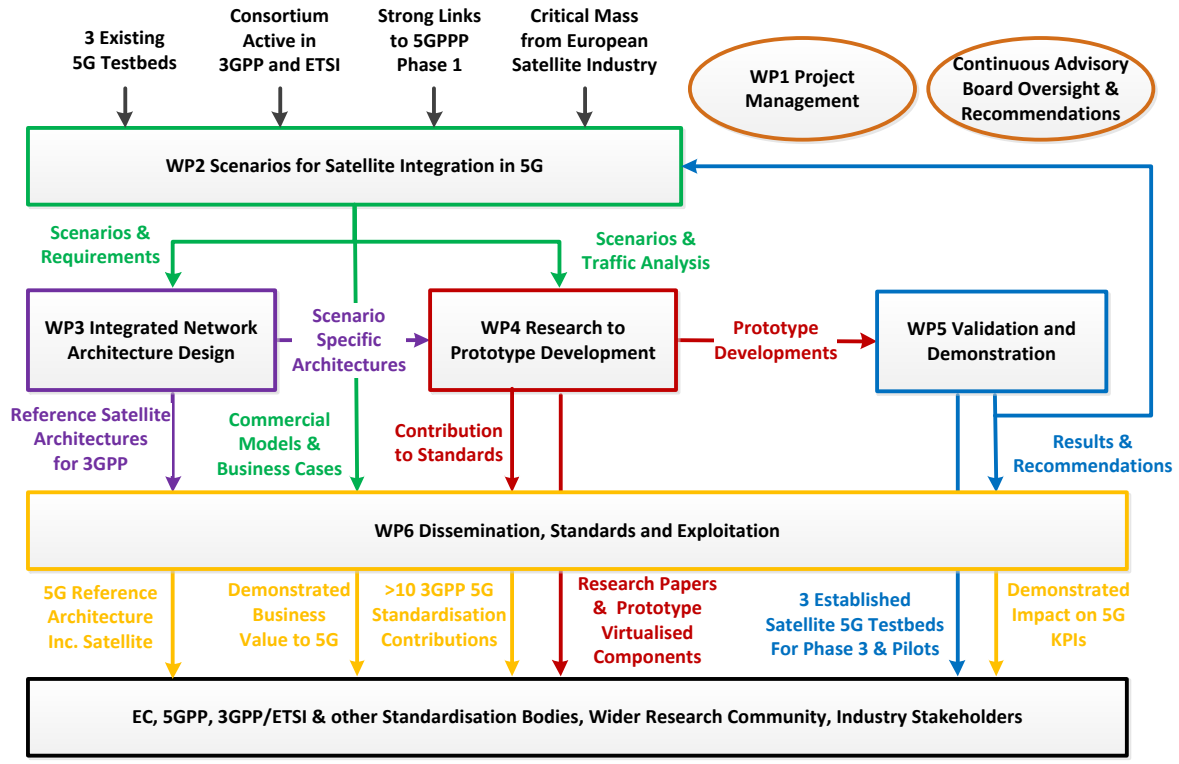

Figure 1-1: WP6 interdependencies with other WPs

1.3 *Document Organisation*

This document is organized as follows:

- Section 1 introduces the document, defines its context, and its organisation.
- Section 2 provides stakeholders' interest in the SaT5G project and summarises the aims of each of the consortium partners within the SaT5G project. These are expanded on within Sections 3 and 4 of this document.
- Section 3 provides an overview of the SaT5G exploitation elements. In particular, four broad areas are considered in terms of SaT5G exploitation elements:
  - Products: the potential hardware and software functions that will, at least in part, be developed during the SaT5G project by the partners;
  - Services: the potential integrated 5G and satellite service offerings that might be available as a result of the developments in SaT5G, based on the defined SaT5G use cases;
  - R&D: potential areas for future research that can further enhance the integration of satellite communications in to 5G;
  - Standards: the various standards that the SaT5G project has been contributing in order to simplify exploitation.
- Section 4 provides the individual exploitation plan of each of the SaT5G consortium partners. As such, sixteen sub-sections are included in this Section, one for each SaT5G consortium partner. Each such sub-section provides details of the mission and vision for the respective partner, their exploitable knowledge, their opportunities for exploitation, and their progress and outcomes so far.
- Section 5 concludes the document and summarizes the main outputs of the analysis conducted in WP6.4.
- Section 6 lists the various references used throughout this document.

2 Stakeholders Interest in SaT5G

Table 2.1 below summarises the aims of each of the consortium partners within the SaT5G project. These are expanded on within Sections 3 and 4 of this document.

Table 2.1: Aims of the SaT5G partners within the SaT5G project

Partner	Role	Exploitation Interests	Exploitation Overview
AVA	Satellite Operator	Services, Standards	**Short term:** Build the business case and developments required to integrate its satellites into 5G and inform any critical work required to pave the way for satellite being an intrinsic element of 3GPP 5G standards and services. **Long term:** To offer a universal platform incorporating multi-vendor virtualized satellite network (i.e. GLT, iDR, TAS) with 5G managed services delivered in partnership with mobile operators and verticals across all our footprint across Europe, the Middle East and Africa.
TAS	Satellite Systems Prime, Network Equipment Vendor	Products, Future R&D, Standards	**Short term:** Implement the developed features in its SatCom product (SpaceGate) that will exploit the future VHTS systems that are being developed in parallel. It will also enable to promote joint solutions with "cellular network" stakeholders whether SMEs, technology vendors, or even network integrators. **Long term:** Develop SatCom solutions through a tighter integration with 5G to address business opportunities in high growth markets such as high growth/low ARPU regions, wireless services on board air planes/vessels and broadband divide.
UoS	University, 5G Testbed Provider	Future R&D, Standards	**Short term:** Upgrade 5GIC testbed to include virtualised satellite terminals and demonstrate integrated satellite/mobile-backhaul to remote site, caching and multicast and backhaul; to home terminal and demonstrate to mobile industries across Europe. **Long term:** Demonstrate connection of 5GIC testbed with other remote testbeds, add user trials connected to verticals in follow on project and include new PhD topics connected to the system and flow results into teaching programmes.
SES	Satellite Operator	Services, Standards	**Short term:** Expedite service offerings of its GEO/MEO satellite fleet with associated ground segments for commercially attractive 5G use cases. Existing SES cellular backhaul and broadband to unserved areas will benefit first from SaT5G project results. Other segments (i.e., mobile) are expected to follow. **Long term:** Optimise new space segment and associated ground networks to serve 5G verticals and continue partnership with terrestrial mobile industry in commercial and standardisation in order to further promote satellite role in 5G ecosystem.
ADS	Satellite Systems Prime, Network Equipment Vendor	Products, Services, Future R&D, Standards	**Short-term:** Foster standardisation contributions in the frame of 3GPP NextGen architecture during the project, aiming to achieve a fully embracement of satellite based backhaul solutions as an integral part of 5G global architecture. **Long-term:** Contribute to the definition of future 5G Space Segment solutions to meet the technical and economical requirements associated to 5G backhaul scenarios and to foster specific satellite designs to ease 5G integration for satellite operators.
OA	Network Equipment Vendor	Products	**Short term:** Work on merging the next generation satellite into the current 5G terrestrial and mobile approaches thanks to innovations in SDN/NFV, integrated management, Backhauling, WAN Optimisation, Transport and QoS, and Link Aggregation technologies. **Long term:** Pave the way to the next OA product generation through demonstrating in a live 5G testbed the innovations developed in within the project.
TNO	Research Institute, 5G Testbed Provider	Future R&D, Standards	**Short term:** Develop knowledge on integration of satellite networks with 5G to enable research and consultancy assignments for European operators and public administrators and facilitate opportunities to develop new IPR. **Long term:** Develop the TNO testbed (based on OpenEPC) which will

Partner	Role	Exploitation Interests	Exploitation Overview
			form the base for further research with other market parties (primarily network operators and vendors), as well as for the demonstrators (aimed at policymakers). Additionally, TNO aims to develop and validate new security concepts which will be then brought into 3GPP.
BT	Telecommunications /Mobile Network Operator	Services, Standards	**Short term:** Open up options for BT to use satellite in mobile network backhaul and for certain access uses such as mission critical services and create opportunities for the UK mobile operations with EE and also global opportunities with BT's Global Services business unit. **Long term:** Provide coverage approaching 100% that can be exploited for critical services and for broadband provision to remote or difficult areas.
ZII	Aerospace Equipment Vendor	Products, Future R&D	**Short term:** Continue the established company practice to systematically exploit innovative R&T work by timely transformation into a cutting-edge 5G cabin product. **Long term:** Permanently extend its global leadership role in the IFEC market. Building on its current cellular, WiFi and IoT solutions, 5G architectures and concepts are considered to be the significant step towards a truly integrated and flexible cabin communication.
BPK	Network Equipment Vendor	Products	**Short term:** Model, implement and test various caching and multicast resources allocation strategies in the context of a mobile network. **Long term:** Drive the adaptation of its CDN solution, which currently allows to cache content on fixed networks and to leverage multicast capabilities of ADSL, cable and satellite networks, to the mobile network.
GLT	Network Equipment Vendor	Products, Standards	**Short term:** Leverage SDN and NFV technologies as well as the basic SatCom advantages in the heterogeneous architecture to a competitive solution. **Long term:** Lay the foundations for the company's next generation competitive solutions for 5G backhaul for Fixed OTP and OTM environments.
iDR	Network Equipment Vendor	Products, Standards	**Short term:** Demonstrate that satellite functions, including virtualised functions, can be integrated seamlessly in a 5G network and that as an industry we can work with 3GPP to define standardised approaches for those functions and interfaces which are unique to satellite. **Long term:** Create a tighter integration of satellite into the Telecom Carrier world, making the delivery of services over satellite as flexible and as efficient as over other transmission mediums.
IMEC	University, Research Institute	Future R&D	**Short term:** Expand IMEC's expertise towards future projects through the techno-economic research. This research will progress on business models for virtual (satellite) operators and cost allocation in SDN-enabled multi-operator networks. CDN caching mechanisms and their interaction with SDN-based controllers can be adapted to relevant transport protocols and linked to network management solutions and content profiling. **Long term:** Inclusion of such topics in academic courses.
i2CAT	Research Institute	Future R&D, Standards	**Short term:** Extend its open-source portfolio for integrated network management and orchestration including virtualized satellite functions. Contributions to ETSI OSM. (RP II) **Long term:** Become fundamental element in the future Barcelona urban-based 5G test-bed deployment, envisaged for 2020, bringing the management and orchestration stack, including foreground generated within RP I and II.
UOULU	University, 5G Testbed Provider	Future R&D	**Short term:** Addition of 5G compatible satellite backhauling solution to UOULU's 5GTN testbed via SaT5G partners as well as use it to enhance UOULU's capabilities to attract further research funding **Long term:** Bring in additional PhD research programmes and spin off the technology into UOULU teaching programme.
QUO	Network Equipment Vendor	Products, Standards	**Short term:** Working closely with many leading industry organisations and standards communities to produce a solution that is 'carrier ready' which reduces barriers to entry and accelerates 'time to market' for the solution. **Long term:** Standardisation of the deployment models for 5G over satellite would make this technology more widely adopted, generating increased volumes.

3 Overview of SaT5G Exploitation Elements

3.1 *Introduction to SaT5G Exploitation Elements*

In this chapter, four broad areas are considered:

- **Products:** Section 3.2 looks at the potential hardware and software functions that will, at least in part, be developed during the SaT5G project by the partners. The features that can be exploited are identified.
- **Services:** In section 3.3 the potential integrated 5G and satellite service offerings that might be available as a result of the developments in SaT5G are described. This analysis is provided by both terrestrial and satellite service providers and is based on the SaT5G use cases.
- **R&D:** SaT5G is constrained within its DoW to certain elements to allow it to meet commitments within the time and budget allocated. Section 3.4 identifies areas for future research that can further enhance the integration of satellite communications in to 5G.
- **Standards:** The areas in which SaT5G is contributing to various standards as a key part of its dissemination strategy are listed as the use of standards and standards compliant systems are intended to simplify exploitation.

3.2 *Product Exploitation*

SaT5G product exploitation centres on the outputs of the six SaT5G research pillars which address key technical enablers for “plug and play” SatCom elements for 5G.

Table 3.1: SaT5G Research Pillars

Research Pillar (RP)	Scope
Research Pillar I: Implementation of 5G SDN and NFV across satellite networks	Virtualise SatCom network functions to share the same virtualised core as cellular network functions, ensure compatibility with the SDN/NFV architecture and support network slicing
Research Pillar II: Integrated Network Management & Orchestration	Allow the cellular network management system to control the radio resource of SatCom systems and harmonise management between terrestrial and satellite technologies
Research Pillar III: Multi-link and Heterogeneous Transport	Exploit multi-link and heterogeneous links of the transport network at the backhaul level and mitigate the possible QoS and latency imbalance between the links
Research Pillar IV: Harmonisation of SatCom with 5G Control and User Plane	Leverage 5G features in satellite radio access network and foster the integration with other network technologies
Research Pillar V: Extending 5G Security to Satellite	Provide an efficient key management and authentication method and harmonise Authentication and Authorisation between terrestrial and satellite technologies
Research Pillar VI: Caching and multicast for content and VNF distribution	Provide efficient delivery of multimedia content and NFV functions to mobile edge computing/caching entities through the exploitation of the intrinsic broadcast capability of SatCom

Research pillar outcomes include publication and reports into technology enablers, but also include technology prototypes of hardware and software functions which in many cases will be integrated into SaT5G testbeds and demonstrations. The exploitable features for future products are outlined below.

3.2.1 Next Generation Virtualised Satellite Hub and User Terminals

SaT5G provides a unique opportunity to mutually discuss and define how future satellite systems will be expected to interface and interwork with 5G end-to-end service delivery systems. It is acknowledged that additional work will be required to further enhance initial proof of concept outputs that will be defined and standardised by SaT5G project. Satellite platform vendors would like to leverage this work in the future to further define the satellite interoperability requirements as well as supporting pre-5G or 5G systems to leverage satellite advantages. The intention is to further test and improve the interface and auto provisioning of end-to-end service by further simplifying the interfaces between different network architectures.

The future satellite Radio Access Network (RAN) will be comprised of the following main building blocks:

- Satellite GW functions which will become distributed and virtualised to lower as much as possible overall cost of maintaining and building multiple GW sites. This will be done by utilising COTS equipment in each GW site and dynamically allocating virtualised satellite processing functions resources based on actual need in every different satellite foot print.
- Remote sites which will include virtualisation capabilities to facilitate VSAT (satellite modem interface) or any additional 5G NF that will be required to complete the end to end service delivery to the users, these NF will be dynamically allocated per need based on each service delivery definition.
- Management system which will orchestrate the entire satellite delivery segment with tight correlation and integration with a higher-level orchestration system. This management integration will ensure an end to end service delivery while maintaining interoperation between terrestrial and none terrestrial infrastructures.

3.2.2 Next Generation Satellite-Terrestrial Integrated MANO

With the emergence of 5G, a radical change on the Information and Communications Technology (ICT) is observed. Networks are evolving quicker than ever towards smart systems featuring ultra-low latency, huge traffic volume and higher data rates. Cloud-enabled solution promises effective means to realize future communication goals. With the help of softwarisation techniques and cloud/edge processing capabilities, benefits such as increased resource pooling, scalability, layer interworking, and spectral/cost efficiency are achievable.

Thanks to the maturity of the softwarisation technologies, i.e. Network Functions Virtualisation (NFV) and Software Defined Networking (SDN), it is possible to guarantee higher flexibility, programmability, automation and significant cost/energy reduction on the mobile technology ecosystem. With the help of NFV and SDN, the embedded general purpose IT resources at the network are employed to offer special network functionalities, e.g. AMF, SMF, etc. and added value services, e.g. innovative media services, aiming to improve the end user's Quality of Experience (QoE) and creating new business opportunities for service providers. With a closer look to the added value services, it is possible to infer that they are complex operations composed by one or a set of software applications, e.g. Virtual Network Functions (VNF), cooperating together towards a common goal.

For example, an end-to-end innovative media service is composed of a series of software each taking a specific responsibility. A virtual machine is imitating the functionalities of a specialised "hard-wired" device like a firewall. This virtual device helps pre-filtering the incoming video files from end users to the mobile network edge. Non-blocked contents are directed to a video production application designed for sport events. The processed video by the application is then broadcasted locally to the end users who are interested to have a 360 vision of the goal. To guarantee the Quality of Service (QoS) at any traffic status the whole media service is constantly monitored and optimised by a Self-Optimising Network (SON/Self-X) functionality against the agreed QoS metrics on the Service Level Agreement (SLA).

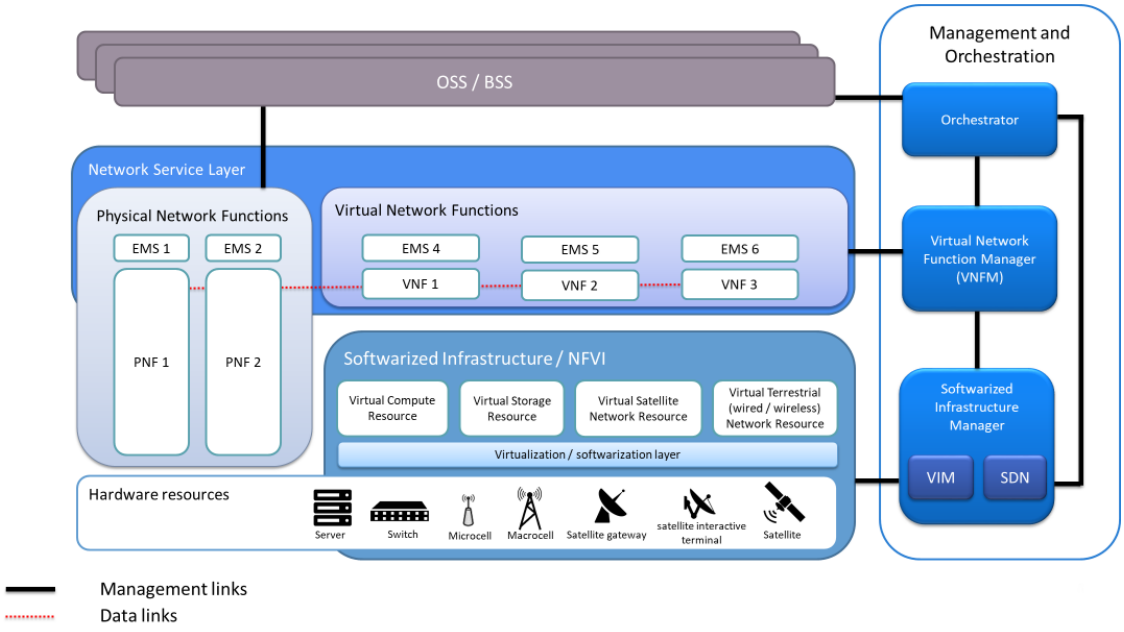

Figure 3-1: ETSI MANO Framework

However, lifecycle management of virtual functions (instantiation, modification, termination) without having an effective management and orchestration systems is not possible. The management system is a coordination layer on top of all domains, responsible for automated cross-domain lifecycle management / coordination as well as interfacing with the operators (satellite and terrestrial). From one side, 3GPP SA5 focuses on the specifications, requirements, architecture for provisioning and management of the network and its services. Following SA5 specifications, an end-to-end management solution covers the general NF management concept which includes: physical and virtual NF lifecycle management; configuration; fault management and performance management. From the other side, the European Telecommunications Standards Institute (ETSI) plays a leading position worldwide to define a management and orchestration framework for the cloud-enabled future 5G networks. ETSI has defined a framework, known as Functions Virtualisation Management and Orchestration (NFV MANO) (see Figure 3-1) to address all the issues related with the management and orchestration of cloud resources, i.e. computing, networking, and storage. MANO framework is divided into three main functional blocks:

- NFV Orchestrator: Responsible for actions such as:
  - The on-boarding of new network services (NS) and virtual network function (VNF) packages;
  - Global resource management;
  - NS lifecycle management;
  - Validation and authorisation of network functions virtualisation infrastructure (NFVI) resource requests;
- VNF Manager: Oversees VNF lifecycle management and configurations;
- Virtualised Infrastructure Manager (VIM): Controls and manages the NFVI compute, storage, and network resources

Nevertheless, merging 3GPP next generation architecture with MANO framework is a very challenging task, especially when considering a wide picture that includes both satellite and terrestrial communication technologies. SaT5G targets to tackle this challenge by design and introduction of a holistic management and orchestration system able to coordinate all terrestrial and satellite elements. Such a solution will be based on open source available MANO implementation, in particular Open Source MANO (OSM), and will support northbound interface (Os-Nfvo) with both terrestrial and satellite operators.

3.2.3 Next Generation MEC-enabled Edge Network Delivery

The possibility of streaming video from a location that is as close as possible from the end-user is one of the objectives of a Content Delivery Network (CDN) solution. Multi-access Edge Computing (MEC) provides a framework for hosting a local cache and streaming server as an application, and to allocate dynamically the resources (processing power, storage, IO) to the network functions based on the evolution of the needs. It is a key enabler for value-added converged satellite-terrestrial 5G service delivery. The MEC caching high level architecture is depicted in Figure 3-2.

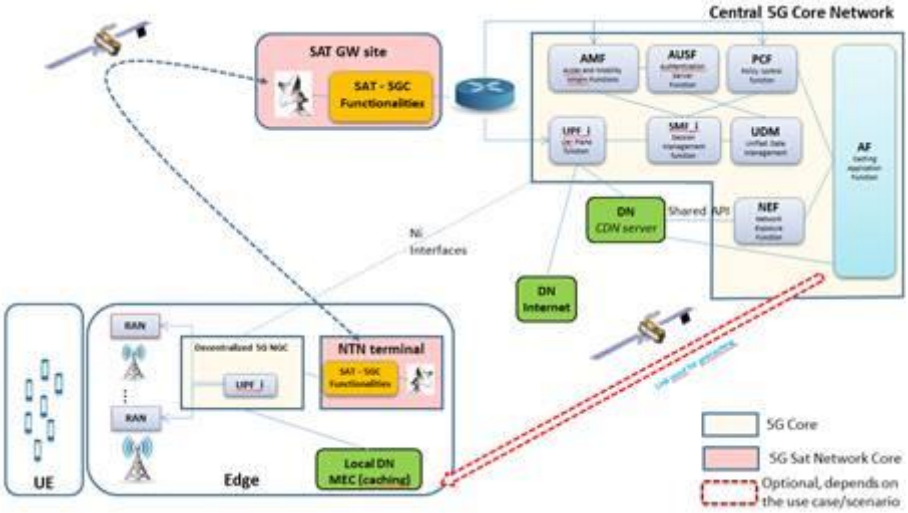

Figure 3-2: MEC caching high level architecture

The following elements play a key role in this new architecture:

- Cache equipment within the Edge Network titled “Local DN MEC”. This cache is linked to a local UPF which may be elected by the SMF based on traffic steering policies;
- A new Caching Application Function in the 5G Core: decides on traffic steering policies and provides them to the SMF via PCF;
- Multicast Controller: function in charge of pushing the assets in the network using multicast technology.

The MEC platform provides to the streaming system information about the localisation of the user covered by the cell and about the bandwidth used. This information allows the streaming system to allocate the best cache server to address the content request.

The dynamic allocation of resources helps keeping the operational costs low by saving power and can also be used to trigger the launch of other applications that do not require resources at the same time.

3.2.4 Next Generation Multi-link and Heterogeneous Transport

The satellite coverage depends on the satellite and its beams and not on a deployed terrestrial infrastructure. The characteristics of the service itself are relatively homogeneous within the covered area and satellite operators design beam coverage overlaps to somewhat hide the performance deterioration at the area edges. Considering this coverage is orders of magnitude larger than 5G cells, using satellite to improve 5G where its reception is low or "would be expensive" to improve is a clear use case. This requires combining the satellite link and a terrestrial (5G but not only) link to transport the 5G traffic from the User Equipment to the 5G mobile core.

Transport protocols such as MPTCP, and more recently MPQUIC, have setup the path to combine multiple links so the overall throughput is roughly equivalent to the sum of the different links' bandwidth. To achieve this, load-balancing algorithms such as Weighted Round Robin dynamically distribute the traffic on the links and make sure to re-assemble it at the reception. Note that link cost, QoS and Policy rules, for example application-based similar to SD-WAN, can be added.

The first challenge for this project is the very different characteristics, especially latency, of the considered links: terrestrial 5G is typically between 10 and 100ms latency while satellite can be up to 600-800ms for geo-stationary orbits (a figure reduced for LEO and MEO constellations). As a result,

re-ordering packets that have been sent simultaneously but arrive in a complete random order is very inefficient.

The second challenge is the difficulty to analyse encrypted traffic that does not allow the use of Deep Packet Inspection-based policies, and this raises the question of where to start and stop the multi-link, e.g. in the User Terminal itself, or limited to backhauling?

Multi-link technologies allowing the system assess in real-time the characteristics of each link and to adapt its load-balancing weighs also unlock the mobile use case. A vehicle (car, boat, plane, etc.) would leverage the availability of multiple links along its route by coupling them as those are available.

Multi-link technology applied to satellite and 5G must be compliant with 3GPP standards such as AT3S (Access Traffic Steering, Switching and Splitting) to be seamlessly deployed.

3.2.5 Next Generation 3GPP/Non-3GPP Satellite Access

The SaT5G project is considering satellite networks (part of the non-terrestrial networks which also include HAPS based networks) according to several scenarios of integration in the 5G system each leading to a specific CAPEX/OPEX impact compared to existing SatCom solutions. The higher the technology commonalities with 5G technology may also impact the acceptance by the 3GPP ecosystem.

Beyond state of the art “backhaul”, satellite networks can provide equivalent service but using instead the “indirect access to UE” feature based on Relay capable UE. For some use cases, SatCom networks can also provide direct access to UEs. The integration scenarios of satellite in 5G are overviewed below [1]:

- **Scenario A1 - Direct 3GPP access:** NTN enabled UE (NTN UE on the Figure 3-3) accesses the 5G Core Network (5G CN) via a 3GPP NTN Access Network. UE management applies to the NTN enabled UE, such as NAS-Mobility Management (including Handover, Location Tracking, Paging to take into account NTN cell mobility and pattern, NAS-Connection Management, UE Initial Access, PDU session establishment.

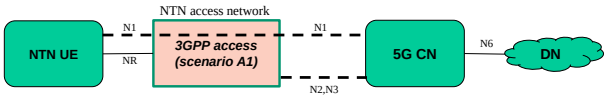

Figure 3-3: Scenario A1, SatCom serving UE directly

- **Scenario A2 - Indirect 3GPP access:** 5G UEs are served by an access point (NTN Relay UE, as illustrated in Figure 3-4). This access point is served by a 3GPP NTN Access. UE management function applies to this access point. It also endorses a multiplexer node role. The “NTN Radio Interface (NRI) is implemented with the full 5G New Radio (NR). The NTN Relay UE implements the local gNB to serve the UEs and a NTN UE function served by the NTN Access Network.

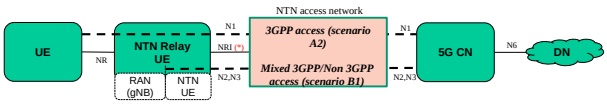

Figure 3-4: Scenarios A2/B1, SatCom serving UE indirectly via relay node

- **Scenario B1 - Indirect mixed 3GPP NTN access:** this scenario is very similar to Scenario A2, with a main difference that the NRI interface is implemented as a mix of NR higher layers over non-3GPP L2, L1 layers.

- **Scenario B2 – Indirect access via transparent transport network:** the gNBs are served by an access point named NTN terminal (see Figure 3-5), connected to the 5G CN via an NTN transport network. Here, the UE management does not apply to the NTN terminal. It may

endorse a gNB multiplexer node role. The NTN transport network shall be considered as trusted by the operator of the UEs.

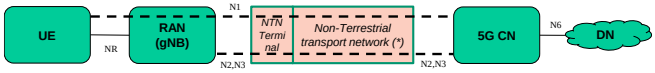

Figure 3-5: Scenario B2, Indirect access via transparent transport network

- **Scenario B3 - Indirect untrusted access:** the gNB is served by an untrusted non 3GPP access network, including the NTN Terminal. UE management does not apply to this NTN terminal that may endorse a multiplexer node role. It shall be interconnected to the 5G CN through a security tunnel. As depicted in Figure 3-6, a new reference point is introduced and named NWg, between the local security gateway (SEC) and an extended N3IWF security proxy, namely the N3IWFg function, for establishing secure IPsec tunnel(s) per gNB. The number of IPsec tunnels and the related overheads are decreased compared to current solutions with tunnels setup per UE. The proposed N3IWFg relays the N1 interface between the UE and the 5G CN and N2 and N3 interfaces between the RAN (gNB) and the 5G CN.

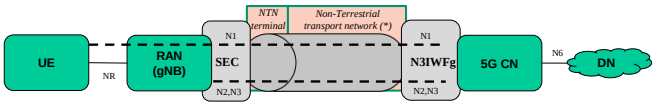

Figure 3-6: Scenario B3, SatCom providing transport to the CN/RAN interface

The main characteristics of the scenarios are summarised in the table below:

Table 3.2: Main characteristics of integration scenarios of non-terrestrial networks in 5G system

Scenario	NTN terminal Radio Access technology	Access type for UE	Functions in the NTN Terminal	UE management supported by NTN terminal	Trusted NTN network
A1	5G NR	Direct	3GPP UE	Yes	Yes
A2	5G NR	Indirect	3GPP relay UE, Multiplexing node	Yes	Yes
B1	Mixed 3GPP/Non 3GPP NTN access	Indirect	Mixed 3GPP/Non 3GPP relay UE, multiplexing node	Yes	Yes
B2	Agnostic	Indirect	IP / frame Relaying, Access Point for local RAN	No	Yes
B3	Agnostic	Indirect	Same as for B2 plus security gateway	No	No - IPSeC tunnels established between N3IWF and security gateway co located with NTN terminal

SaT5G project work is establishing the fundamental design for next generation access techniques that will be exploitable to enable this broader set of scenarios. The implementation of these scenarios ranges from short term (less than 2 years) to long term (more than 5 years) from mid-2018.

3.2.6 Next Generation 5G Security for Satellite Networks

Integration of satellites and 5G network(s) is a challenging task. 5G is being developed by 3GPP, association of mainly terrestrial network operators and vendors, while satellite networks have been having their own standardisation bodies, vendors and operators. Bridging these two worlds is not trivial. 5G brings number of innovations, of which the softwarisation of networks and integration of existing networks into 5G are having large impact on how data paths are organized, and how operators run their networks.

Data can cross number of domains and different networks, without user noticing anything. All the while different networks that are providing path for data to end-user, can belong to different parties, and have different implemented security mechanisms.

To be able to deliver that, SaT5G will deliver a security architecture that leverages on existing 5G security architecture and improves aspects relevant for satellite integration. Work that 3GPP is doing on 5G is so that other types of networks can be integrated into 5G framework, and respective 5G networks elements providing interoperability and managing mobility are present. The SaT5G project considers different use cases and different possible architecture. Each different architecture will have a different trust model, each with its own limitations and necessary security measures. The architectures are divided into direct access and indirect access, and also they could be supporting hybrid (terrestrial and satellite) access.

The state of the art and the assumptions of SaT5G are that the satellite link is used as if it is an untrusted link between the remote area and the data centre of the MNO. From a security perspective, this approach is very similar to what happens in the state of the art because the security is provided 'over the top' as seen from the satellite operator and the satellite operator does not become part of the ecosystem, but rather becomes a provider of the transportation network to and from the radio sites.

A true integration of the satellite provider would mean that it becomes part of the 5G network, similar to how a visited network or a home network is a part of the 5G ecosystem. In order to achieve this, the satellite network and the 5G network would need to converge.

Here we will just mention challenges related to direct access and to indirect access, as the elements of their security framework will be also present in other cases.

3.2.6.1 *Direct access*

The direct access architectures refer to the architectures where the UE uses (higher layers of) 5G to access the satellite network. For direct access there are three possible scenarios. One is the possibility where the UE is only satellite network capable and can only attach to one network (i.e. there is no roaming), the second one is where the UE is only satellite network capable, but can attach to multiple satellite networks (i.e. there is roaming provided between satellite operators) and the last one is where the UE is satellite and terrestrial 5G capable (i.e. it can roam to both satellite operators and terrestrial 5G cellular operators). In this section we discuss the trust model of these versions.

The architecture for direct access without roaming is given in 3GPP document TS 23.501 [2], figure 4.2.3-1. The security requirements for this architecture are given in 3GPP document TS 33.501 [3].

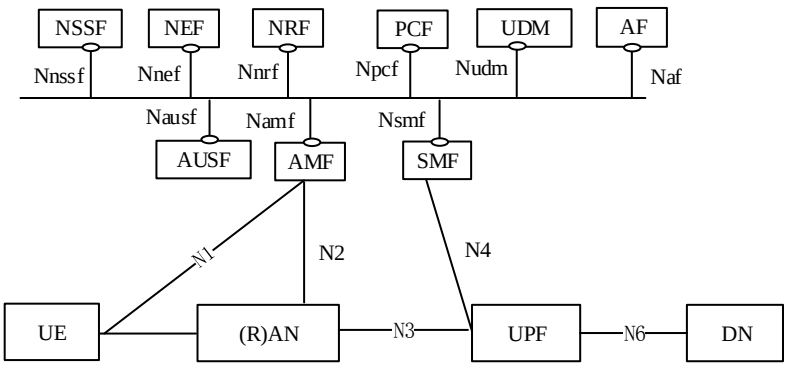

Figure 3-7: 5G System architecture according to 3GPP TS 23.501

Such architecture may actually require many changes to the satellite network, however most of these would be out of scope for this document. The changes that are necessary from a security point of view can be summarised:

- The satellite RAN may need to be modified in order to support transport of authentication. In isolated deployment, the satellite provider could opt to use a different EAP method than specified in TS 33.501. If the satellite provider opts to use standard 5G authentication methods, then the satellite RAN would need to be modified to support transport for both EAP-AKA' and/or 5G AKA.
- The satellite RAN needs to be modified to support the RRC security mechanisms specified in TS 33.501. This would be necessary in order to support key refreshment and key establishment on the radio layer.

Satellite networks are different compared to the terrestrial networks in that handovers may not take place for geostationary satellites, which would lead to a long term usage of the same key. Clause 6.9.4.5 in TS 33.501 provides a key refresh procedure that could be used to refresh the key. Satellite networks with non-geostationary satellites on the contrary may encounter a large number of handovers and will not have this problem.

The trust model of this architecture is a simplified model compared to the model presented in TS 33.501 in clause 4.1. This trust model has two actors, namely the end-user of the device and the satellite operator. The end-user of the device controls the device and the satellite operator controls the credential storage in the device, the radio network and the core network. In TS 33.501 it is assumed that the network operator stores the credentials in a secure storage on a UICC. For the case at hand, the operator may decide to deviate based on its own risk assessment.

3.2.6.2 *Indirect 5G UE Access*

The Indirect Access architecture is further subdivided in one where the satellite network is only “transport” for the 5G network and one where the satellite network is a relay. Furthermore, there are options where there is support for a MEC, which we will treat separately as well.

3.2.6.2.1 Satellite Network as Transport Network

In the case that the satellite network acts as a transport network for the backhaul between the gNB and the core network of an operator, the architecture is deceivingly simple. The trust model, however, may not be and is highly dependent on whether this backhaul serves a site for one or multiple operators and whether the backhaul has to be “slice aware”. In this section, the satellite network is assumed to serve multiple operators and to be slice aware; these two cases are treated separately below. Since much of the work has been performed already by 5G-ENSURE project, only the differences between what has been already presented in 5G-ENSURE and what is needed here are reported hereinafter.

3.2.6.2.2 Satellite network serving multiple operators

A typical scenario is one where the satellite network serves multiple operators that share the same site, but have different core networks. In such a scenario, there are multiple domains and multiple domain transitions. If we follow the domains identified by 5G-ENSURE [4] we can identify the following domains:

- Infrastructure provider domain 1: The satellite operator providing backhaul connectivity
- Infrastructure provider domain 2: The remote site operator
- MNO core network domains: For each MNO that is served via the infrastructure, there is a core network corresponding to this domain. For this case the model of the MNO core network domain is simplified to a monolithic domain and do not distinguish the slice domain and the infrastructure domain inside the MNO core network.
- MNO slice domains: The MNO slices running on the satellite operator’s infrastructure and on the remote site operator’s infrastructure.
- UE domains: For each operator there is a corresponding UE domain. The details of this domain are left out of scope for this trust model.

In the figure below, the different domains are depicted as stacked on top of the different infrastructure domains. The operator slice domain is therefore shown twice, once on top of the satellite provider

(that may only see one slice for each operator) and the shared infrastructure domain at the remote end (which will need to know about all slices).

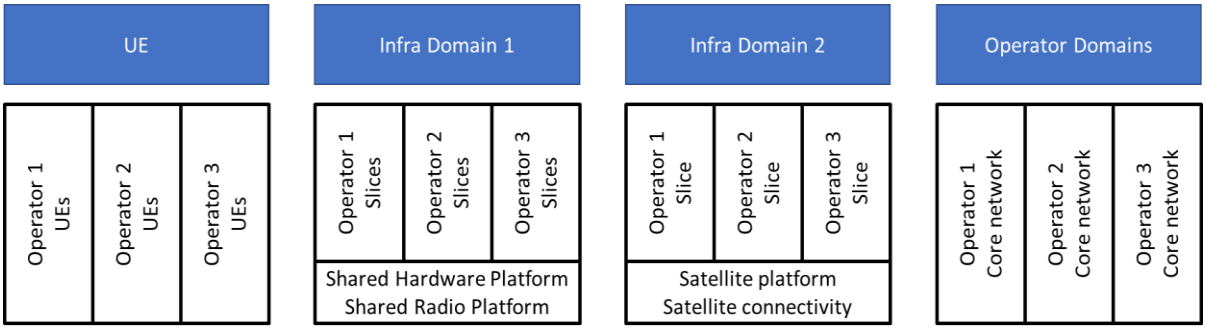

Figure 3-8: A graphical representation of the domains relevant for satellite network serving multiple operators

3.2.7 Next Generation Space Segment for Integration within 5G

Space segment infrastructure as such is **out of scope** of the SaT5G project, which addresses mainly innovation with respect to the ground segment infrastructure.

However, next generation space segment is expected to provide higher performance in terms of throughput, user bandwidth as well as higher flexibility in terms of bandwidth per area compared to state of the art space segment in order to provide flexibility as required by the different identified uses cases.

SaT5G will however support the development of future 5G space segments by identifying radio interfaces characteristics and architectural constraints that will impact future satellite network scenarios.

In this context, several concepts or technical approaches are investigated in order to design the future "5G ready" space segment:

- Very High Throughput Satellites (GEO-VHTS): Future GEO VHTS satellites with capacity up to 1 Tbps implementing techniques and technologies such as beam hopping, active antennas, fully processed on-board payload and optical feeder links enabling higher degree of flexibility in terms of resource allocation and coverage reconfiguration with a limited number of ground stations;
- Broadband mega-constellations (LEO/MEO): Lower orbit satellites constellations enabling lower propagation latency allow improving End-User QoE; and providing a better polar coverage compared to GEO, achieving thus a full global Earth coverage. In addition to techniques and technologies already mentioned in the GEO VHTS case above, broadband mega-constellations will require inter-satellite links to optimize ground segment dimensioning and end-to-end service latency;
- Multi-layer Missions (GEO-MEO-LEO-HAPS): This refers to a combination of the above mentioned systems which may include HAPS to provide even lower propagation latency and faster service deployment.

3.3 *Service Exploitation*

As described, the vision of SaT5G is to develop cost effective "plug and play" SatCom (Satellite Communication) solutions for 5G to enable telecom operators and service providers to accelerate 5G deployment in all geographies and at the same time create new and growing market opportunities for SatCom industry stakeholders. SaT5G focuses primarily on backhaul via satellite and on enhanced mobile broadband (eMBB) use cases for 5G.

In particular, by providing complementary satellite service propositions to terrestrial fixed and wireless networks, SaT5G addresses the mobile network operators' (MNOs) needs for the inclusion of satellite in the early 5G roll out, where bypassing congested backhaul and offloading high bandwidth video download have been found to be major drivers. It also seeks to establish how converged services can support new 5G services to verticals such as Media & Entertainment, Transport and Public Safety

where satellite value propositions (ubiquity, mobility, resilience, multicast) can create business opportunities. SaT5G is identifying novel business models and economically viable operational collaborations that integrate the satellite and terrestrial stakeholders in a win-win situation.

By following the methodology described in the SaT5G Deliverable D2.1 [5], four Satellite Use Cases for eMBB have been selected (see Table 3.3). These use cases correspond to service exploitation opportunities for the SaT5G project partners.

- Edge delivery and offload of multimedia content and MEC VNF software, through multicast and caching to optimise the operation and dimensioning of the 5G network infrastructure;
- 5G fixed backhaul, to provide 5G service especially in areas where it is difficult or not possible to deploy terrestrial communications;
- 5G to premises, to provide 5G service into home/office premises in underserved areas via hybrid terrestrial-satellite broadband connections;
- 5G moving platform backhaul, to support 5G service on board moving platforms, such as aircraft, vessels, trains, etc.

Table 3.3: SaT5G Use Cases: Selected Satellite Use Cases for eMBB

Selected Satellite Use Case for eMBB	Description	Correspondence to Satellite Use Case Category in 5G [6]
SaT5G Use Case 1: "Edge delivery & offload for multimedia content and MEC VNF software"	Providing efficient multicast/broadcast delivery to network edges for content such as live broadcasts, ad-hoc broadcast/multicast streams, group communications, MEC VNF update distribution	Backhauling and Tower Feed
SaT5G Use Case 2: "5G fixed backhaul"	Broadband connectivity where it is difficult or not (yet) possible to deploy terrestrial connections to towers, for example, coverage on lakes, islands, mountains, rural areas, isolated areas or other areas that are best or only covered by satellites; across a wide geographic region	Trunking and Head-end Feed
SaT5G Use Case 3: "5G to premises"	Connectivity complementing terrestrial networks, such as broadband connectivity to home/office small cell in underserved areas in combination with terrestrial wireless or wireline	Hybrid Multiplay
SaT5G Use Case 4: "5G moving platform backhaul"	Broadband connectivity to platforms on the move, such as airplanes or vessels	Communications on the Move

Figure 3-9 below illustrates the SaT5G use cases and how they will be integrated into a 5G network. In this figure, it is important to highlight two aspects: a single 3GPP NexGen Core is capable to manage multiple use cases and, multiple satellites from multiple SNOs may be used in a single use case. By mixing both capabilities, the end-to-end network achieves a high degree of freedom that results in an optimal resource usage and consequently, in an optimal service to clients.

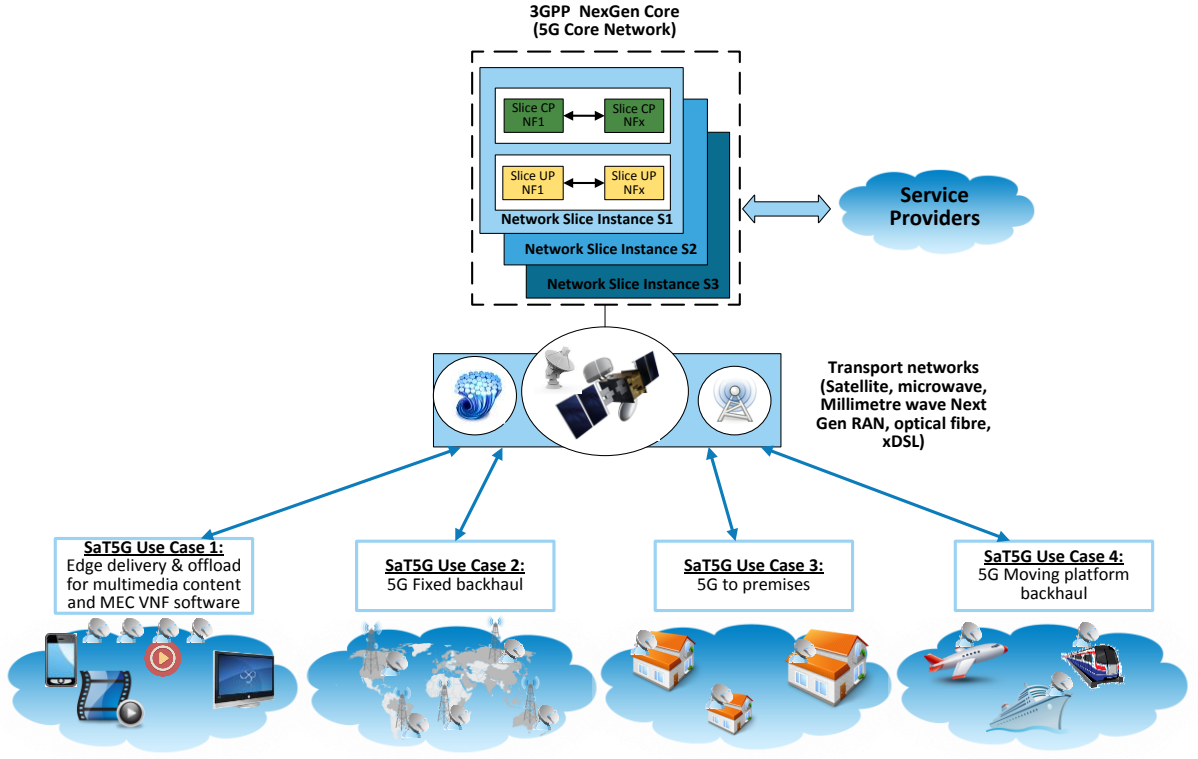

Figure 3-9: SaT5G Use Cases in 5G Integrated Satellite-Terrestrial Networks for eMBB

Satellite networks, as a new 5G actor, will create new synergies between companies that will result in new business agreements. In order to complete the 5G satellite systems overview, 3GPP defines 5G satellite requirements in [7].

Each SaT5G use case corresponds to one of the four satellite use case categories in 5G identified by ESOA [6], or else referred to as Satellite "Sweet Spots" in 5G (see Figure 3-10). Each of these four broad categories of satellite use cases in 5G has distinct connectivity characteristics, which are elaborated below.

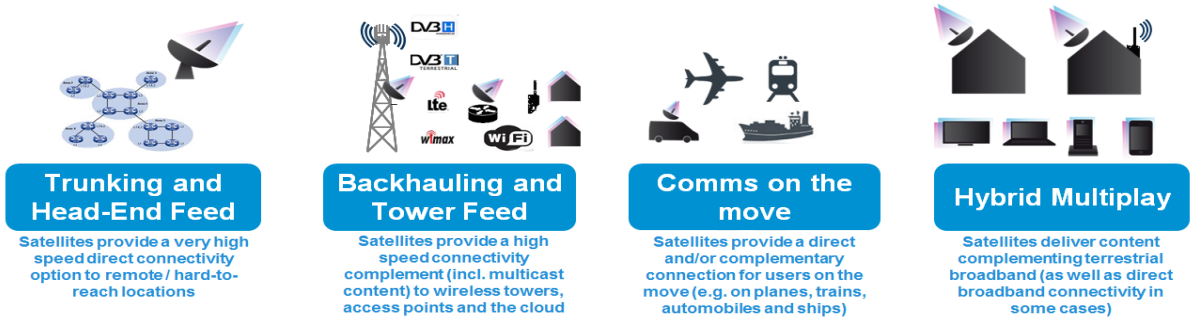

Figure 3-10: Four Satellite "Sweet Spots" in the 5G Ecosystem (Source: ESOA [6])

- **Trunking and Head-end Feed:** This Satellite Use Case Category (SUCC) in 5G addresses high speed trunking of video, IoT (Internet of Things) and other data to a central site, with further terrestrial distribution to local cell sites, for instance neighbouring villages, as shown in Figure 3-11 below. A very high speed satellite link (up to Gbps speed) from geostationary and/or non-geostationary satellites will complement existing terrestrial connectivity, where available. Note that this SUCC assumes that limited or no existing terrestrial connectivity is available. Moreover, the satellite user links are bidirectional since only broadband (i.e., unicast, thus VSAT) communications are supported by this category (i.e., no broadcast/multicast). In particular, there is no use of multicasting to populate edge caches in this SUCC, which corresponds to a major difference with respect to the other SUCCs. SaT5G Use Case 2 "5G Fixed backhaul" corresponds to this SUCC in 5G.

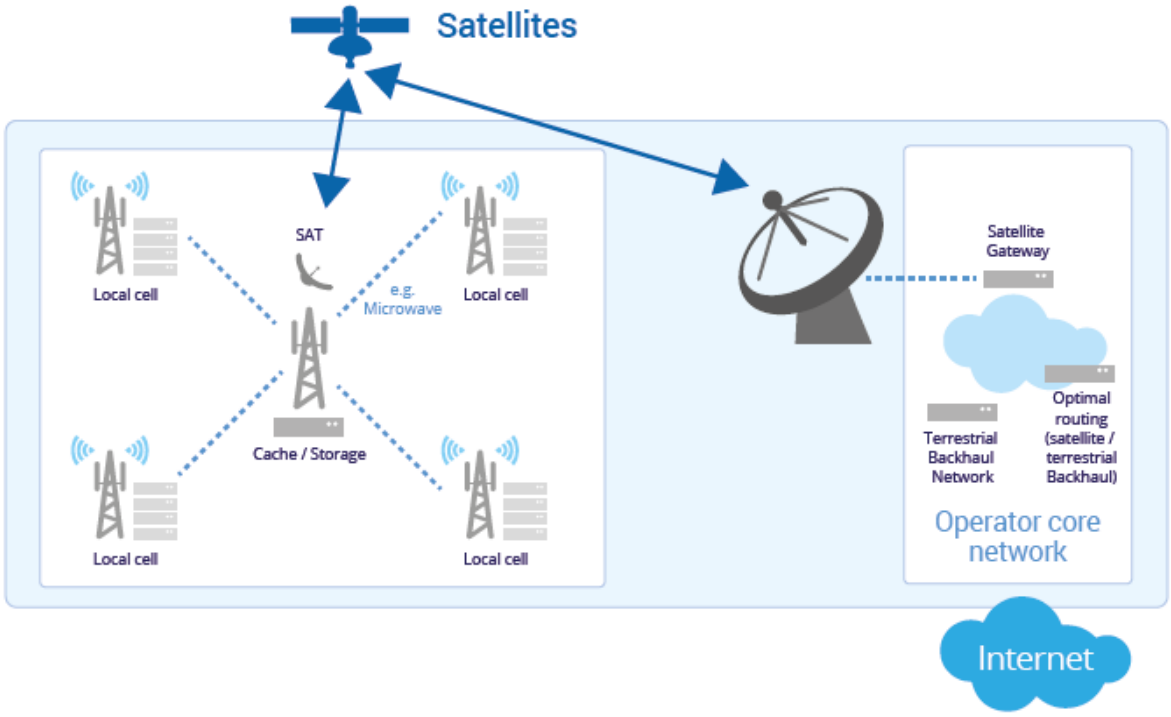

Figure 3-11: Trunking and Head-end Feed (Source: ESOA [6])

- **Backhauling and Tower Feed:** This SUCC in 5G is about high speed backhaul connectivity to individual cells, with the ability to multicast the same content (e.g. video, HD/UHD TV, as well as other non-video data) across a large coverage area (e.g. for local storage and consumption), as shown in Figure 3-12 below. The same capability also allows for the efficient backhauling of aggregated IoT traffic from multiple sites. A very high speed, multicast-enabled, satellite link (up to Gbps speed), direct to the local cell towers, from geostationary and/or non-geostationary satellites will complement existing terrestrial connectivity. Note that this SUCC assumes that satellite connectivity will complement existing terrestrial connectivity. Moreover, the satellite user links are either bidirectional and/or unidirectional since, depending on the case, broadband (i.e., unicast, thus VSAT) and/or broadcast/multicast (thus, receive-only terminals) communications are supported by this category. In particular, the use of multicasting to populate edge caches is a major difference of this SUCC with respect to the previous one. SaT5G Use Case 1 “Edge delivery & offload for multimedia content and MEC VNF software” corresponds to this SUCC in 5G.

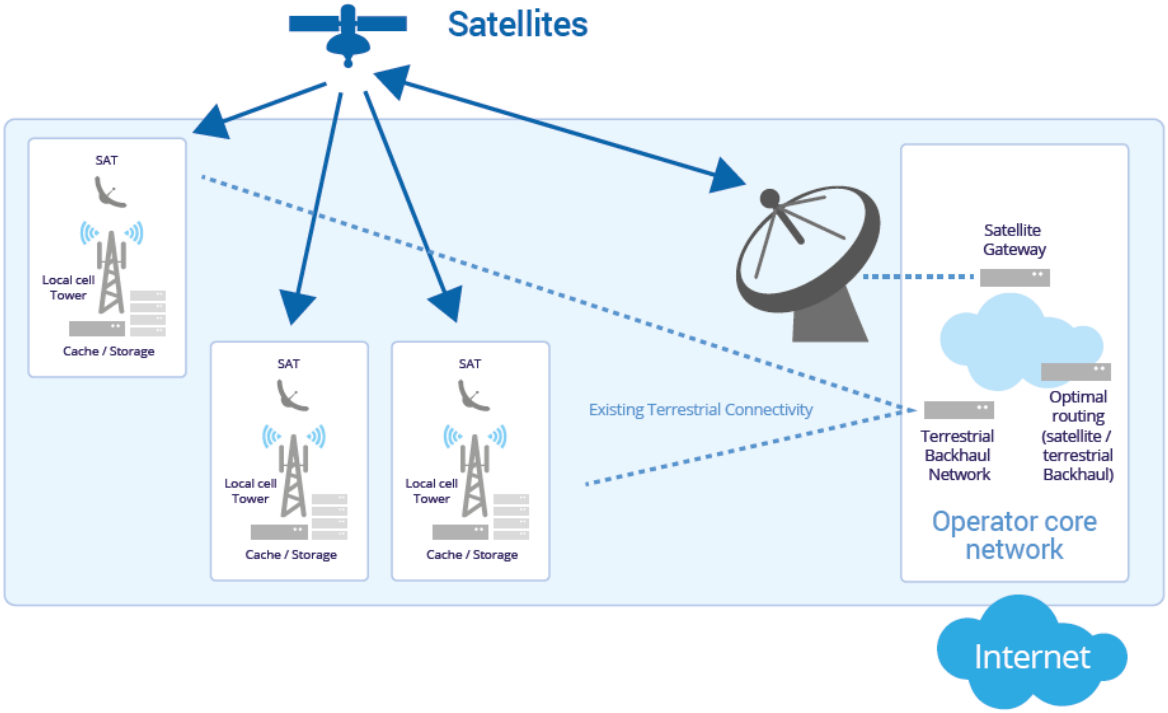

Figure 3-12: Backhauling and Tower Feed (Source: ESOA [6])

- **Communications on the Move:** This SUCC in 5G is about high speed backhaul connectivity to individual in-motion terminals on airplanes, vehicles, trains and vessels (including cruise ships and other passenger vessels), with the ability to multicast the same content (e.g. video, HD / UHD TV, SOTA (Software Over-The-Air), FOTA (Firmware Over-The-Air), as well as other non-video data) across a large coverage area (e.g. for local storage and consumption), as shown in Figure 3-13 below. The same capability also allows for the efficient backhauling of aggregated IoT traffic from these moving platforms. A very high speed, multicast-enabled, satellite link (up to Gbps speed), direct to the plane, vehicles, train or vessel, from geostationary and/or non-geostationary satellites will complement existing terrestrial connectivity, where available. Note that this SUCC assumes that satellite connectivity will complement existing terrestrial connectivity, where available (such as, airports, harbours, train stations, connected cars, etc). Moreover, the satellite user links are either bidirectional and/or unidirectional since, depending on the case, broadband (i.e., unicast, thus VSAT terminals) and/or broadcast/multicast (thus, receive-only terminals) communications are supported by this category. SaT5G Use Case 4 “5G Moving platform backhaul” corresponds to this SUCC in 5G.

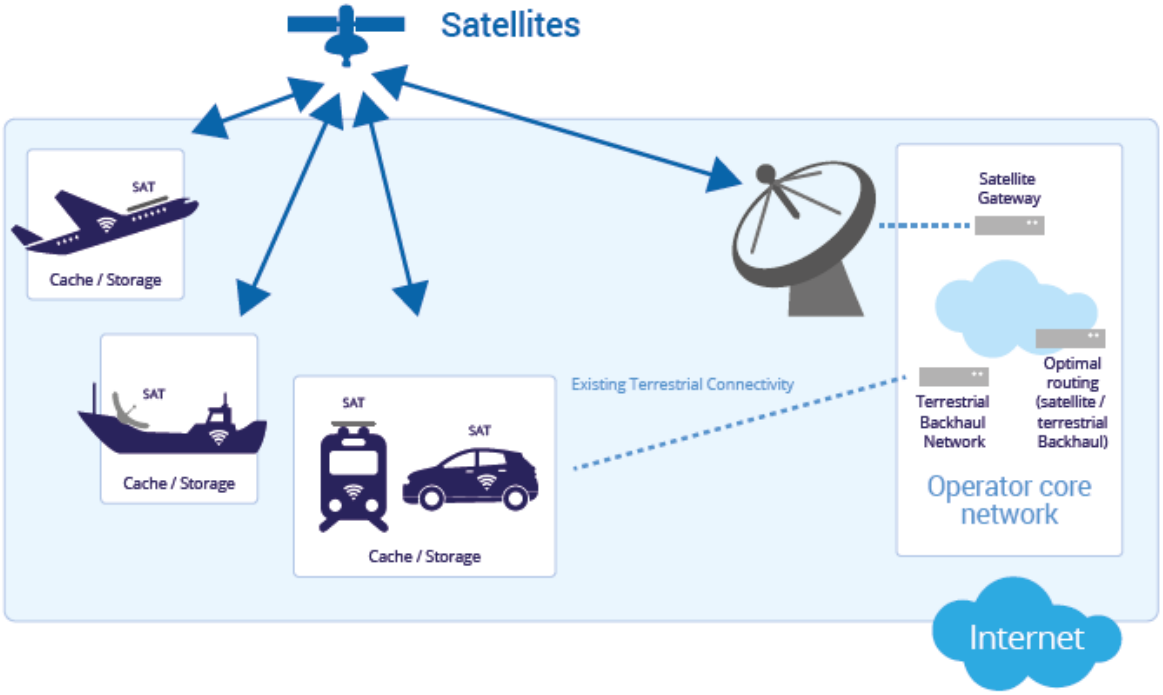

Figure 3-13: Communications on the Move (Source: ESOA [6])

- **Hybrid Multiplay:** This SUCC in 5G is about high speed connectivity including backhaul to individual homes and offices, referred to as premises, with the ability to multicast the same content (video, HD/UHD TV, as well as other non-video data) across a large coverage area (e.g. for local storage and consumption). The same capability also allows for an efficient broadband connectivity for aggregated IoT data. In-home distribution via Wi-Fi or home/office small-cell (femtocell) is shown in Figure 3-14 below. A very high speed, multicast-enabled, satellite link (up to Gbps speed), direct to the home or office, from geostationary and/or non-geostationary satellites will complement existing terrestrial connectivity. Direct-To-Home (DTH) satellite TV, integrated within the home or office IP network, will further complement this use case. Note that this SUCC assumes that satellite connectivity will complement existing terrestrial connectivity. Moreover, the satellite user links are either bidirectional and/or unidirectional since, depending on the case, broadband (i.e., unicast, thus VSAT) and/or broadcast/multicast (thus, receive-only terminals) communications are supported by this category. SaT5G Use Case 3 “5G to premises” corresponds to this SUCC in 5G.

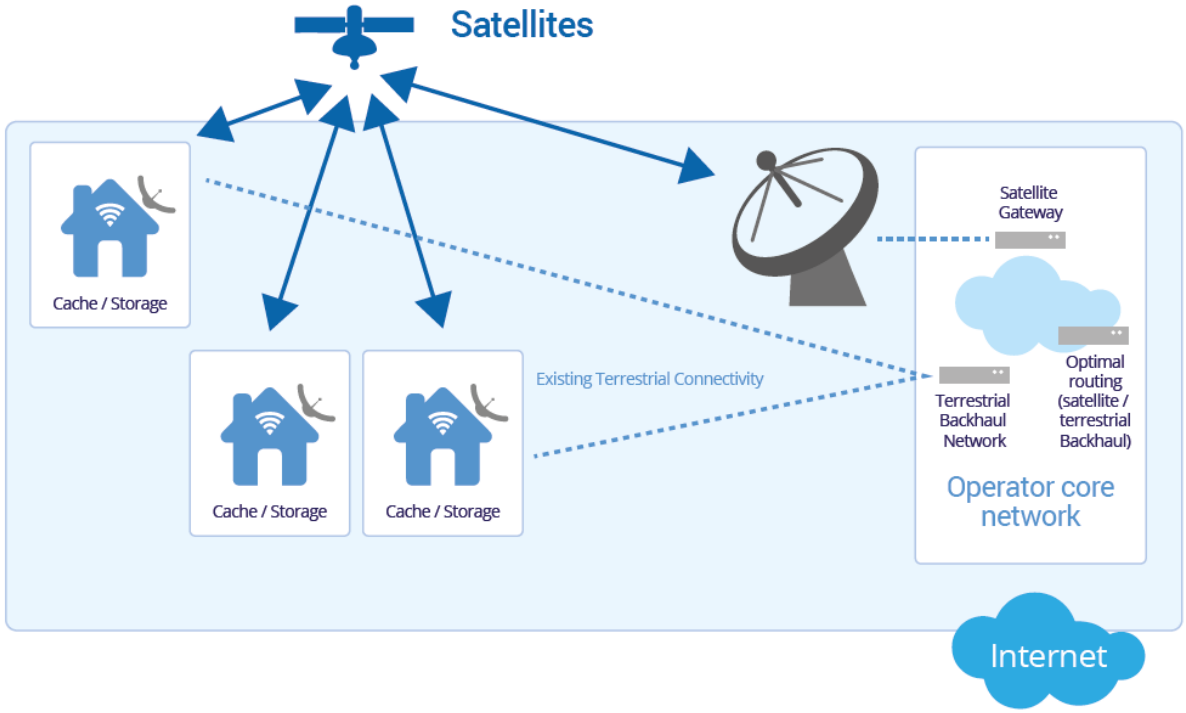

Figure 3-14: Hybrid Multiplay (Source: ESOA [6])

Such converged services, as well as the flexibility enabled by network virtualisation and network slicing over common infrastructures, requires that new service value chains are created – where satellite industry stakeholders no longer focus on wholesale bandwidth provision but on building the business and operational tools to be value-added partners for service delivery This requires new approaches to service creation, configuration, management, delivery and billing.. Sat5G seeks to build the standardised products (see section 3.2) that enable these approaches but also seeks to identify business driven service models that can be implemented by satellite operators and their technology partners. The cost analysis and value-chain modelling under taken by the project are therefore key exploitable elements in the delivery of future services.

3.4 *Future R&D*

The establishment of 5G test beds that incorporate satellite elements is seen to be an important output of SaT5G in establishing the basic infrastructure to perform early trials and demonstrations. The project will allow only the basic demonstrations but the facilities established can then be built upon to be included in future larger user trials and demonstrations such as described in the 5GAI and ESA task force proposals. These will allow satellite 5G to be integrated with specific vertical areas.

There will be a need to continue the research into virtualisation of the satellite element and its orchestration and to input this to the on-going 3GPP NTN documents that have just been kicked off. The SaT5G solution to this is a key input but will need to be followed up post the end of the project. Other research elements such as the QoS and security elements across the integrated system will need to be continued post SaT5G. Again contributions into 3GPP NTN standards are seen as very important for the satellite community.

Research on the NR air interface over satellite is an area that we are covering within SaT5G but is much wider than the resources available will cover. As 3GPP has now opened study work towards a release 16 standard on this topic we see that this is an area of extension of the work in SaT5G.

The SaT5G project studies mainly NR air interface but lifting gNodeBs into satellites that have on board processing capability could mean that the next generation core (5GC) needs some modifications or new features that have to be identified and developed.

Looking further ahead it is noted that in SaT5G the satellite element itself is considered as a pipe and not as an integral part of a virtualised E2E system. A topic for future research will be to consider what

software virtualised elements can be accommodated on board future satellites and be subject to the overall orchestration process. An example would be gNodeB elements on board the satellite which could be interesting in the context of LEO constellations.

Finally, the research performed on the business modelling and techno-economic analysis for the virtualised, converged networks will not be finalised after the project. New evolutions in terms of network slicing for both terrestrial and satellite, as well as the emergence of new stakeholders or the shift in roles of existing stakeholders are developments that need to be investigated to correctly estimate the socio-economic and organisational impact on the sector. For this, also the underlying methodologies, modelling frameworks and software tools need to be further developed.

3.5 *Standards*

A key objective of the SaT5G project is to contribute to the standardisation at the 3rd Generation Partnership Project (3GPP) and the European Telecommunications Standards Institute (ETSI) of the features enabling the integration of SatCom solutions in 5G. To this aim, various activities have been undertaken by SaT5G project partners to promote satellite integration into 5G in various standardisation groups.

In its public Deliverable D6.2 “Standardisation Action Plan” [8] published in September 2017, the SaT5G project considered the opportunities to leverage economies of scale and to foster acceptance of future SatCom solutions by all 5G ecosystem stakeholders, in order to achieve the project standardisation objective above, standardise the integration of satellite in 5G and enable multi-vendor deployment. The goal is to open more business opportunities for SatCom solutions as well as for terrestrial ones. Hence it is recommended to contribute to standardisation organisations involved in the definition of the 5G system directly or indirectly with the aim to define:

- Protocols and functions extensions or amendments to enable 5G to support satellite systems at access or transport levels in single or multi connectivity context in a “plug and play” manner;
- The architecture and protocols of future satellite communication systems featuring high technology commonalities with the 5G system;
- Virtualised satellite network functions as well as software defined satellite networks featuring high scalability, reconfiguration, multi tenancy;
- Tests and procedures.

The standardisation effort on 5G will span over 3GPP Release 15 and Release 16 and possibly beyond as well as in other bodies in parallel. Hence the standardisation on the integration of satellite in 5G can take place in a phased approach taking into account SDOs schedule constraints.

Note that this standardisation approach was used to shape ESOA’s (EMEA Satellite Operator Association) vision on standards as reflected in its white paper “ESOA Satellite Action Plan for 5G Standards” published in ESOA’s website in June 2018 [9].

Table 3.4 below summarises the current SDO work items for satellite integration into 5G. The outputs of these standardisation activities correspond to SaT5G exploitation elements, on which the SatCom community will leverage in order to ensure satellite integration into 5G.

Table 3.4: Current SDO Work Items for Satellite Integration into 5G

SDO	WG	WI Reference	WI Title	Output Document	Target Completion Date	Rapporteur
3GPP	SA1	FS_5GSAT	Study on using Satellite Access in 5G	3GPP TR 22.822	June 2018	TAS
3GPP	SA1	5GSAT	Release 16 New WID on Integration of Satellite Access in 5G	3GPP TS 22.261	September 2018	TAS
3GPP	SA2	FS_5GSAT_ARCH	Release 16 New SID - Study on architecture aspects for using satellite access in 5G	3GPP TR 23.737	June 2019	TAS

SDO	WG	WI Reference	WI Title	Output Document	Target Completion Date	Rapporteur
3GPP	RAN	FS_NR_nonterr_nw	Study on NR to support non-terrestrial networks	3GPP TR 38.811	June 2018	TAS
3GPP	RAN3/2/1	NR-NTN solutions	Release 16 New SID - Study on solutions evaluation for NR to support Non Terrestrial Network	3GPP TR 38.8XX	December 2019	TAS
ETSI	SCN TC-SES	DTR/SES-00405	Integration of satellite and/or HAPS (High Altitude Platform Station) systems into 5G and related architecture options	ETSI TR 103 611	December 2018	TAS
ETSI	SCN TC-SES	DTR/SES-00447	Edge delivery in 5G through satellite multicast	ETSI TR TBD	June 2019	AVA
ETSI	SCN TC-SES	DTR/SES-00446	Reference Virtualised Network Functions data model for satellite communication systems	ETSI TR TBD	March 2019	TAS
CEPT ECC	FM44	FM44/ECC PT1	Satellite solutions for 5G	ECC Report 280	May 2018	SES
ITU-R	WP4B	NGAT_SAT	Key elements for the integration of satellite systems into Next Generation Access Technologies	ITU-R.M Report TBD	Q2 2020	SES

4 Exploitable Knowledge and Individual Plans

4.1 *AVANTI COMMUNICATIONS LTD (AVA)*

4.1.1 Mission and Vision

Overview

Avanti connects people wherever they are - in their homes, businesses, in government and on mobiles.

Through the HYLAS satellite fleet and more than 150 partners in 118 countries, the network provides ubiquitous internet service to 27 per cent of the world's population. Avanti delivers the level of quality and flexibility that the most demanding telecoms customers in the world seek.

Avanti is the first mover in high throughput satellite data communications in EMEA. It has rights to orbital slots and Ka-band spectrum that cover an end market of over 1.5bn people. The Group has invested $1.2bn in a network that incorporates satellites, ground stations, datacentres and a fibre ring. Avanti has a unique Cloud based flexible customer interface that is protected by patented technology.

Avanti's capacity expansion is focused over Africa; with 3 satellites servicing the continent we are biggest provider of Ka-band High-Throughput Satellite (HTS) services to the continent.

Avanti is UK based, listed on the London Stock Exchange and headquartered in London, with operations in Cornwall, Cyprus, Turkey, Germany, Kenya, Tanzania and South Africa. The company employs over 200 highly skilled staff coming from many different nationalities.

Figure 4-1: Avanti coverage

HYLAS Satellite Fleet and Infrastructure

Avanti has 3 satellites currently in orbit (HYLAS 1, 2 and 4) and a further scheduled for launch in 2019 (HYLAS 3). The HYLAS fleet provides significant advantages to customers:

- **Full coverage:** Avanti delivers 100% national coverage of primary countries with overlapping beam patterns (no in-country coverage gaps) so that service providers can offer a truly national service with consistent quality
- **High spectral density:** Service providers can use the smallest possible terminals providing a cheaper, attractive and more efficient way of delivering bandwidth to customers
- **Smart beam clustering:** Avanti's beam clusters land in a single Gateway in the relevant country or region.
- **Diverse networks deliver resilience:** Avanti's ground network is protected from atmospheric events with redundant gateway offering market beating Service Level Agreements.

Avanti has redundant Gateway Earth Stations ("GES") in the UK, Cyprus, Germany, Turkey, Nigeria and South Africa. Avanti's network is designed to offer the levels of quality and flexibility that the most demanding telecoms customers seek:

- 99.99% uptime due to redundancy and no single points of failure

- Cloud based interface (operational support system) allows customers to become virtual network operators with minimal investment
- Direct connections into major network peering centres and internet exchanges in London, Amsterdam, Frankfurt, and Istanbul

Products and Customers

Avanti provides products and services in four market facing verticals Consumer, Enterprise, Carrier and Government.

Avanti sells on a wholesale business-to-business basis. Customers choose from a range of products:

- **Pure:** Service Providers have exclusive use of a defined number of MHz in specific beams.
- **Adapt:** Fully flexible bandwidth. Service Providers have exclusive use of a defined number of Mbps in specific beams via a Virtual Network Operator access model.
- **Connect:** Packaged broadband. Service Providers buy individual broadband internet services from an Avanti defined list of standard tariffs.
- **Serve:** Managed services for focussed service delivery.

The customer base is evolving from a core of regional ISPs and specialist providers to include organisations with potentially very large demand requirements, including national carriers, global telecoms operators, global internet and media companies and government customers.

Avanti has prided itself as being a leader innovative satellite services for mobile networks and carriers.

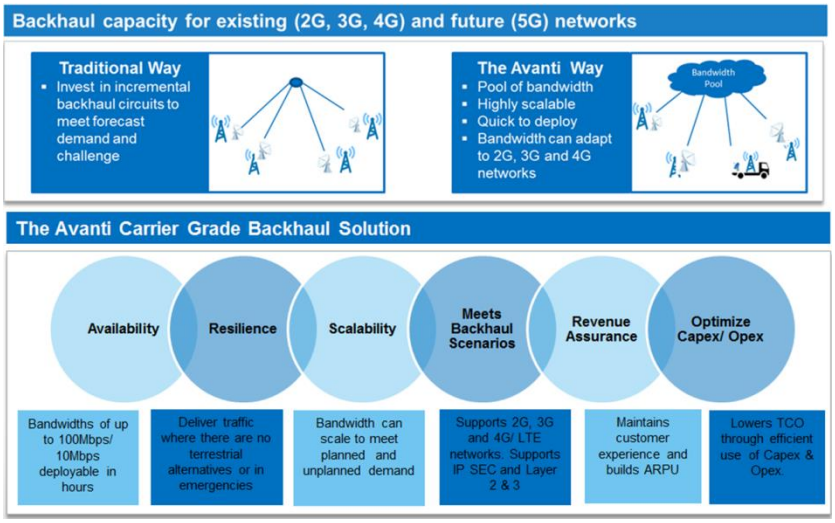

Figure 4-2: Avanti Carrier Services Overview

The solution model outlined below has resulted in significant projects – including carrier grade backhaul to ~1000 sites for the BT/EE 4G network in the UK to support delivery of the Emergency Services Network (ESN) system.

4.1.2 Exploitable Knowledge

Exploitable knowledge developed by AVA in the framework of the SaT5G project is summarized in Table 4.1.

Table 4.1: Exploitable knowledge for partner AVA

#	Exploitable Knowledge & Products	Sector(s) of Application	Timeframe	Patents or Other IPR Protection
1	Business and operational models	Enterprise, Carrier Services	2020 onwards	Publications, Know-how

#	Exploitable Knowledge & Products	Sector(s) of Application	Timeframe	Patents or Other IPR Protection
	for converged satellite-terrestrial 5G service delivery			
2	Satellite 5G reference Requirements Architectures and Standards	Carrier Services	2020 onwards	Publications, Know-how
3	Pre-5G Satellite Platforms integrated into Avanti Network Environment	Enterprise, Carrier Services	2020 onwards	Know-how
4	Satellite 5G Edge Caching & Multicast Approaches	Media & Entertainment, Content Distribution	2020 onwards	Publications, Know-how

4.1.3 Opportunities for Exploitation

The following are opportunities that have been identified from the exploitable knowledge being acquired in SaT5G.

New Business Models and Services

Avanti believes that satellite can open new markets for 5G services and extend existing ones leveraging by fundamental strengths in ubiquity, mobility, resilience, multicast & cost. In particular satellite will support 5G service delivery in rural, remote and developing world regions; for mission critical services demanding resilience, coverage and persistence; with network offloading, resilience and content delivery to the edge; on mobile platforms including vehicles, trains, ships and planes; and by ubiquitously connecting massive machine networks

This will realise new opportunities for Avanti by allowing satellite operators to meet the price points for future converged services, integrate with terrestrial networks seamlessly and move from being wholesale providers of bandwidth to value add partners for Future Networks.

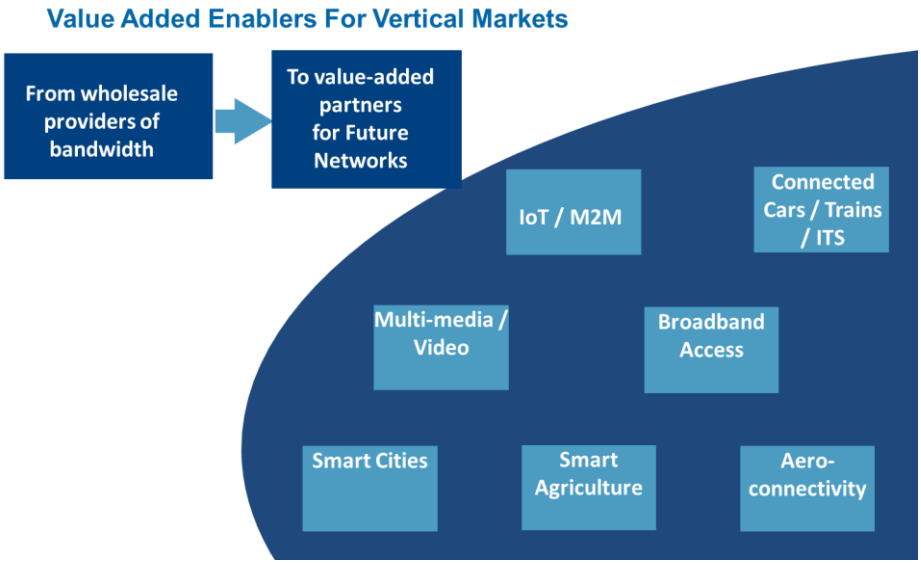

Figure 4-3: Satellite Operator Role in 5G Future Networks

SaT5G's operational and business modelling work (including on new value networks and service chains) on how satellite backhaul for eMBB services will function will be a key input in supporting

definition and development of services in verticals including mobile platforms, media and content distribution and for enhanced consumer broadband access both.

Integration with MNOs for Converged 5G Service Delivery

Post 2020 Avanti is likely to seek to structure its carrier offerings such that there will be transparent interworking or integration between Telco, MNO and Satellite operators in the user, control and management planes. This will be key to support efficient carrier grade backhaul in the 5G era in particular by supporting fast, flexible end-to-end service creation and management. Key items include:

- Interoperability of satellite network solutions with the 5G network management system allowing a third party to manage and configure virtualised satellite network resources. This also includes virtualisation of satellite communication elements as non-conventional
- Integration of the satellite communications system into the 5G core network to provide secure end-to-end 5G services to and through satellite terminals;
- Multi-vendor interoperability between elements (e.g., terminals, radio access networks) of satellite network solutions for 5G.

SaT5G work on requirements, use-cases and standards definition for converged 5G delivery (as well as lessons learnt from the integration of live satellite networks into 5G testbeds) will provide Avanti a head-start in preparing its network and operational systems.

Future Network Platform Procurements and Next Generation OSS (Avanti Cloud)

In order to realise this potential it is necessary that the satellite community adopt the technology paradigms and standards of the 5G community to transparently support end-to-end hybrid service delivery to the Verticals; and drive interoperability & economies of scale in satellite networks.

For Avanti a key output of SaT5G is the development of satellite network platforms that are priced effectively (by leveraging economies of scale from standardisation including at 3GPP) and that meet 5G requirements for converged service delivery. SaT5G provides a forum in which to work with satellite network platform developers (iDirect, Gilat, TAS) for Avanti to shape and better understand future satellite network platform capabilities (including by use of prototype capability in testbeds). This know-how will feed through directly into future satellite network platform procurements.

Further the Avanti Cloud Operational Support System is developed in house. The OSS is fundamental to successful and scalable service delivery. To allow Avanti to readily work with 5G MNOs and service providers it is necessary to adopt an industry standard driven interface rather than a partially Avanti driven interface. SaT5G is developing an open source based approach to integrated network management and orchestration systems for 5G satellite systems. This work will be used to inform the development of the Avanti OSS.

4.1.4 Progress and Outcomes

Avanti has made the following progress within the SaT5G project:

- Converged satellite 5G business and operational modelling is identifying new routes to markets and the commercial & operational constraints that will exist in future.
- We have leveraged interim work on satellite integration into 5G testbeds to support proposals for 5G demonstrations and trials at multiple testbeds and for multiple market verticals. Demonstration of pre-5G satellite-terrestrial services will support operational roll out of satellite 5G post 2020.
- Support definition of standards based approaches for satellite network platform virtualisation, multi-vendor interoperability and management/orchestration in 3GPP and ETSI – laying the groundwork for future procurements and OSS development.

4.2 *THALES ALENIA SPACE FRANCE (TAS)*

4.2.1 Mission and Vision

TAS, a world leader in manufacturing satellite systems, is responsible in the SaT5G project for the technical coordination and specifically research to prototype development as well as standardisation activities.

TAS ambitions to develop satellite network solutions which enable always best user experience with marginal impacts on the devices, and minimised additional OPEX and CAPEX for mobile network operators when integrating seamlessly the satellite technology in 5G systems.

4.2.2 Exploitable Knowledge

Exploitable knowledge developed by TAS in the framework of the SaT5G project is summarized in Table 4.2. Note that short term refers to less than 2 years, and long term to more than 5 years from mid-2018.

Table 4.2: Exploitable knowledge for partner TAS

#	Exploitable Knowledge & Products	Sector(s) of Application	Timeframe	Patents or Other IPR Protection
1	Implementation of 5G SDN and NFV across satellite networks	Broadband satellite network	Short term	Know-how
2	Integrated Network Management & Orchestration	Broadband satellite network	Short term	Know-how
3	Multi-link and Heterogeneous Transport	Satellite network solutions for 5G	Short term	Know-how
4	Harmonisation of SatCom with 5G Control and User Plane	Satellite network solutions for 5G	Mid/long term	Know-how
5	Extending 5G Security to Satellite	Satellite network solutions for 5G	Short term	Know-how
6	Caching and multicast for content and VNF distribution	Satellite network solutions for 5G	Short term	Know-how
7	Satellite Standardisation roadmap in ETSI and 3GPP	Satellite network solutions for 5G	Mid/long term	Know-how

4.2.3 Opportunities for Exploitation

TAS is taking part in the SaT5G project to work in the context of 5G eMBB service on the definition of technical enablers for a smooth integration of SatCom network solution in the 5G network infrastructure and have them standardised in ETSI and 3GPP.

This will allow TAS to prepare the definition of future space segment that will best support the performance and functional requirements of satellite network to be integrated in the 5G system.

Beyond the SaT5G project, collaboration with the consortium partners will be mainly threefold:

- Integration of technologies and products developed by partners such as iDR, GLT, OA, QUO, BPK and ZII, in the satellite solution;

- Deployment of the satellite solution for service providers such as AVA, SES and BT;
- Research on future satellite solutions with research centres and universities such as UoS, TNO, IMEC, I2CAT and UOULU.

4.2.4 Progress and Outcomes

In parallel with the SaT5G project, TAS is preparing its satellite broadband system offer for bids calling deployment at the Horizon 2020-25. This includes the space segment design, the inter GW network and the end-to-end satellite network solution based on in-house Space Gate product evolution.

The Space Gate solution constitutes the TAS solution for satellite access network system to be deployed in broadband telecommunication systems or telecommunication ground user segments. The Space Gate solution is constituted by the following elements (see Figure 4-4):

- The Space Gate Hub and modems providing the infrastructure for building the satellite access network to be used by the service providers on one hand and by the end users on the other hand;
- The Space Gate NMS providing the facilities allowing to configure and supervise the satellite access network;
- The Space Gate security management providing all the functionalities necessary to manage the security features embedded in the satellite access network.

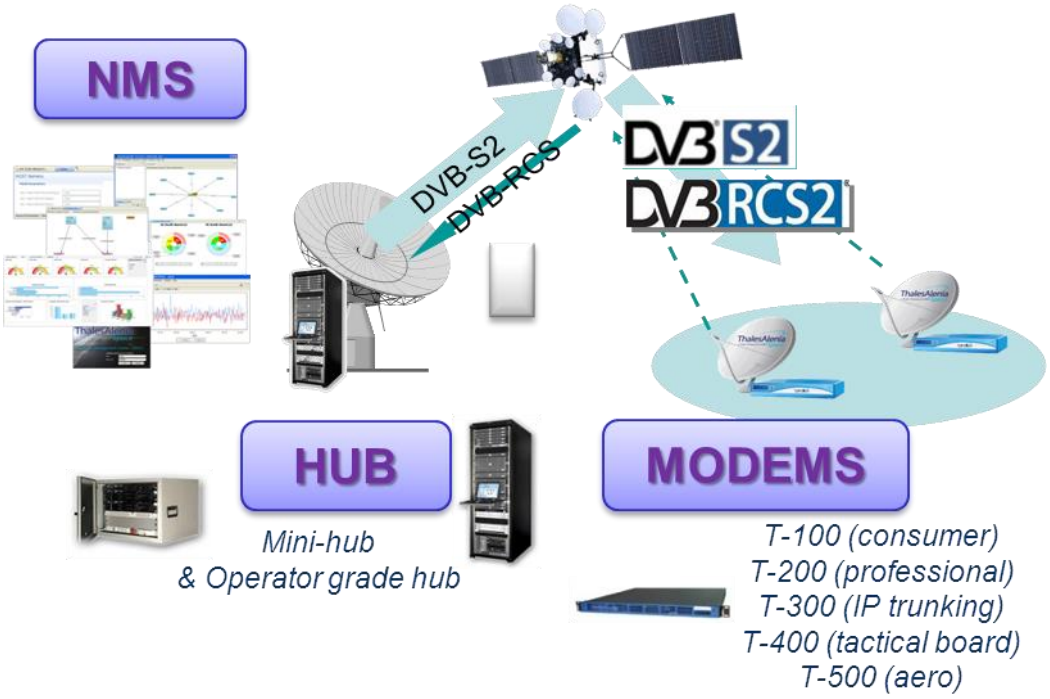

Figure 4-4: Space Gate Satellite IP Network solution from TAS

In addition, TAS is taking advantage of the SaT5G project to develop its network expertise to support satellite service providers in the integration of the solution in 5G network.

4.3 *UNIVERSITY OF SURREY (UoS)*

4.3.1 Mission and Vision

The University of Surrey is engaged in research and teaching of undergraduate and postgraduate students. Its mission is the advancement of knowledge and its exploitation in research and the preparation of the next generation workforce for business and industry as well as academia. Its mission is to be among the leading Universities in the UK as well as worldwide. Surrey has a legacy of excellent contact with the world of work being based on four year undergraduate courses where one year is spent in industry with a supervised project. This together with its industrial faced research programme has led to excellent interactions with industry and business and established the relevance of the university to modern day life.

Participating in SaT5G the Institute for Communications Systems, houses the 5G Innovation Centre (5GIC) with 26 Industrial members including major mobile operators and manufacturers plus over 100 SME's engaged together in research and development of 5G technologies. 5GIC have installed via over £15m funding a comprehensive 5G test bed with virtualised core network and a radio access network of 46 small cells around the campus and beyond. This has become the UK 5G test bed with significant UK government funding, and hosts many UK as well as EU based projects. The vision is to use this test bed as a vehicle for testing the outcomes of UoS' research as well as hosting partners' prototypes to accelerate the roll out of 5G. The vision is also to link the test bed to wider applications areas both within the UK and abroad and to facilitate and be part of larger 5G trials.

SaT5G provides UoS with the ability to integrate satellites into the test bed and to extend, via coverage and applications, its portfolio of trials in the future. IPR exists within the test bed which is the property of 5GIC and has been declared as background to the SaT5G project. Additional IPR is here restricted to that developed exclusively within the SaT5G project.

In the teaching domain, UoS seeks to include the latest research results into its undergraduate and postgraduate courses to make them state of the art and attractive. The SaT5G project results and knowledge gained will be fed back into UoS' courses. In addition, UoS will seek to involve its postgraduate students in projects associated with UoS' research.

4.3.2 Exploitable Knowledge

Exploitable knowledge developed by UoS in the framework of the SaT5G project is summarised in Table 4.3.

Table 4.3: Exploitable knowledge for partner UoS

#	Exploitable Knowledge & Products	Sector(s) of Application	Timeframe	Patents or Other IPR Protection
1	5G Virtualisation	5G equipment	2019 onwards	Know-how
2	5G orchestration	5G Networks	2019 onwards	Know-how
3	Network and RAN slicing	5G networks	2019 onwards	Know-how
4	Prefetching	Content/media	2019 onwards	Know-how
5	5G test bed	Trials	2019 onwards	Know-how
6	5G Non 3GPP security algorithm	5G AKA security	2019 onwards	Know-how

4.3.3 Opportunities for Exploitation

UoS has the background knowledge in 5G which has allowed it to develop one of the first pre 5G test beds in the world. Within 5GIC there is a large test bed team engaged in continuous updating and implementation of 5G technology which together with its academic research input keeps us ahead of the game. UoS now has the opportunity to use the test bed on larger and wider scale trials that will involve a satellite element. UoS has already established international connectivity of its test bed to other EU projects as well as connectivity within the UK to the smart city project in Bristol and to five

regional trials around the UK. UoS plans to be involved in the EU 5GAI/ESA Task Force trials which will involve the outputs of the SaT5G project. There are also plans to link with UK DCMS funded projects within the UK.

The 5GIC has built a world-leading mobile network testbed that is composed of 44 LTE-A sites including three macro cells. The testbed is currently connected to virtualisation systems in Italy and Germany, forming a Europe-wide federated research and innovation testbed, for conducting SDN, NFV, and Mobile Edge Computing (MEC) experiments, in the context of 5G networks and applications. The 5GIC testbed runs the world-first mobile core network slicing technology to support multiple vertical industry sectors. This technology was first demonstrated in late 2016, followed by numerous demonstrations given to visitors of the Centre during 2017 and 2018. In its latest demonstration in March 2018, 5GIC showcased network slicing capabilities, covering both the transport network and the core network across a fabric of interconnected testbed islands.

There are opportunities for 5GIC to work with the manufacturers of satellite equipment to transfer UoS' knowledge of 5G systems and assist in the virtualisation and integration of such equipment to the 5G core network. Close collaboration here in virtualisation and orchestration techniques is necessary.

There are also opportunities to exploit the UoS prefetching technique being extended in SaT5G over a satellite network. Collaboration with another EU project 5GXCAST could lead to a satellite delivery system being merged with Multimedia Broadcast Multicast Service (MBMS) delivery to mobile UE's.

4.3.4 Progress and Outcomes

UoS has commenced work in WP5 of SaT5G for an early demonstration of integrating satellite terminals with the 5GIC core network and to provide a demonstration of content delivery over the satellite for the EuCNC conference in June 2018. This will be an important first demonstration of satellites within 5G.

UoS is in the process of at least one new research bid that uses the 5GIC satellite implemented test bed for larger user trials in 2019/20.

In the teaching domain UoS has already incorporated some material from SaT5G into its post-graduate courses.

4.4 *SES S.A. (SES)*

4.4.1 Mission and Vision

SES is the world's leading satellite operator with over 70 satellites in two different orbits, Geostationary Orbit (GEO) and Medium Earth Orbit (MEO). It provides a diverse range of customers with global video distribution and data connectivity services through two business units: SES Video and SES Networks.

- SES Video reaches over 351 million TV homes worldwide, through Direct-to-Home (DTH) platforms and cable, terrestrial, and IPTV networks globally. The SES Video portfolio includes MX1, a leading media service provider offering a full suite of innovative services for both linear and digital distribution, and the ASTRA satellite system, which has the largest DTH television reach in Europe.
- SES Networks provides global managed data services, connecting people in a variety of sectors including telecommunications, maritime, aeronautical, and energy, as well as governments and institutions across the world. The SES Networks portfolio includes LuxGovSat, a 50/50 public-private partnership between SES and the Luxembourg government, and O3b, the only non-geostationary system delivering fibre-like broadband services today.

SES owns and operates the world's largest commercial satellite fleet with over 70 satellites covering 99% of the globe and world population. SES also owns and operates a global terrestrial access network to support the video and data communications needs of its customers. Based on this unique

network map, which is illustrated in Figure 4-5, SES is strategically positioned as the unique satellite operator to offer combined GEO-MEO service capabilities for the future 5G infrastructure globally.

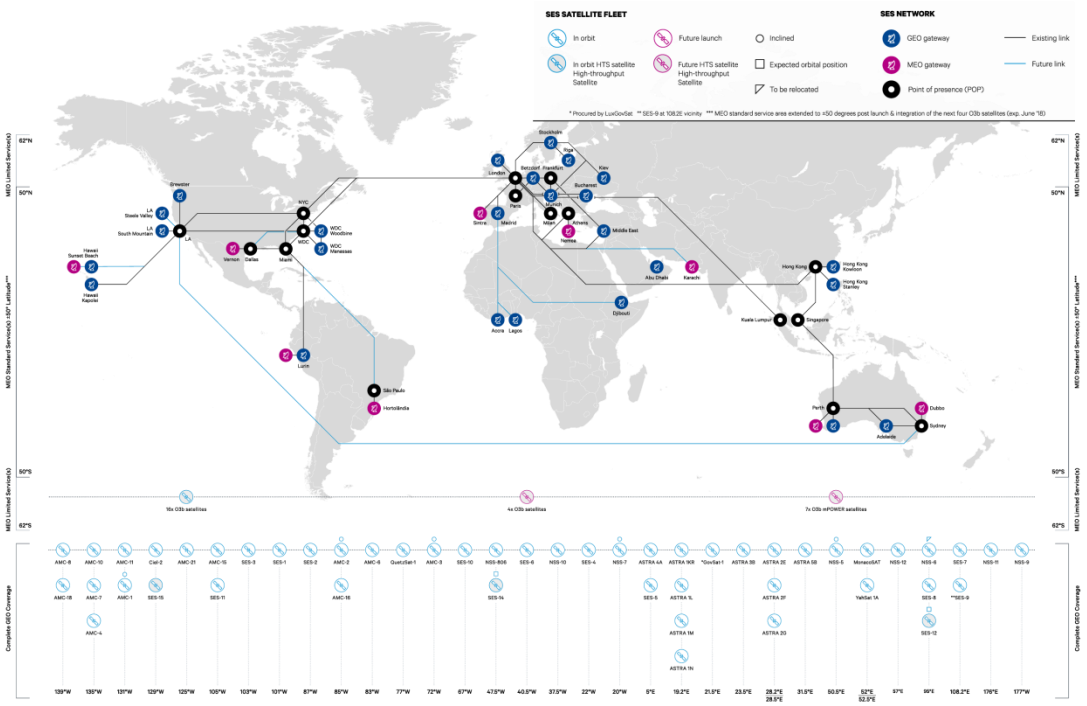

Figure 4-5: SES Satellite Fleet and Ground Access Network Map

SES Networks is a provider of Global Managed Data Services, which has been created by the combination of O3b Networks and SES's data business. From connecting the "other three billion" to going "beyond frontiers" as a connectivity and experience leader, it has opened the door to the digital world for millions of people from the Amazon basin to sub-Saharan Africa to the middle of the Pacific. An overview of the SES Networks' Lifecycle Services Portfolio is illustrated in Figure 4-6.

Figure 4-6: SES Networks' Lifecycle Services Portfolio Overview

Participation in innovation projects like SaT5G is essential since it allows SES:

- To expedite service offerings of its GEO/MEO satellite fleet with associated ground segments for commercially attractive 5G use cases.
- To optimise new space segment and associated ground networks in order to serve 5G verticals.
- To continue partnership with MNOs and mobile industry ecosystem in commercial and standardisation in order to further promote satellite integration within 5G.
- To remain at the forefront and validate state-of-the-art 5G technologies, such as SDN, NFV, MEC and Network Slicing, over GEO/MEO satellite networks.
- To understand how and where to apply such innovative solutions, business and operational models more effectively for converged satellite-terrestrial 5G service delivery.
- To acquire the necessary skills and know-how allowing so to proceed to potential future investments as necessary.

Thus, participation in SaT5G project coupled with other SES's relevant initiatives enables SES to realise its vision towards a software-defined, automated, cloud-scale platform, as illustrated in Figure 4-7.

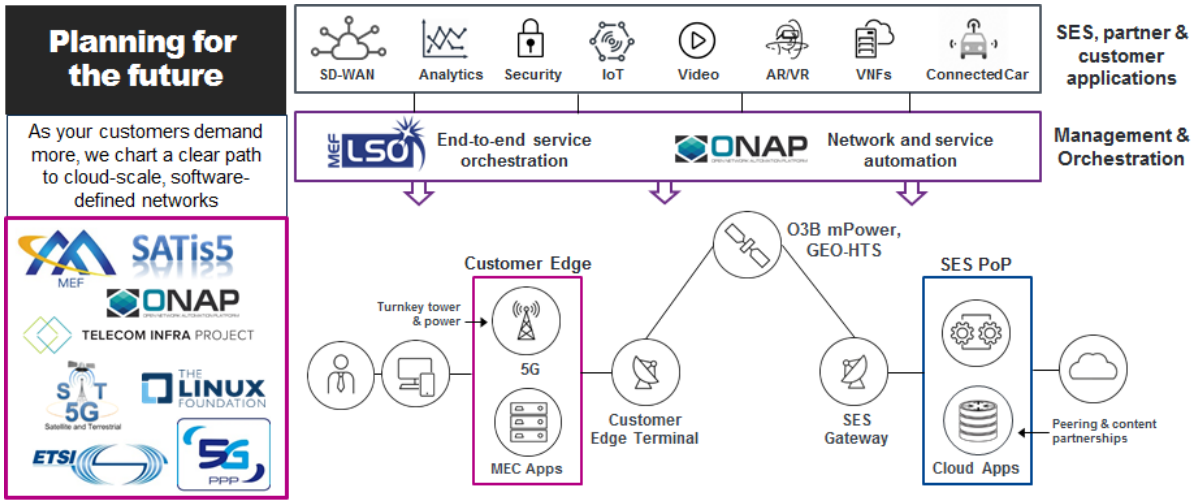

Figure 4-7: SES vision towards a software-defined, automated, cloud-scale platform

4.4.2 Exploitable Knowledge

Exploitable knowledge developed by SES in the framework of the SaT5G project is summarised in Table 4.4.

Table 4.4: Exploitable knowledge for partner SES

#	Exploitable Knowledge & Products	Sector(s) of Application	Timeframe	Patents or Other IPR Protection
1	Converged satellite-terrestrial reference architectures, requirements and standards	Cellular Backhauling Services	Immediate	Know-how
2	Integrated satellite-terrestrial 5G reference architectures, requirements and standards	Global Managed Data Services	2020 onwards	Know-how
3	Business and operational models for converged satellite-terrestrial 5G service delivery	Global Managed Data Services	2020 onwards	Know-how
4	Next generation 5G-enabled virtualised ground segment infrastructure for network slicing	Global Managed Data Services	2020 onwards	Know-how
5	Next generation MEC-enabled edge network delivery	Global Managed Data Services	2020 onwards	Know-how

4.4.3 Opportunities for Exploitation

For the exploitation of SaT5G project results, SES intends to use them in multiple ways:

Integration with MNOs and mobile industry ecosystem for converged 5G service delivery

As demand for capacity intensifies, driven by faster mobile broadband speeds and bandwidth-hungry applications, such as video services and IoT, satellite solutions are proving a cost-effective and agile piece of the global network jig-saw supporting the delivery of 4G and upcoming 5G services.

Increased RAN density requirements and the need for rapid deployment put pressure on MNOs to reconsider infrastructure plans—including urban infill, small towns and truly rural areas—in order to remain competitive. Satellite backhaul solutions can provide the required velocity and flexibility to accelerate time to market. In addition, MNOs can leverage the access to capacity to tap into new segments driven by surge and seasonal requirements. By partnering with satellite operators, MNOs can expand their footprint into regions that are difficult or impossible to serve via their terrestrial assets. Satellite represents a path for MNOs to expand their footprint and thus deliver on the promise of seamless, universal 5G coverage and services.

For SES, this strategy represents a natural extension of its existing synergistic relationships with MNOs. Its cellular backhaul solution has long been used by MNOs to expand the reach of their mobile offerings, allowing them to meet customer demands and generate new revenue streams without the capex associated with network builds and expansions. The diversity of SES's multi-orbit, multi-band satellite fleet allows us to tailor backhaul solutions for MNOs' specific requirements, optimizing connectivity based on one or more key service attributes, including cost, capacity, latency, coverage and reliability.

SES's cellular backhaul solution has the potential to address MNOs' 5G requirements from a commercial perspective as well. One of the challenges associated with 5G is the uncertainty around business models – whether and how mobile operators will generate revenue from 5G use cases. SES applies a comprehensive, end-to-end managed services approach to cellular backhaul to minimise risk by handling the procurement, operation and maintenance of the network from the cell site to the packet core. This proven approach, coupled with highly flexible commercial terms, could help reduce the risk of deploying specific 5G use cases such as IoT or enterprise services to remote regions. SES's commercial flexibility extends to traditional CIR-based pricing and volume-based opex pricing models, which could enable its MNO customers to better align their costs with revenue when 5G arrives. The greater network visibility and insight that comes from such an approach positions SES to optimise capacity allocation, and scale capacity to address MNOs' traffic requirements more cost-effectively.

Satellite players must "plug into" the MNO ecosystem and become a true enabler of value-based outcomes. This is the approach adopted by SES, which is enabled by participation to the SaT5G project among other SES initiatives. If satellite players are a fully integrated part of the mobile industry ecosystem, MNOs don't need to incur extra costs by adjusting their systems and operations to tap into satellite capacity. Put simply, the cost and complexity of bespoke engineering for traditional satellite capacity is removed by SES, offering standard managed end-to-end IP and Ethernet services seamlessly across its fleet towards converged 5G service delivery.

Partnership with mobile and satellite industry in standardisation to promote satellite integration in 5G ecosystem

SES sees 5G as an opportunity to integrate satellite more deeply into the mobile industry ecosystem, but one key ingredient remains missing – open standards. Satellite companies have been targeting the mobile sector for years with services like cellular backhaul. But it's generally been a niche play for a variety of reasons, not least of which the fact that satellite doesn't integrate seamlessly with 3G and 4G networks. 5G will be different because this time, satellite players have been directly involved with standardisation bodies, such as 3GPP and ETSI. Together with SaT5G project partners, SES has been trying to get a lot more integrated with the bodies that are responsible for defining the standards so that they understand more about satellite, they understand more about the future of satellite, and that 5G is going to be a network of networks embracing every technology, including satellite.

However, one of the key challenges for satellite is that satellite technology systems are still mainly closed, proprietary systems – which flies in the face of the rest of the telecoms sector's march (albeit not quite enthusiastically) towards open standards and open source software. To this end, participation in SaT5G project enables SES to encourage further satellite equipment vendors to move

away from their proprietary systems and move more into standards based systems. The interfaces used in satellite need to be interfaces that are seamless in 5G networks going forward.

The starting point for 3GPP to work on a standard about the use of satellites in the 5G network has been established through key satellite initiatives, such as SaT5G. SES in collaboration with other SaT5G project partners has contributed to several 3GPP Technical Reports addressing the satellite integration into the 5G ecosystem. Apart from 3GPP, SES has also been an active member of ETSI, CEPT and ITU-R relevant standardisation groups promoting the integration of satellite into 5G.

SES's other relevant activities which demonstrate its commitment to the advancement of 5G and the development of 5G standards for the satellite industry include its certification activity with the MEF (Metro Ethernet Forum) and SES's participation with the Linux Foundation's open source networking activities (for further details, see Section 4.4.4 below).

As such, SaT5G enables SES to continue partnership with terrestrial mobile and satellite industry in standardisation in order to further promote satellite role in 5G ecosystem. The standardisation of the underlying network and device technologies will help in the development and commercialisation of satellite ground segment systems with new capabilities, which in turn will enable SES to provide improved and cost-effective service offerings to its customers. This constitutes an important opportunity for SES.

Next generation 5G-enabled virtualised ground segment platforms for integrated satellite-terrestrial MANO and network slicing

Based on the standardisation efforts above, SES expects that the use of satellite ground segment systems enabled with SDN/NFV technologies will be offered commercially in reasonable short-medium timeframe by the industry stakeholders and suppliers. The implementation of these technologies will allow operational integration of satellite into 5G and will provide SES with the benefit to be in a position to provide further improved cellular backhaul and broadband services to unserved and underserved areas, as well as to mobile platforms, such as airplanes and vessels. Such next generation 5G-enabled virtualised satellite hub platforms will allow the application of network slicing over integrated satellite-terrestrial networks, which will in turn allow SES to obtain flexible bandwidth allocation, where and when it is needed, in an entirely automated way. In this context, the collaboration with SaT5G industrial partners, and particularly the ground segment equipment vendors and MNOs, provides an important opportunity towards this direction.

By adopting industry standard Ethernet service constructs and orchestration, it is possible for a satellite-based backhaul solution to plug seamlessly into an MNO's backhaul landscape — in the same manner as any terrestrial solution does. Leveraging upon the relevant R&D work within SaT5G towards an integrated satellite-terrestrial Management and Orchestration (MANO) system, and coupled with the inter-carrier visibility and control of an Open Network Automation Platform (ONAP) based automation solution, as well as with the use of MEF compliant lifecycle service orchestration (LSO), it is possible for an MNO to turn every bit transported over satellite into a productive bit with no stranded capacity. Satellite players must "plug into" the MNO ecosystem and become a true enabler of value-based outcomes. This is the approach adopted by SES, which is enabled by participation to SaT5G project among other SES's initiatives.

Moreover, with the help of SDN and LSO, MNOs can have clear visibility on satellite-network resources, as well as the tools to leverage and manage them in a very flexible manner. There are other advantages. In much the same way as MNOs can use SDN technologies to run their networks "hotter", they will be able to do the same with capacity delivered within the framework advocated by SES. Flexible bandwidth allocation to match network demand with available satellite capacity improves network efficiency in the process. This capability better matches their business-model needs. Going forward, MNOs will be less tied to buying dedicated bandwidth links, which are likely to be under-used most of the time.

SES is focused on providing aggregated pools of capacity to be allocated, where and when it's needed, in an entirely automated way. Think of it as on-demand bandwidth coupled with easy-to-use management tools. Data services enabled over satellite remain an underutilised mechanism for unlocking new markets for MNOs quickly and cost-effectively. By using satellite-based Ethernet links for end-to-end mobile backhaul connectivity, MNOs can reach remote areas to unlock demand and provide new applications to users faster than with terrestrial alternatives. To connect new or

underserved subscribers, an MNO's time to market is as fast as it takes to ship equipment, rather than the weeks or months it takes to deploy fibre.

Network slicing technologies investigated within SaT5G will enable SES to pursue its vision towards an application-aware intelligent routing concept for multi-orbit support. That is, the "plug and play" integration of satellite networks in the sliced and virtualised 5G network for the support of backhaul services will allow an intelligent routing that sends the right data to the right user over the best path, be it terrestrial or satellite, allowing so even seamless multi-orbit support over GEO/MEO.

With a roadmap to deliver standards-based automation, orchestration and related APIs, SES is working with industry stakeholders and MNOs to extend networks seamlessly into new markets, improving visibility and management of critical services. And SaT5G provides an important opportunity towards this direction.

New Bids and Contracts

Last but not least, knowledge gained from conducted R&D work within the SaT5G project is intellectual property that SES will exploit as background knowledge in bidding for and acquiring additional innovation related contracts. Moreover, participation in SaT5G project allows SES to acquire the necessary skills and know-how to proceed to potential future investments as necessary.

4.4.4 Progress and Outcomes

SES has made the following progress **within the SaT5G project**:

In **WP2**, SES has led the definition of the SaT5G use cases and scenarios which correspond one-to-one to the satellite sweet spots in 5G ecosystem (see Table 3.3 and Figure 3-10). SES has also contributed to the requirements definition of an integrated satellite-terrestrial 5G reference architecture, and has also been contributing to the business modelling activities for converged 5G service delivery.

In **WP3**, SES has contributed to the definition of a reference integrated satellite-terrestrial 5G architecture, with focus on backhauling.

In **WP4**, SES has been contributing to the R&D work towards key technology enablers, such as: SDN, NFV, MANO, MEC, Caching and Multicast.

Moreover, SES partnered with SaT5G consortium members - iDR, BPK, i2CAT and UoS – for the first-of-its-kind over-the-air live demo at EuCNC 2018 in Ljubljana (18-21 June 2018) to demonstrate key benefits of satellite integration with an SDN/NFV/MEC-enabled pre-5G construction testbed, with its in-orbit geostationary satellite system ASTRA 2F as a proof-of-concept for integration of those features into a full 5G network (see Figure 4-8).

In **WP5**, together with its SaT5G consortium partners – ZII and GLT – SES has contributed to the design of the 5G aero backhauling testbed and demonstration planning over O3b MEO satellite system.

SES has a leading role in **WP6** activities in order to promote satellite role in 5G ecosystem. In particular, together with SaT5G consortium partners, SES has been actively participating in 3GPP SA/RAN, ETSI TC-SES SCN, ITU-R WP4B and CEPT FM44 standardisation activities to promote the satellite role into the 5G ecosystem. SES has also actively disseminated the SES-led WP2.1 outputs to international peer-reviewed scientific and technological journals, conferences and book chapters, as well as to various industrial fora and public dissemination events.

Figure 4-8: EuCNC 2018 Demo Setup

In parallel to the SaT5G project activities, SES has made the following progress towards satellite integration within 5G:

SES has recently announced the investment to the next generation of O3b MEO satellite system, the so-called “O3b mPOWER” (see Figure 4-9). A system unlike any other, O3b mPOWER includes step change technology advancements, including a new constellation of advanced MEO satellites, ground infrastructure innovation and convergence, and new software intelligence. The result is cloud-scale connectivity for low-latency, application-aware services virtually anywhere in the world. O3b mPOWER introduces a new concept in network endpoints: Customer Edge Terminals. Bringing together application-specific antennas, storage, compute and routing resources, virtualised network functions and network intelligence in a small device that is fast and simple to install, O3b mPOWER puts high-performance data services in reach for more kinds of customers and in more places than ever before. Moreover, SDN capabilities enable O3b mPOWER to deliver services that are automated, agile and assured.

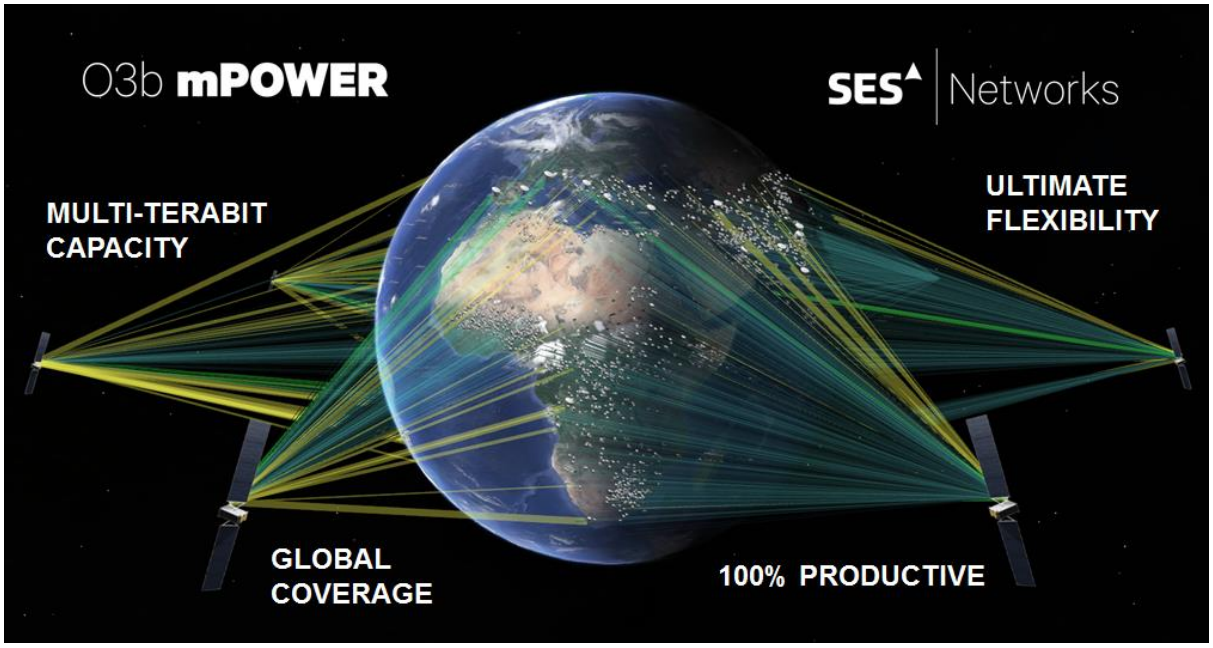

Figure 4-9: O3b mPOWER Overview

Other SES's relevant initiatives which demonstrate its commitment to the advancement of 5G and the development of 5G standards for the satellite industry include its certification activity with the MEF and its participation with the Linux Foundation's open source networking activities. In particular, one important part of ensuring that SES has close alignment with MNOs is deep involvement with the MEF and the ONAP project. Other satellite service providers might claim that terrestrial API plug-ins are hardly unique, but SES goes much further than basic connectivity. By adopting LSO developed within MEF, SES embraces an automated, standards-based, multi-carrier approach to service fulfilment and assurance. Similarly, through its work with ONAP, the functionality of SES's satellite constellation goes up another notch. It supports the project's open-source automation platform — the only satellite service provider to do so, and a main contributor in developing ONAP API extensibility to satellite networks — which is backed by big-name carriers from around the world. SES is the only provider of managed data services over satellite in the world that can provide MEF Carrier Ethernet 2.0 (CE 2.0) services. That means its Ethernet product has the same backhaul service attributes that MNOs purchase from terrestrial providers. MEF certification validates its delivery of fibre-equivalent connectivity. Throw in the added bonus of being able to offer that to pretty much anywhere on the planet with very short deployment times, and it amounts to a powerful proposition. What's more, through development of the "MEF 55" reference architecture and framework, MEF has emerged as a major industry force in LSO standardisation. Aimed at streamlining and automating the service lifecycle on an end-to-end orchestrated basis, MEF 55 coordinates management and control across all network domains. These technical activities, combined with the business and operational flexibility inherent in its managed services offerings, position SES well in this new and exciting 5G ecosystem.

SES has also been contributing its expertise to a number of important 5G initiatives aimed at timely deployment of 5G in Europe. SES is co-founder and Vice-Chair of the 5GIA, the 5G Infrastructure Association (IA), grouping European-based wireless industry acting as the private counterpart of the European Commission in the 5G Public-Private Partnership (PPP), the world's biggest 5G research programme aimed to deliver 5G solutions, architectures, technologies and standards.

Last but not least, the knowledge gained within SaT5G project has already helped SES to bid and acquire new R&D and innovation projects to further promote the satellite integration into 5G. As an illustration, SES has successfully kicked-off the following relevant projects:

- **5G-VINNI**: 5G Verticals INNovation Infrastructure (EU H2020 5G PPP Phase 3)
  - Aim: To accelerate the uptake of 5G in Europe by providing an end-to-end facility that validates the performance of new 5G technologies by operating trials of advanced vertical sector services
  - Project Website: https://www.5g-vinni.eu/
- **SATis5**: Demonstrator for Satellite-Terrestrial Integration in the 5G Context (ESA ARTES)

- Aim: To build a large-scale real-time live end-to-end 5G integrated satellite terrestrial network proof-of-concept (PoC) testbed that enables the satellite terrestrial convergence into the 5G context, with focus on 5G use cases towards enhanced mobile broadband (eMBB) and massive machine type communications (mMTC)
- Project Website: https://artes.esa.int/projects/satis5

4.5 *AIRBUS DEFENCE AND SPACE SAS (ADS)*

4.5.1 Mission and Vision

Airbus Defence and Space is a world leader in the design and manufacturing of satellite systems. In the field of satellite telecommunication, Airbus Defence and Space is well known as a system integrator and major satellite prime contractor. Airbus Defence and Space has accumulated a long-standing experience covering all domains of satellite systems: earth observation, science, telecommunication and navigation.

Inside Airbus Defence and Space, the telecom system department of the Space System division regroups telecom expertise, satellite system and system of system design, network and radio communication engineering. Key competences focused on five expertise domains, which are: broadband communication, data relay services, mobile and aeronautical communications and system of system integration. Through multiple projects, Airbus Defence and Space has acquired a wide range of skills, encompassing the definition of requirements, architecture and protocols, performance analysis simulations, end-to-end network test-beds, up to the integration and installation.

The telecom system department is actively involved in the 5G Infrastructure Association which is committed to the advancement of 5G in Europe and to build global consensus on 5G. The 5G IA carries out a wide-range of activities in key strategic areas including standardisation, frequency spectrum, R&D and cooperation with other strategic industry sectors.

The participation of ADS in SaT5G project allows:

- Understanding potential new service offerings through GEO/MEO/LEO satellite fleets (with associated ground segments) targeting commercially attractive 5G use cases in order to better anticipate satellite operators space infrastructure requirements.
- Identifying the main 5G-related technological advancements in order to optimize the space segment infrastructure accordingly in order to better serve 5G verticals through integrated satellite/terrestrial architecture.
- Identifying the potential changes in the value chain with respect to SNOs, MNOs and mobile industry ecosystem in commercial and standardisation domains in order to further understand the potential roles ADS can assume in the future 5G environment.
- Acquiring the necessary skills and know-how of terrestrial 5G technologies such as SDN/NFV, edge delivery, orchestration, network slicing and multilink technologies to anticipate the potential client demands in this respect and better evaluate the potential impact on GEO/MEO/LEO constellations designs.

4.5.2 Exploitable Knowledge

Exploitable knowledge developed by ADS in the framework of the SaT5G project is summarised in Table 4.5.

Table 4.5: Exploitable knowledge for partner ADS

#	Exploitable Knowledge & Products	Sector(s) of Application	Timeframe	Patents or Other IPR Protection
1	Integrated satellite-terrestrial 5G reference architectures,	5G Networks	2020 onwards	Know-how

#	Exploitable Knowledge & Products	Sector(s) of Application	Timeframe	Patents or Other IPR Protection
	requirements and standards			
2	Next Generation Space Segment requirements for integration into 5G	Spatial infrastructure manufacturing and design	2020 onwards	Know-how
3	Business and operational models for integrated satellite-terrestrial 5G service delivery	Business strategy	2020 onwards	Know-how
4	Next generation SDN/NFV-enabled SatCom ground segment platforms	SatCom Ground segment in 5G Networks	2020 onwards	Know-how

4.5.3 Opportunities for Exploitation

Next Generation Space Segment requirements for SatCom integration into 5G networks

Even if the space segment is not the main focus of the work in SaT5G, ADS will certainly be able to exploit the know-how acquired by anticipating the main requirements that future spatial infrastructure needs to meet in order to be compliant with SaT5G use cases identified in the study. Better understanding the level of flexibility required to meet the demands, the level of configurability of the payload and how it is exposed for a third party to be managed and exploited is key to prepare future 5G-empowered satellites systems (and/or LEO/MEO constellations).

SDN/NFV-enabled SatCom ground segment

Future end-to-end GEO/MEO/LEO satellite systems are required to be more capacitive, flexible and reconfigurable in order to achieve a high level of integration desired into 5G networks. It becomes thus capital for the satellite industry and more concretely, for the SatCom ground segment to be handled and conceived in much more flexible way, providing suitable interfaces with terrestrial networks to ease the cooperation and strengthen the integration. The objective being to support new concepts such as network slicing recognised as a fundamental feature to meet the challenging 5G requirements and more specifically, to reach a successful SatCom 5G integration.

The introduction of SDN/NFV paradigm in satellite access networks is clearly a key element which will provide such framework and will enable a fully new way to operate the satellite systems. Leveraging upon the relevant R&D work within SaT5G, an integrated satellite-terrestrial Management and Orchestration (MANO) system will enable MNO (or several MNOs) to manage satellite resources in a more flexible way, enabling advanced features such as dynamic BW allocation, dynamic billing and slicing support (among others) and thus, become a true enabler of value-based outcomes. At the same time, virtualising some of the main functionalities on the satellite hub will ease the slicing support and the “plug and play” capabilities targeted in the project.

Understanding the 5G value chain ‘revolution’

In the frame of 5G networks, the traditional value chain as per MNOs, SNOs, equipment’s providers and service providers is shifting as fast as the 5G networks are being specified. The uncertainty on how the different stakeholders currently well-established will be able to “reinvent” themselves and how the potential new stakeholders enabled by the 5G ecosystem will rise quickly on the market conforms an extremely open and challenging landscape in the coming years.

In this context, the SaT5G business modelling work has allow setting the right mind-set in order to better understand the challenges ahead and how ADS, mainly an spatial manufacturer, could position itself in the 5G ecosystem in alternative roles. Discussing about functionalities instead of current well-known stakeholders (e.g. “Satellite operation” vs “Satellite operator”, “Mobile operation” vs “Mobile operator”,…) has allowed to go beyond the pre-established schemes and try to understand how ADS

roles in the value chain (and the ones from other partners of the consortium) can evolve in the near future.

Competitive advantage on new Bids and Contracts

The knowledge and know-how achieved the SaT5G project is intellectual property that ADS will exploit as background knowledge in bidding for and acquiring additional innovation related contracts. Moreover, participation in SaT5G project allows ADS to acquire the necessary skills and know-how to proceed to potential future investments as necessary and to better adapt to new and challenging client requirements.

4.5.4 Progress and Outcomes

ADS has made the following progress **within the SaT5G project**:

- In WP2, ADS has contributed to the definition of the SaT5G use cases and scenarios. ADS has also contributed to the technical/operational requirements definition of an integrated satellite-terrestrial 5G reference architecture, and has also been contributing to the business modelling activities for converged 5G service delivery.
- In WP3, ADS has led the definition of a reference integrated satellite-terrestrial 5G architecture, with focus on backhauling and caching/edge delivery. After an intense period of periodic meetings and a dedicated architecture workshop (hosted in ADS premises), the main implementation options when it comes to UE indirect access (backhauling) and edge delivery features and architecture impacts have been identified, paving the way to the more detail analysis in WP3.2 and WP3.3, in which the backhaul and the edge delivery/caching architectures have been deeply studied. ADS has also contributed to the definition of a high level architecture in terms of integrated management and orchestration, setting the base for WP4 techno bricks development. This work, still on-going, has led to a conference paper on the architecture implementations and contribute to several standardisation contribution in 3GPP and ETSI.
- In WP4, ADS has been contributing to the R&D work towards key technology enablers, such as: SDN, NFV, Caching and Multicast and multilink strategies.
- In WP5, ADS has contributed to the review of the final document and provide insights on the testbed planning ensuring the coherence with respect to the integrated architecture definition and SaT5G use cases defined in WP2.
- ADS has also contributed in WP6 activities in order to promote satellite role in 5G ecosystem. In particular, together with SaT5G consortium partners, ADS has been actively participating in 3GPP SA1/SA2/CT4 and ETSI TC-SES SCN standardisation activities to promote the satellite role into the 5G ecosystem. ADS has also actively disseminated WP3 outputs by means of paper submission in scientific journals, conferences and contributed to book chapters (w.r.t. WP2 work), as well as to various industrial fora and public dissemination events.

4.6 *EKINOPS (ONEACCESS) (OA)*

4.6.1 Mission and Vision

Ekinops (the new name of OneAccess since 13 June 2018) is a leading provider of open and fully interoperable Layer 1, 2 and 3 solutions to service providers around the world. OA's programmable and highly scalable solutions enable the fast, flexible and cost-effective deployment of new services for both high-speed, high-capacity optical transport as well as virtualisation-enabled managed enterprise services.

OA's product portfolio consists of two highly complementary product sets. One, marketed under the Ekinops 360 brand name, provides a single, fully integrated platform for metro, regional, and long-haul applications. The other, marketed under the OneAccess brand name, provides a wide choice of physical and virtualised deployment options for Layer 2 and Layer 3 network functions.

As service providers embrace SDN and NFV deployment models, Ekinops' solutions enable them to deploy today in the knowledge that they can seamlessly migrate to an open virtualised delivery model at a time of their choosing.

4.6.2 Exploitable Knowledge

Exploitable knowledge developed by Ekinops in the framework of the SaT5G project is summarized in Table 4.6.

Table 4.6: Exploitable knowledge for partner OA (Ekinops)

#	Exploitable Knowledge & Products	Sector(s) of Application	Timeframe	Patents or Other IPR Protection
1	Link Aggregation in 3GPPP context	The updated ONEvHYA VNF will deliver a versatile Hybrid Access solution enabling satellite and (5G) terrestrial links to be combined for service providers to offer significantly better user experience	End of project	Know-how
2	WAN Optimisation	The updated ONEvWOC VNF will deliver a versatile WAN Optimisation solution (PEP) enabling satellite and terrestrial service providers to offer SMBs, Enterprises and their remote offices significantly better user experience for their privately and publicly hosted Cloud and data applications	End of project	Know-how

4.6.3 Opportunities for Exploitation

The output of WP4.3 is aimed at progressing the standardisation to support seamlessly multi-link transport across 5G and satellite. Ekinops expects the project will allow applying 3GPP standards such as AT3S to satellite and will converge on where the associated VNFs must be deployed. The opportunity of exploitation is a commercial VNF, complementing or combined with its vRouter and GTP vPEP, for the satellite market. The output also targets improving SD-WAN solutions by allowing more diverse links to be consolidated optimally.

4.6.4 Progress and Outcomes

In WP4, since the beginning of the project, 3GPP multi-link current and under development standards have been investigated and AT3S, which is expected to be standardized before the end of SaT5G, has been found to be the most promising. Similarly, state-of-the-art protocols such as QUIC have been assessed, including their multi-link version in the light of the MPTCP expertise gained from the H2020 VITAL project.

Those elements served as the basis to design the different multi-link architectures applying to the SaT5G use cases and estimate their feasibility. The study outcome was presented in Q2 during the formal launch of the WP4.3 activity and is the basis for the next reporting period work on the multilink integration in the UoS testbed: finalizing an architecture and developing its element to be integrated into the UoS testbed.

In order to study a deployment close to what it would be with AT3S steering, an architecture aiming to deliver the same functionalities, i.e. seamless 3GPP traffic across multiple links, has been drafted. The objective is to mimic future AT3S-enabled 5G networks using discrete elements instead of AT3S integrated ones. Non AT3S UEs are also addressed to extend the range of test and demonstration possibilities, targeting implementation on the UoS testbed.

4.7 *NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO (TNO)*

4.7.1 Mission and Vision

TNO is a not-for-profit research organisation with approximately 3500 staff whose mission is to support industry and society in general in transforming knowledge into products, processes and policies of economic and societal value. In the innovation ecosystem, TNO acts as an intermediary between science and market. TNO's customers value its broad knowledge base and independent position.

Within TNO, the Information Society theme focuses on the gains that ICT can bring to society. The theme works with many European academic institutes, manufacturers, operators and service providers to develop and implement innovations in networks and services.

The mission of the Networks department is to bring innovation in network and communication protocols and network deployment for the benefit of the users of networks. Its focus is on the telecom market (fixed and mobile broadband Internet), the defense market and the intelligent transportation market. Activities range from research into new network technology concepts and protocols, via promoting the adoption of such newly developed concepts and protocols in worldwide standards, lab, up to field tests and network pilots. The group uniquely combines its strengths in protocol innovation with network deployment and system innovation, and has a long track record of participating in European projects in the field of mobile networks.

Together with partners, TNO has a dedicated long term research program, to develop new knowledge and networking concepts and protocols. In recent years this program included the fields of 5G, network virtualisation, machine-to-machine communications, smart radio technologies and content distribution. In 3GPP, TNO is active contributor to SA1 (requirements), SA2 (architecture), SA3 (security), SA4 (content delivery) and SA5 (virtualisation and management). In the CDN area, TNO has been contributor to a series of IETF standards (RFC 6770, RFC 6707, RFC 7337, RFC 6983, RFC 7336) on Content Delivery Network Interconnection (CDNi), that enables network operators to provide standardised access to operator-based CDN.

4.7.2 Exploitable Knowledge

Being knowledge institute, goal of TNO is to develop knowledge on integration of satellite networks with 5G to enable research and consultancy assignments for European operators and public administrators and facilitate opportunities to develop new IPR.

This will be done in two prongs, one being knowledge development and the other one by building testbed that can be used for further research.

Knowledge development

Thanks to its active role in 3GPP, TNO to provide to SaT5G project its expertise, knowledge and contacts within 5G, which relate to the essential elements of the project:

- System architecture
- 3GPP security mechanisms
- Content delivery
- End-to-end service delivery
- Slicing mechanisms within 5G core networks

TNO 5G demonstrator

TNO is currently developing a 5G testbed which is based on the Open5GCore network, product developed by Fraunhofer FOKUS. Due to the close cooperation with Fraunhofer, TNO is in state to provide feedback on current state of platform, and how well it fits to current 3GPP standards. This provides TNO with unique position to be close to developments and be aware of all "ins-and-outs" of implementation, and in this way it benefits the SaT5G project as well.

The testbed further consists of three different eNB (4G base stations) by different vendors (Nokia, Ericsson and OpenAirInterface). This is done as 5G radio access products which are in line with 3GPP standards are not available at this moment.

The testbed will be used to develop solutions on end-to-end service delivery, to analyse impact of satellite introduced latency on efficiency of 3GPP security mechanism in the SaT5G integrated network, and implementation of slicing in integrated network.

Long term: Develop the TNO testbed (based on OpenEPC) which will form the base for further research with other market parties (primarily network operators and vendors), as well as for the demonstrators (aimed at policymakers). Additionally, TNO aims to develop and validate new security concepts which will be then brought into 3GPP.

Table 4.7: Exploitable knowledge for partner TNO

#	Exploitable Knowledge & Products	Sector(s) of Application	Timeframe	Patents or Other IPR Protection
1	How to integrate non-3GPP networks with 5G core network for seamless performance	Telecom sector (operators, vendors, standardisation)	End 2019	Know-how
2	Analysis on sensitivity of 3GPP security mechanisms to increased latency in system.	Telecom sector (operators, vendors, standardisation)	End 2019	Know-how
3	Slicing across different transport and access networks (including non-3GPP)	Telecom sector (operators, vendors, standardisation)	End 2019	Know-how

4.7.3 Opportunities for Exploitation

In its role, TNO will use developed knowledge and testbed to start new project with telecom operators and vendors, and also to transfer knowledge to SMEs via joint projects.

4.7.4 Progress and Outcomes

TNOs contributions to SaT5G are related to 5G. In WP3 that is WP3.1 on 3GPP core network architectures, protocols and functional blocks, in WP3.4 is that on end-to-end service delivery and specifically slicing mechanisms that are defined by 3GPP and their mapping to satellite networks. In WP is TNO working on security framework for integrated network (WP4.5) and applicability of current 3GPP to integrated terrestrial-satellite network. Further, in WP4.3 mechanisms defined in WP3.4 are further worked out, with focus on matching QoS mechanisms in 5G and satellite networks and support for slicing. Finally, in WP4.6, TNO still has to start work on CDN delivery mechanism and pre-fetching of content.

In WP5.5 TNO will work on slicing as part of demonstrator that is led by UOULU.

4.8 *BRITISH TELECOMMUNICATIONS (BT)*

4.8.1 Mission and Vision

BT is a leading communications services company, serving the needs of customers in the UK and across 180 countries worldwide. The main activities are the provision of fixed-line services, broadband, mobile, and TV products and services as well as managed networked IT services. Following the acquisition of EE in January 2016, BT became the UK's largest mobile operator with a customer base of 30 million subscribers, of which 15.1 million are 4G users.

BT's main research and development centre is in Adastral Park in Suffolk, UK, and is home to over 3,700 of BT scientists, engineers, and business people. These research labs play a leading role in the development of global communications standards.

BT invested £470 million in research and development in 2015/2016 to support the drive for innovation. Other global development centres, located in the US India, and Asia, help draw together key and complementary skills and resources with the objective of increasing agility, efficiency and delivery of innovation to the market.

As a global operator, BT aims to remove all technological obstacles to its clients. The SaT5G project provides a unique opportunity to include satellite systems as part of a 5G standard system in a seamless coexistence with current terrestrial wireless system, such as LTE or NR. The BT standards team, in tight collaboration with research team, works to achieve a global network where all of its clients are able to be always connected to a 5G network, no matter where they are, and no matter how far they move.

BT is looking for innovation to impact its clients in new services and capabilities without raising its clients' costs. BT takes into account the business requirements from the beginning to ensure an optimal solution from the economical and the business point of view.

4.8.2 Exploitable Knowledge

Exploitable knowledge developed by BT in the framework of the SaT5G project is summarised in Table 4.8.

Table 4.8: Exploitable knowledge for partner BT

#	Exploitable Knowledge & Products	Sector(s) of Application	Timeframe	Patents or Other IPR Protection
1	Integration of non-3GPP networks with 5G core network	Consumer telecoms	5 years	Know-how
2	Satellite distribution of content to distributed ground-based caches	Consumer TV	5 years	Know-how
3	Wholesaling of critical communications	Police, fire, emergency	3 years	Know-how
4	Wholesaling of special events communications	Sports, concerts	3 years	Know-how

4.8.3 Opportunities for Exploitation

For the exploitation of SaT5G project results, BT intends to use them in multiple ways:

- Remote rural areas with no other options than satellites.
- Reliability for specific services as critical communications.
- Efficient content delivery allowing to move content to the edge in a more efficient way.
- Fast 5G network deployment in areas where coverage is needed for a short period of time like disaster areas.
- Moving platforms where satellites may be combined or not with wireless terrestrial networks.
- Flexible and efficient usage of satellite resources.

4.8.4 Progress and Outcomes

BT's focus during the remaining time of the project will be on:

- Evaluating the business case for satellite backhaul for consumer broadband.
- Contributing to those parts of SaT5G testbeds when an operator involvement is appropriate.

- Mathematical modelling of ground-to-satellite channel models and link budgets.
- Algorithm design for radio resource management in multi-radio scenarios.
- Implementation of a software emulation environment for demonstrating the algorithms in the previous step.

4.9 *ZODIAC IN-FLIGHT INNOVATIONS (ZII)*

4.9.1 Mission and Vision

Zodiac Aerospace is a world leader in aerospace equipment and systems on-board commercial aircrafts and develops and manufactures solutions to improve inflight comfort and living conditions, as well as high-technology systems that boost aircraft performance and enhance flight safety. The Zodiac Inflight Innovations (ZII) business unit is part of the Zodiac Aerospace group and is mainly involved in the development of innovative, intuitive and trusted IFEC (Inflight Entertainment and Connectivity) systems such as the RAVE™, currently used by more than 50 leading airliners and aircraft manufacturers worldwide. The ZII-Germany unit previously was known as TriaGnoSys GmbH, acquired by the Zodiac Aerospace group in 2013, is a world-leading technology provider for satellite backhauling of mobile/remote wireless systems and mobile/wireless passenger communication systems on-board aircrafts, and has a long track record in R&D, successfully integrating prototypes, testbeds and demonstrators for various aeronautical applications. With the know-how and the results gathered from SaT5G project, ZII-Germany intend to contribute to the internal roadmap and R&D activities that will enhance visibility within the customer-facing departments in the business unit, accelerating the potential adoption of technologies developed/presented through the project. Further, the testbed integrated into the cabin mock-up test environment will be maintained for internal/external customer showcases even after the project completion with direct project acknowledgement.

4.9.2 Exploitable Knowledge

Exploitable knowledge developed by ZII in the framework of the SaT5G project is summarized in Table 4.9.

Table 4.9: Exploitable knowledge for partner ZII

#	Exploitable Knowledge & Products	Sector(s) of Application	Timeframe	Patents or Other IPR Protection
1	Satellite-Mobile Network Convergence	Aviation Market	2019 and beyond	Prototypes and Know-How
2	Virtualisation of the satellite segment	5G Network	2019 and beyond	Know-how
3	Virtualisation of the mobile network segment	5G Network	2019 and beyond	Know-how
4	Multi-access Edge Computing use cases	Aviation Market	2019 and beyond	Prototypes and Know-How
5	Support of use cases with different requirements	5G Ecosystem	2019 and beyond	Know-How

4.9.3 Opportunities for Exploitation

ZII, as a world technology leader for commercial aircrafts, puts significant emphasis on research and development strategy. To carry out this activity, the ZII-Germany unit is involved in an ample range of projects in which technology scouting and testing of cutting edge solutions are a prime. Particularly,

ZII-Germany has a significant tradition of involvement in large EU projects and German co-funded projects that complement internal product-oriented research and development activities. At EU level, ZII is currently involved in two H2020 5G PPP Phase 2 projects (i.e. 5G ESSENCE besides SaT5G), as well as it was a partner of FP7 SPARTACUS and ABSOLUTE projects. To provide example of the involvement in German technology programmes, ZII is currently involved in the LuFO-V2 programme through the project ConCabInO. By means of this strategy, ZII targets to bring the market of civil aviation inside the verticals portfolio supported by the 5G network. Specifically, ZII will exploit the convergence and integration between satellite and terrestrial networks, benefit of 3GPP standardised technology and enrich ZII's know-how, which is materialised through the addition of virtualisation in the products offer to airline companies.

4.9.4 Progress and Outcomes

ZII has contributed to technical work packages, laying specific focus on the virtualisation technology pursued by SaT5G both in satellite and terrestrial networks. This was motivated by the exploitation potentials of virtualisation in the next generation of products for Inflight Entertainment and Connectivity. Although the exploitation of SaT5G outcomes is still in progress, ZII has set in place already concrete actions in this regard. Specifically, ZII has tested a virtualisation environment based on the OpenStack cloud controller ready to host both satellite and terrestrial core network functions deployed as virtual machines. Moreover, ZII has set in place a test LTE network to connect personal devices of passengers, besides the Wi-Fi connectivity already provided by means of aeronautical certified Wi-Fi access points designed by ZII. ZII has also restructured its aircraft cabin mock-up infrastructure to be part of the SaT5G testbed. Furthermore, alongside with the business unit Zodiac Data System (ZDS) and the SaT5G partner SES, ZII has undertaken work activities with respect to the possibility of using the ZDS Aero Ka-band prototype antenna for the purpose of delivering SaT5G project demonstrations. These assets are meant to be used inside the project, as well as for commercial customers to offer them an advanced and innovative demonstration playground.

ZII's focus during the remaining time of the project will be on implementing the testbed to be used in the SaT5G project demonstration of "5G Moving Platform Validation" and, as demonstrator leader, to ensure the proper testbed development to be deployed in Munich for the final demonstration in October 2019. Moreover, ZII will contribute to the elaboration of business models and exploitation tasks in order to appropriately identify the technology maturation and commercialisation potential of SaT5G technology towards achieving an end-to-end system that can accelerate the adoption of 5G technology in inflight communications.

4.10 *BROADPEAK (BPK)*

4.10.1 Mission and Vision

Broadpeak is a global leader in Content Delivery Technology, providing video caching solutions to more than 50 operators (cable and teleconferences) worldwide, with a deployed streaming capacity of 6 Tbps, and serving more than 3 billion streams to end-users every month.

In 2012, Broadpeak has launched the nanoCDN technology that consists in leveraging multicast capabilities of operator's networks and their control of the home gateways to deliver live T channels in Adaptive Bit-Rate (ABR) formats (HLS, HSS, MPEG-DASH), without impact on the reception device. This technology has been adapted to the satellite domain in 2014, allowing the delivery of ABR live channels to multiscreen and pre-caching popular content in home network equipment like satellite gateways or set-top-boxes.

Broadpeak mission within the SaT5G project consists in adapting its video delivery solution to the 5G mobile domain, leveraging satellite delivery and its multicast ABR approach to provide an efficient service for both live streaming and Video on Demand (VOD) pre-cache. Moreover, a local cache solution based on MEC infrastructure, provided within the project, will allow the delivery system to allocate streaming resources dynamically.

A focus is made on optimising the end-to-end latency for live content to mobile devices (can currently reach 10s of seconds), that becomes crucial with the development of social networks that provide information in near-real-time.

4.10.2 Exploitable Knowledge

Exploitable knowledge developed by BPK in the framework of the SaT5G project is summarised in Table 4.10.

Table 4.10: Exploitable knowledge for partner BPK

#	Exploitable Knowledge & Products	Sector(s) of Application	Timeframe	Patents or Other IPR Protection
1	Fixed/Mobile convergence in 5G	5G networks	2019 & beyond	Know-how
2	Low latency for live video delivery	5G networks	2019 & beyond	Know-how
3	Integration within 5G ecosystem	5G ecosystem	2019 & beyond	Know-how
4	5G offline caching	5G ecosystem	2019 & beyond	Know-how
5	Virtualisation	5G ecosystem	2019 & beyond	Know-how

4.10.3 Opportunities for Exploitation

The SaT5G project is allowing Broadpeak to build a reference solution for video delivery over 5G networks. The solution based on multicast ABR will be exploitable by operators who are targeting to deliver video services to their subscribers on mobile devices, with a great quality of experience (no re-buffering, short start-up time, low latency for live, high video quality).

These operators, when moving to 5G, will upgrade their infrastructure to support MEC-based frameworks for allocating resources dynamically.

4.10.4 Progress and Outcomes

Since the beginning of the project and through the work conducted in the various work packages, Broadpeak was able to:

- produce an architecture for implementing local caching in a MEC environment
- design workflow diagrams to follow the establishment of a session
- study an implementation at the head-end level (unicast to multicast transcaster) to reduce end-to-end latency (by using chunked transfer encoding and low latency CMAF format)
- prototype a push VOD solution
- set up a demo for the EuCNC2018 conference in Ljubljana, Slovenia, with its partners: iDirect, SES, i2CAT and the University of Surrey.

The live test planned in Ljubljana demonstrates the integration of satellite into a 3GPP core network, comprising an SDN / NFV / MEC-enabled pre-5G construction testbed, with an in-orbit geostationary satellite system. It will also showcase satellite backhauling features and efficient edge delivery of multimedia content in pre-5G networks, which act as Proof-of-Concepts for integration of those features into a full 5G network.

4.11 *GILAT SATELLITE NETWORKS LTD (GLT)*

4.11.1 Mission and Vision

Gilat designs and manufactures cutting-edge ground segment equipment, and provides comprehensive solutions and end-to-end services, powered by its innovative technology.

Gilat's integrated VSAT systems are built to enable its customers to exploit the full potential of satellite capacity regardless if it is based on High Throughput Satellites (HTS), Extreme HTS (xHTS), or wide-beam satellites. Gilat is also actively involved in defining and developing technologies for the next generation of equipment to support MEO and LEO future satellite constellations.

Innovation is at the heart of everything Gilat does. Its pioneering technologies and high value competitive solutions allow customers to stay ahead of the curve. Gilat's rich portfolio includes its next generation cloud-based VSAT network platform, high-speed modems, high performance on-the-move antennas and high efficiency, high power Solid-State Power Amplifiers (SSPAs) and Block Up Converters (BUCs). Gilat's infrastructure includes the usage of SDN/NFV technologies to provide and allow network programming.

Gilat provides thousands of enterprises, service providers and operators with efficient and reliable satellite-based connectivity solutions. Addressing the needs of residential broadband access, cellular backhaul, enterprise communications, in-flight connectivity, rail and maritime mobility, defence and public safety applications, Gilat's products and solutions are in use in more than 90 countries worldwide.

Gilat is a worldwide leader for Tier-1 3G & 4G backhaul services, as such it is only natural that Gilat will leverage its existing 4G service deployments to quickly and seamlessly evolve into future 5G service provisioning. 5G service provision is expected to be a combination of two main factors; team work and technological partnerships with leading stake holders across the industry and contribution and partnership in leading standardisation bodies to help introduce satellite technology as a valid network solution in the evolving 5G ecosystem.

Gilat is a member in the ETSI 3GPP standardization group and supports and advances the integration of the satellite communication with the next generation of the terrestrial mobile communication.

4.11.2 Exploitable Knowledge

Exploitable knowledge developed by GLT in the framework of the SaT5G project is summarised in Table 4.11.

Table 4.11: Exploitable knowledge for partner GLT

#	Exploitable Knowledge & Products	Sector(s) of Application	Timeframe	Patents or Other IPR Protection
1	Integration of satellite networks into heterogeneous networks	Satellite communication	2019 & beyond	Know-how
2	NBI to network Orchestration	Satellite Communication	2019 & beyond	Know-how
3	SDN/NFV in satellite communication	Satellite Communication	2019 & beyond	Know-how
4	MEC support in satellite and heterogeneous network	Satellite Communication	2019 & beyond	Know-how
5	VF distribution	Satellite Communication	2019 & beyond	Know-how
6	5G backhauling through MEO	Satellite Communication	2019 & beyond	Know-how & prototype

#	Exploitable Knowledge & Products	Sector(s) of Application	Timeframe	Patents or Other IPR Protection
	constellation			
7	Satellite and terrestrial service convergence	Satellite Communication	2019 & beyond	Know-how
8	5G mobility testbed	Satellite Communication	2019 & beyond	Know-how & prototype
9	Virtualised satellite communication elements	Satellite Communication	2019 & beyond	Know-how

4.11.3 Opportunities for Exploitation

Satellite communication can support the social objectives of providing 5G connectivity everywhere at any time in a competitive cost. Communications on the move (OTM) and Communication on the pause (OTP) have become an important part in our current communication needs and expectations. Whether commuting to work on the train, sitting on a cruise ship or flying to an important business meeting, everyone expects to be able to make a voice call or access the Internet at the blink of an eye. Satellite communication is the most cost-effective and at times the only feasible way to ensure reliable broadband connectivity on moving objects anywhere on the planet. Due to its unique characteristics satellite cannot be just a transparent technology to be used; instead it must be a fully integrated solution that supports seamless switching between terrestrial and satellite infrastructures. Satellite must actively participate in the complex overall network topology and architecture. To this end, 5G network architecture is a very good opportunity to integrate satellite as an acknowledged infrastructure alternative when considering different service options.

In this context, GLT envisions the following main use cases as main service targets for 5G service delivery using satellite backhaul:

- Reliability and resilience for critical communications and disaster recovery scenarios.
- Multicast / broadcast service for efficient content delivery.
- Mobility service for Aero, Maritime and terrestrial platforms.
- Global ubiquitous coverage providing broadband service.

GLT plans to exploit the SaT5G outcome for its SatCom solutions for 5G, mainly for backhauling of 5G terrestrial network. This will allow expanding the deployment of 5G networks to underserved locations. GLT will leverage the SDN and NFV technologies as well as the basic SatCom advantages in the heterogeneous architecture to a competitive solution. This includes interfacing the SatCom to the network Orchestrator, to introduce a heterogeneous network that will have network programmable capabilities.

Within the SaT5G project, in the **short-term**, GLT plans to enhance its TotaNMS management system and SDN/NFV offering beyond its current existing scope to enable better support and flexibility when interfacing with a 5G core and deploying different services end to end. Today the complexity of defining an end to end service delivery over a heterogeneous architecture of terrestrial and satellite is limiting the ability to automatically deploy such services and prevents the industry from scaling out such services. Providing a better integrated option is an important goal in the short term until SaT5G project end. GLT will base its next generation of the mobile backhauling solution on SaT5G developments as well as on other technologies that the company is developing. It is expected that the SatCom will serve the terrestrial backhauling through GEO and Non-GEO satellite constellations.

In the **long-term**, GLT will lay the foundations for the company's next generation competitive solutions for 5G backhaul for Fixed OTP and OTM environments.

4.11.4 Progress and Outcomes

WP3.2 – GLT contributed to the definition of the satellite communication backhaul architecture for the 5G. GLT contributed to the different architectural options and provided insights for the different options, including the advantages and disadvantages of the different suggested topologies.

WP3.3 – GLT took an active part in the definition of the architecture to support caching and multicast. GLT provided insights to the discussion and also provided specific contribution assigned to Gilat in the architecture on D2D caching. GLT also provided additional contribution by overview the sections on multicast.

WP3.4 – GLT participated in the discussions and definition of the suggested architecture, and provided feedback on the different architectural options. GLT provided its suggestions for a new architecture options by preparing a PPT and presenting it to the WP participants. GLT also provide inputs and contributed to the architecture document.

WP4 – GLT took part in the analysis of the architecture options that relates to SDN/NFV that will benefit from the satellite and 5G architecture. GLT also evaluated required interfaces between OpenStack and satellite MANO. Currently ongoing discussions refer to the option to standardise the NBI including evaluating the requirements for the abstraction required. GLT has also been analysing the requirements and options for trusted Non-Terrestrial Network access into 3GPP compliant architecture. GLT also analysed the requirements for trusted VF distribution.

WP5 – GLT contributed to the design and planning of the moving platform demonstration planned to be demonstrated on MEO satellites. GLT included description of the H/W and S/W that will be part of the testbed. In addition, GLT has been cooperating with SES and ZII to define the 5G Aero Backhauling testbed, its objectives and plans.

WP6 – GLT participates and contribute to the different activities of the WP. GLT is the WP6.1 leader, and thus coordinated the first draft version of the technology roadmap deliverable, which is in sync with the present document deliverable. GLT disseminated and promoted the project during the 5G World Summit conference held in London during June 2018 via lecture and panel participation. GLT has also been supporting the standardization activities towards including the satellite communication as part of the 3GPP activities.

4.12 *VT IDIRECT SOLUTIONS LTD (iDR)*

4.12.1 Mission and Vision

VT iDirect, a subsidiary of VT Systems, is a global leader in IP-based satellite communications providing technology that enables its 350+ partners to optimize their networks, differentiate and profitably expand their businesses. The iDirect Intelligent Platform™ allows its partners to run their entire business operations more efficiently via a single, unified IP-based satellite architecture, whether it's providing core IP applications to the enterprise or specialised services to any number of diverse vertical markets. iDirect is the #1 name in global satellite communications in key industries including maritime, military/government, and oil and gas, with a 62% hub market share and more than a quarter million remotes installed worldwide. In 2007, iDirect Government Technologies (iGT) was formed to drive adoption of its IP-based solutions in the U.S. government market. In 2008, iDirect Asia Pte Ltd. was established in Singapore to enhance its value-add and responsiveness to customers in the Asia Pacific region. For more information please visit www.idirect.net.

VT iDirect Solutions Ltd. (Ireland) was established in 2015 as a research and development organisation, initially specialising in optimising satellite backhaul for cellular communications protocols and the development of 3GPP standard based networking solutions within Satellite.

4.12.2 Exploitable Knowledge

Exploitable knowledge developed by iDR in the framework of the SaT5G project is summarised in Table 4.12.

Table 4.12: Exploitable knowledge for partner iDR

#	Exploitable Knowledge & Products	Sector(s) of Application	Timeframe	Patents or Other IPR Protection
1	Integration of	Satellite	Immediate	Prototype &

#	Exploitable Knowledge & Products	Sector(s) of Application	Timeframe	Patents or Other IPR Protection
	Satellite communications into standard 3GPP architecture.	communications and Telecommunications		Know-how
2	Adoption of SDN and NFV technologies and management systems	Satellite communications	Immediate	Prototype & Know-how
3	Satellite and Terrestrial network and service convergence	Satellite communications and Telecommunications	Immediate	Prototype & Know-how
4	Definition of data model for satellite interoperability	Satellite communications	2018 onwards	Prototype & Know-how
5	Next generation 5G-enabled virtualised satellite hub platforms	Satellite communications and Telecommunications	2019 onwards	Prototype & Know-how
6	Support for Network Function distribution and MEC-enabled Edge Network	Satellite communications and Telecommunications	2019 onwards	Prototype & Know-how
7	5G-enabled satellite testbeds	Satellite communications and Telecommunications	Immediate	Know-how
8	Influence standards to support seamless integration of satellite in 5G	3GPP standards, Satellite communications and Telecommunications	Immediate	Know-how, Standards

4.12.3 Opportunities for Exploitation

The SaT5G project provides an opportunity to demonstrate that satellite functions, including virtualised functions, can be integrated seamlessly in a 5G network and that the satellite industry can work with 3GPP to define standardised approaches for those functions and interfaces which are unique to satellite.

This will be achieved by firstly integrating satellite communications into a standard 3GPP telecommunications network architecture and secondly, evolving to the 5G architecture once the specifications mature and solutions become available throughout the project.

Taking a standard approach to satellite network architecture design will allow satellite network operators to leverage the many years of seamless multiparty integration and interoperability which has seen the telecommunications industry flourish.

Working together with the telecommunications industry will create tighter integration of satellite into the Mobile Network Operator world, making the delivery of services over satellite as flexible and efficient as over other transmission media.

4.12.4 Progress and Outcomes

The following is a summary of iDR activities to date in SaT5G.

General

As WP4.1 ”Implementing 5G SDN and NFV in satellite networks” lead, iDR coordinated with all WPs and Technical board on general progress and alignment.

WP2 “Scenarios for Satellite Integration in 5G”

iDR attended regular WP2 calls on Architecture review and requirements and contributed to the architecture requirements deliverable.

WP3 “Integrated Network Architecture Design”

iDR participated in regular WP3 and SWP calls in order to ensure the architecture definition was captured and aligned with what is planned in WP4, especially WP4.1. We attended the joint workshop with WP3 at ADS (Feb 2018) which helped to progress and reach agreement on the representative architecture.

WP4 “Research to Prototype Development”

iDR is leading the WP4.1 activities. This includes ongoing coordination with WP4.1 members, WP4 and other WP leaders.

One of the major Year One deliverables targeted by WP4.1 was the live over-the-air demonstration at the EuCNC 2018 conference which took place in Ljubljana on 18-21 June 2018. The demonstration uses iDR technology, an integral part of which is the integration of satellite communications into a standard 3GPP network architecture. iDR along with partners SES, BPK, i2CAT and UoS led the preparation and execution of a successful live demonstration at EuCNC 2018. This involved:

- Working with all demo partners, SES, BPK, UoS and i2CAT, to deliver demo proposal and execution plan.
- Coordinating with SaT5G leadership to ensure the demonstration was aligned with SaT5G objectives.
- iDR organizing weekly calls to coordinate the preparation and execution of demonstration.
- Staging of live demo setup at iDR lab in Ireland.
- Integration and demonstration of BPK nanoCDN and multicasting adaptive bit rate (mABR) software.
- Installation of iDR equipment and software, including virtualized Satellite Network Functions at SES Teleport.
- Setting up live demo onsite at EuCNC 2018 event in Ljubljana.
- Providing primary booth support for demo.

The first-of-its-kind demonstration uses iDR ground segment and remote satellite equipment along with the latest software to show how satellite communications networks can be integrated into a standard 3GPP network architecture to provide seamless end to end satellite connectivity. The 3GPP architecture integration results in the satellite network operating like a 3GPP network with the satellite terminal acting as a user terminal and the satellite communications network presenting as a Radio Access Network to the standard 3GPP core network.

The demonstration illustrates the use of SDN, NFV and MEC technologies and importantly paves the way for full 5G network integration.

An overview of the demonstration can be seen in Figure 4-8 above.

The live over-the-air demonstration, using satellite capacity provide by SES’s in-orbit geostationary ASTRA 2F satellite, was well received and generated a lot of interest from the industry (see WP6 “Dissemination, Standards and Exploitation”).

The proof-of-concept demonstration represents a major step forward in satellite network integration into a standard 3GPP network architecture and lays the foundation for 5G integration.

WP5 “Validation and Demonstration”

The EuCNC 2018 event required close co-operation between iDR and UoS 5GIC testbed to support the successful demonstration. This included the following key topics:

- Establishing networking connection between iDR equipment hosted at SES Teleport and the UoS to provide end to end connectivity.
- Hosting the BPK head-end software.

- Testing the UoS pre-fetching solution which was successfully demonstrated at the EuCNC event.

Apart from the EuCNC 2018 event, iDR has also worked closely with WP5 on other topics

- Defined testbed requirements for HUB, remote equipment and NFV infrastructure for UoS testbed integration.
- Provided support and consultation to ZII for their 5G Aero Platform Backhauling Demo testbed.
- Attended regular WP5 meetings.

WP6 "Dissemination, Standards and Exploitation"

Together with SES, iDR co-led preparation of marketing and promotional material for the EuCNC 2018 first-of-its-kind over-the-air live demo of satellite integration towards 5G, incl. press releases, blog posts, Social Media campaign, magazine articles, promotional video, etc. For example:

http://www.idirect.net/Company/Press-Room/Press-Releases/2018/Release-611-SaT5G-Consortium-Members-Showcase-Satellite-and-5G-Integration-Capabilities-at-EuCNC2018.aspx

https://www.ses.com/press-release/ses-showcases-satellite-and-5g-integration-part-sat5g-consortium-live-demo

http://blog.idirect.net/sat5g-demo-5g-integration-milestone/

http://www.satnews.com/story.php?number=918897934

iDR contributed to the following standardisation activities and related Technical Reports promoting the satellite integration within 5G ecosystem, with focus on satellite use cases in 5G:

- 3GPP SA1 FS_5GSAT "Study on using Satellite Access in 5G" - 3GPP TR 22.822, where 3 of 4 SaT5G use cases have been adopted.
- ETSI SCN DTR/SES-00447 "Edge delivery in 5G through satellite multicast".
- ETSI SCN DTR/SES-00446 "Reference Virtualised Network Functions data model for satellite communication systems".

During Reporting Period #1, iDR physically attended the following standardisation WG meetings promoting the satellite integration within 5G ecosystem:

- 3GPP SA, CT, RAN Plenaries #80, 11-15th June 2018, La Jolla, CA, USA.

In its role as liaison lead with ETSI MEC, iDR facilitated initial engagement discussions with the ETSI MEC leadership.

iDR provided general support and contributions to D6.1 "Roadmap for Satellite into 5G", D6.2 "Standardisation Action Plan" with inputs on 3GPP and ETSI standardisation activities iDR is partaking and contributed to D6.4 "Dissemination Plan".

iDR also provided input to the following papers:

- EuCNC 2018 Conference paper titled "Architecture Options for Satellite Integration into 5G Networks" – published.

4.13 *INTERUNIVERSITAIR MICROELECTRONICA CENTRUM (IMEC)*

4.13.1 Mission and Vision

Inter-university Microelectronics Center (IMEC) is a world-leading independent research centre in nano-electronics and digital technology. IMEC is headquartered in Leuven, Belgium, and also has distributed R&D groups at a number of Flemish universities, in the Netherlands, Taiwan, USA, China, and offices in India and Japan. IMEC staffs more than 3500 people including over 600 industrial residents and guest researchers. IMEC's uniqueness relies in the combination of a widely acclaimed

leadership in microchip technology and a profound software and ICT expertise. IMEC leverages its world-class infrastructure and local and global ecosystem of partners across a multitude of industries to create innovation in application domains such as healthcare, smart cities and mobility, logistics and manufacturing, and energy. IMEC's research bridges the gap between fundamental research at universities and technological development in industry.

One of IMEC's ICT-focused departments is IDLab (http://idlab.technology/). IDLab performs fundamental and applied research on internet technologies and data science. IDLab collaborates with many universities and research centres worldwide and jointly develops advanced technologies with industry (R&D centres from international companies, Flanders' top innovating large companies and SMEs, as well as numerous high-tech start-ups). IDLab is a core research group of IMEC and a large part of IDLab's research activities are embedded in Ghent University. In the SaT5G project, IMEC is represented by the IDLab group related to Ghent University.

4.13.2 Exploitable Knowledge

Exploitable knowledge developed by IMEC in the framework of the SaT5G project is summarised in Table 4.13.

Table 4.13: Exploitable knowledge for partner IMEC

#	Exploitable Knowledge & Products	Sector(s) of Application	Timeframe	Patents or Other IPR Protection
1	TESS and BEMES software library	Multiple application domains	Continuous	Software library under license
2	Techno-economic cost modelling methodology	Multiple application domains	Continuous	Know-how

4.13.3 Opportunities for Exploitation

There are three important routes towards exploitation of the results. The first is focusing on exploiting outcome and methodologies developed in SaT5G in future research projects, the second will exploit SaT5G in education, and the third focuses on spreading gained insights through academic publications and white papers.

With respect to the first part, IMEC can use the expertise gained in SaT5G to in future research projects with ICT and telecom companies, but also with public authorities. The techno-economic software library can be used to assist decision makers by translating technological innovation into business opportunities and challenges, and this library is expanded and further optimised in all research projects IMEC is involved.

Secondly, as IMEC's research is fully embedded in the different Flemish universities, this allows a very efficient exploitation of knowledge by embedding this in the more advanced master courses in engineering and related high-quality PhD programs. The research group IDLab is part of Ghent University.

Finally, new methodologies (e.g. for a cost allocation model for network slicing) will be published in academic publications and white papers.

4.13.4 Progress and Outcomes

IMEC is currently working on a detailed cost model for satellite integration in 5G networks, for the different use cases identified in the project, with as main starting focus the scenario 2b on connectivity to remote rural areas.

The expected outcome of the business modelling work is twofold: methodological and insight-related. On the methodological side, IMEC aims to develop novel cost model and cost allocation models both for stakeholders as well as for virtualised networks. Secondly, the results of the business case analysis can help involved stakeholders to assess the economic viability of the identified technological solutions.

4.14 *FUNDACIO PRIVADA I2CAT - INTERNET I INNOVACIO DIGITAL A CATALUNYA (I2CAT)*

4.14.1 Mission and Vision

i2CAT's vision is to achieve a leading ICT research and innovation role with a special focus on the market needs. Its ambition is to become an internationally recognized strategic partner driving Internet initiatives across economical, industrial and social sectors and boost the innovation and technology transfer competitiveness.

Experience and knowledge gained in the European funded project is an essential element to earn the required intellectual capital. i2CAT as a research centre collaborates closely with the universities. It helps them to make sure a continuous knowledge transfer to the next generations of experts via offering workshop, courses and scholarships to university students. Moreover, i2CAT contributes to the scientific societies by publishing articles in the prestigious and internationally recognized journals and conferences such as, IEEE GLOBECOM, IEEE ICC, IEEE/OSA OFC, EuCNC, IEEE Transactions on Wireless Communications, IEEE Communication Magazine, IEEE Vehicular Technology Magazine, Transactions on Emerging Telecommunications Technologies and IEEE Communications Letters. i2CAT private foundation has built a good industrial footprint via its board of trustees, composed of key players in the telecom industry such as Nokia, Cisco, Interoute and Vodafone, among others. Presenting project outcomes is a regular exercise to raise the awareness among important industrial partners and impact the technology evolution. Furthermore, i2CAT is committed to promote and support the open source software communities.

4.14.2 Exploitable Knowledge

Exploitable knowledge developed by i2CAT in the framework of the SaT5G project is summarised in Table 4.14.

Table 4.14: Exploitable knowledge for partner i2CAT

#	Exploitable Knowledge & Products	Sector(s) of Application	Timeframe	Patents or Other IPR Protection
1	Joint satellite – terrestrial orchestration solution	Telecommunication	September 2019	Open-source
2	Common satellite – terrestrial northbound interface	Telecommunication	September 2019	Open-source
3	Satellite VNFD schema	Telecommunication	September 2019	Open-source
4	SDN-enabled Propagation Impairments Mitigation Techniques (PIMT)	Telecommunication	September 2019	Open-source

4.14.3 Opportunities for Exploitation

SaT5G is crucially importance to i2CAT as it is aligned with the 5GBarcelona initiative of which i2CAT is a core partner. The goal of 5GBarcelona is to establish a nest for the 5G ecosystem in the region and revolutionise the regional economy and promote the innovation of small and medium enterprises. i2CAT will exploit SaT5G results to become a key 5G technological partner, especially on the incorporation of satellite communication into 5G communication paradigm via an orchestration and

management solution able to simultaneously interact with terrestrial and satellite operators. SaT5G helps i2CAT to play the role of an economical booster for the regional and European SMEs to create advanced services on top of a 5G innovation hub.

By collaboration in SaT5G, i2CAT will enhance 5GBarcelona testbed for enhanced Mobile Broadband (eMBB), massive Machine Type Communications (mMTC) and Ultra-Reliable and Low Latency Communications (uRLLC) use cases. Moreover, i2CAT will contribute to the exploitation / extension of open source NFV management orchestration solutions, e.g., OpenStack, OSM, Open Networking Automation Platform (ONAP) and SDN controllers, e.g., OpenDaylight (ODL) and ONOS. Beyond SaT5G, improving the QoS over the 5GBarcelona facilities and guaranteeing the robustness of system as well as extending the platform to enable future applications is the main future plan of i2CAT.

4.14.4 Progress and Outcomes

As the WP4.2 leader i2CAT is working on the detailed design, specifications and implementation of the targeted exploitable knowledge items. To this end, within the framework on WP4.2, i2CAT created smaller specialised teams among partners involved to accelerate the work. For the time being, the main efforts have been dedicated to the creation of Common satellite – terrestrial northbound interface and integration of it with OSM. The result of all related activities will be presented on D4.2 “Integrated Network Management – Analysis, Design and Proof of Concepts” and in a public code repository hosted by i2CAT.

4.15 *UNIVERSITY OF OULU (UOULU)*

4.15.1 Mission and Vision

The telecommunications branch invents new technologies every day. From cell phones to smart phones, from broadband to cognitive radio networks, communications engineering is integral in creating the wireless future. Centre for Wireless Communications (CWC) conducts excellent education and research in the field of wireless communications engineering. CWC is an innovative academic research centre operating, with arctic attitude, at the University of Oulu in Northern Finland.

Wireless Communications is studied in the Degree Programme in Electrical Engineering and the International Master's Programme in Wireless Communication Engineering (WCE).

CWC’s 150 experts in wireless communications aim at solving the major technological challenges related to global digitalisation, 5G and the emergence of the Internet of Things (IoT) and Internet of Everything (IoE) as a productive member of the global scientific and innovation community. Focal areas include increasing access rates with high reliability and low latency as well as massive numbers of connected devices with varying rates and service levels. CWC expertise covers the systemic, network, device and circuit levels in the following research focus areas:

- 5G and beyond.
- Radio Technologies.
- Internet of Things (IoT).
- Signal Processing and Optimisation.
- Specialised Wireless Solutions.
- Radio Frequency Designs.
- Secure Virtualised Networks.
- Medical and Health Networking.

4.15.2 Exploitable Knowledge

Exploitable knowledge developed by UOULU in the framework of the SaT5G project is summarised in Table 4.15.

Table 4.15: Exploitable knowledge for partner UOULU

#	Exploitable Knowledge & Products	Sector(s) of Application	Timeframe	Patents or Other IPR Protection
1	5G NR over satellite links	Satellite Systems	2022-	Know-how

4.15.3 Opportunities for Exploitation

Due to two decades of intensive industry, European and global cooperation, CWC's teams are able to offer solid experience, skills and tools for theoretical research and identify and solve practical problems and constraints of future wireless systems. CWC operates and develops the world's first open 5G Test Network (5GTN) at the university campus catering for most challenging 5G trials.

SaT5G project allows UOULU to enhance the 5GTN increasing its value as a platform where all aspects of future connectivity could be explored. In May 2018, CWC and University of Oulu started eight years long flagship program of Finnish Academy. The flagship "6G-Enabled Wireless Smart Society & Ecosystem" aims to further increase the quality and impact of Finnish research by funding the most prominent research clusters with high scientific merits and impact in supporting economic growth or society at large. The flagships will carry out ambitious research programmes enabled by substantial funding for a period of eight years. The 5GTN will be an integral part of this development.

CWC is currently working on a project "Arctic Communications Architecture" funded by Interreg Nord. It aims to produce an EU project proposal where things are further developed. Satellite systems and 5G are seen as vital elements of this architecture. Consequently, SaT5G will provide valuable information for these plans.

4.15.4 Progress and Outcomes

UOULU's (CWC) emphasis in SaT5G research is in the 5G NR over satellite link. UOULU looks for challenges and problems that may occur when 5G NR is used over the satellite link and propose solutions for these. Selected features will be demonstrated in WP5.

Due to these goals UOULU's outcomes are research articles around these subjects. UOULU also helps industry, especially TAS, to write standardisation (3GPP and ETSI) proposals and reports in WP6. One of the outcomes will be satellite demonstration capability in UOULU's 5GTN that is foreseen to be a usable property in the future.

4.16 *QUORTUS LTD (QUO)*

4.16.1 Mission and Vision

Quortus enables flexible, agile mobile communications networks that provide a foundation for innovative services tailored to a diverse range of end customers. Its award-winning EdgeCentrix (ECX) virtualized mobile core solutions help increase operator margin and "stickiness". They interwork gracefully with existing mobile networks, with small cell and HetNet architectures and with standard IT infrastructure, to create truly integrated communications platforms.

Quortus's ECX products implement standards-conforming functions of 4G, 3G and GSM cellular core networks, in software. Highly scalable, they can be hosted anywhere – in the cloud, at the network edge, or deeply embedded alongside a cellular radio in a single-chip implementation.

The vision is a mobile network that delivers more: for enterprises that demand truly integrated corporate IT and communications; for MNOs, MVNOs and MVNEs seeking service differentiation; for first responders and public safety teams that need secure coverage everywhere they go; and for the global population not yet served by conventional mobile networks.

Qourtus is leading the way in enabling 5G features on 4G and helping customers to be 5G ready with support for high speed packet interface, QoS enforcements, enhanced CUPS that delivers more, than the standardised PFCP.

Quortus MEC offering is one of frontrunner in this area with advanced set of features enabling local breakout, edge delivery etc.

- Fully featured virtualised EPC & 3G/2G core solutions.
- Enterprise optimised Private LTE.
    - MEC – ETSI phase 2 compliant.
    - Enables Private LTE networks with feature set that helps MNO/MVNO deploy combinations of the services below.

- Field-deployable communications for public service, military and first responders.
    - Quortus has a long history of providing tactical communications solutions for military, public safety and emergency response organisations. Today, these customers have more demanding requirements than ever: robust, secure and sanitised networks that can be deployed anywhere and provide not only guaranteed voice coverage, but also advanced data services.

4.16.2 Exploitable Knowledge

Exploitable knowledge developed by QUO in the framework of the SaT5G project is summarised in Table 4.16.

Table 4.16: Exploitable knowledge for partner QUO

#	Exploitable Knowledge & Products	Sector(s) of Application	Timeframe	Patents or Other IPR Protection
1	High speed user plane – in Gbps	User Plane in 5G core networks	Ongoing	Know-how
2	Advanced CUPS interface based on PFCP that offers more than 3GPP specifications	5G core networks	Ongoing	Know-how
3	Network / service based slicing	Mobile core networks	Ongoing	Know-how

4.16.3 Opportunities for Exploitation

Commercial opportunities to enable stand-alone 5G Testbeds, rural 5G deployments for coverage, enabling IoT / IIoT deployments would be the main drivers for more opportunities for Quortus. Quortus will exploit the know-how gained as part of SaT5G, to further develop and upgrade the CN elements to deliver a wider range of services and service enablers.

With the testbeds already capable to demonstrating several Gbps speeds, Quortus is pursuing to promote the capability not only in Edge computing for traditional MNO/MVNO use cases but also in

various connected services scenarios. Quortus is a key contributor of core network elements into another UK government funded programme for advanced 4G and 5G connectivity.

4.16.4 Progress and Outcomes

Quortus has progressed on the following as part of the SaT5G programme:

- Enabling high speed packet delivery infrastructure using SMF & UPF elements based on DPDK and achieved over 7Gbps speeds on a 10G Ethernet interface.
- Enabling UPF selection to support slicing and breakouts.
- Scoping work to support VNF/NFV to enable orchestration.

5 Conclusions

This deliverable document D6.6 “Exploitation Plan” defines the strategic plan for SaT5G project results exploitation. Firstly, it describes the SaT5G exploitation elements on a per-project basis where four broad areas are considered: Products, Services, R&D, and Standards. Secondly, it describes the exploitation plans with regard to the identified exploitable knowledge on a per-partner basis where details are provided on the mission and vision for the respective partner, their exploitable knowledge, their opportunities for exploitation, and their progress and outcomes up to this stage of the SaT5G project.

Overall, the timeframe for SaT5G project results exploitation corresponds mainly to short-term (2020+). In particular, a fully-fledged implementation for operational integration of satellite into the heterogeneous 5G “network of networks” through a “plug and play” approach with focus on higher layer enablers (NFV, SDN, Network Slicing, Security, etc) under common network management and orchestration is feasible for exploitation within this timeframe. In fact, the ground segment equipment vendors have already been working with the satellite network operators towards this aim and good progress has been achieved so far. As an illustration, the success story of the initial SaT5G demo conducted as part of the EuCNC 2018 event as well as the results achieved so far in the context of ETSI/3GPP standardisation for promotion of satellite integration into 5G demonstrate already the good progress achieved so far along these lines.

The table below provides a synthetic overview of the SaT5G exploitable knowledge and products, based on the analysis conducted in this deliverable:

Table 5.1: SaT5G Exploitable Knowledge and Products

#	Exploitable Knowledge & Products	Sector(s) of Application	Timeframe	Type of IPR	Relevant Partner
1	Business and Operational Models for Converged Satellite-Terrestrial 5G Service Delivery	Data Services	Short-term (2020+)	Publications; Know-how	BT, SES, AVA, IMEC, ZII
2	Satellite 5G Reference Requirements, Architectures and Standards	Data Services; Ground Segment Infrastructure; Space Segment Infrastructure	Short-term (2020+)	Publications; Know-how; Standards	ALL
3	Implementation of 5G SDN and NFV across Satellite Networks	Ground Segment Infrastructure	Short-term (2020+)	Publications; Know-how; Testbed Prototypes; Standards	iDR, GLT, TAS, SES, AVA, UoS, ADS, ZII, QUO
4	Integrated Network Management & Orchestration	Ground Segment Infrastructure	Short-term (2020+)	Publications; Know-how; Testbed Prototypes; Open-source; Standards	i2CAT, SES, AVA, TAS, UoS, TNO
5	Multi-link and Heterogeneous Transport	Ground Segment Infrastructure	Short-term (2020+)	Publications; Know-how; Testbed Prototypes; Patents	OA, TAS, TNO
6	Harmonisation of SatCom with 5G Control and User	Ground Segment Infrastructure	Mid/Long-term (2023+)	Publications; Know-how; Testbed	TAS, UOULU, QUO

	Plane			Prototypes; Standards	
7	Extending 5G Security to Satellite	Ground Segment Infrastructure	Short-term (2020+)	Publications; Know-how; Testbed Prototypes	TNO, UoS, TAS
8	Caching and Multicast for Content and VNF Distribution	Ground Segment Infrastructure	Short-term (2020+)	Publications; Know-how; Testbed Prototypes	UoS, BPK, SES, AVA, TAS, ZII, iDR, GLT
9	Standards for Operational “Plug & Play” Integration of Satellite into 5G	Ground Segment Infrastructure	Short-term (2020+)	Standards; Know-how	ALL

In conclusion the SaT5G project adds real value for the partners and the industry; it has plans to add much greater value to its consortium partners and to the overall SatCom community.

Further work in terms of exploitation activities will be reported into the companion deliverable document D6.7 “Exploitation Activity Report”, which is due for delivery at the end of the SaT5G project. This will be fed with relevant inputs from SaT5G WPs which will have all been completed at the time, including inputs from WP4 R&D and implementation activities as well as from WP5 validation and demonstration activities. In line with the DoW, D6.7 will also provide recommendations on future work and ways to promote the take up of SatCom for 5G and beyond.

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