5G key technology enableRs for Emerging media COntent pRoDuction services

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Project exploitation and dissemination plan

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Abstract

This deliverable describes the standardization, exploitation, regulation and dissemination plans for the 5G-RECORDS project. Potential standardization activities have been described in terms of individual contributions to different SDOs from each partner with respect to the components brought to the project. Regulation issues to be addressed include in particular the licensing conditions for non-public networks, including access to spectrum, roaming between different networks, including between public and non-public networks; conditions for access to network slicing; cross-border operations. The deliverable includes also the individual exploitation plans proposed by each partner. Finally, the dissemination and communication plan has been drafted to ensure that the project’s outcomes reach all the players interested in professional audio and video production using 5G end-to-end networks.

[1] CO = Confidential, only members of the consortium (including the Commission Services)

PU = Public

Keywords

SDO, exploitation, regulation, dissemination, 5G. standardization, 5G components, media component, gateway, media orchestration layer

Disclaimer

Executive Summary

This deliverable describes the standardisation, regulation, exploitation and dissemination activities of the 5G-RECORDS project.

The deliverable includes the description of the use-cases that will be implemented during the project and specific components that will be developed for each scenario.

A list of **potential** contributions to various European and global Standard Developing Organisations (SDOs) and industry fora is provided; in particular, the partners aim to contribute to 3GPP, VQEG, ITU, O-RAN Alliance, ETSI, CEPT, MPEG, SMPTE and AMWA **conditionally** to the results achieved during the project.

The individual exploitation plans will target the following objectives, depending on the scope of activities of different partners:

1. Enhance products and services portfolio
2. Speed-up the development
3. Validation and improvements of the current products and services
4. Influence business strategy decisions
5. Scaling up business and revenues
6. Influence the standardisation bodies for adoption of the new features.
7. Increase knowledge and know-how to be leveraged on for future research projects.
8. Teaching and training future engineers working in the fields of telecommunications
9. Disseminate scientific findings in major research/scientific and academic events
10. Planning alternative services related to content production complementing the existing workflows
11. Engaging with the industry partners and the regulators on issues beyond the technical aspects, i.e., 5G deployment models, business arrangements and regulatory conditions.
12. Developing software and hardware for future (public-domain) collaborative projects and by industry and academia around the world

Regulation issues to be addressed include in particular the licensing conditions for non-public networks, including access to spectrum, roaming between different networks, including between public and non-public networks; conditions for access to network slicing; cross-border operations.

The dissemination and communication plan mainly seeks to reach three communities: the scientific community, promoting the participation of academic and research partners in international scientific conferences and organizing workshops, lectures, keynotes, information days, training, and tutorials, the industrial community, attending key event industries, for the 5G industry, and the media sector, and, finally, the general public, developing a public website, producing audiovisual resources, writing press releases, and disseminating the results of the project in the social networks..

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List of Acronyms and Abbreviations

The acronyms list has a special style defined as “acronyms”. Each acronym is separated by a tabulation with each definition. As is shown below:

3GPP	3rd Generation Partnership Project
5G	5th Generation of mobile communications systems
5G-PPP	5G Public-Private Partnership
AMWA	Advanced Media Workflow Association
ANSI	American National Standards Institute
ATSC	Advanced Television Systems Committee, Inc.
ASMR	AirScale mmWave Radio
AV	Audio-Visual
CEPT	European Conference of Postal and Telecommunications Administrations
CPE	Customer Premise Equipment
CU	Centralized Unit
CU-CP	CU-Control Plane
CU-UP	CU-User Plane
DU	Distributed Unit
DVB	Digital Video Broadcasting
EC	European Commission
ETSI	European Telecommunications Standards Institute
FVV	Free Viewpoint Video
FWA	Fixed Wireless Access
HbbTV	Hybrid broadcast broadband TV
HEVC	High Efficiency Video Coding
HSS	Home Subscriber Server
gNB	gNodeB
ICT	Information and Communications Technologies
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IEM	In-Ear monitoring
IETF	Internet Engineering Task Force
ISO	International Standards Organization
ITU	International Telecommunications Union
KPI	Key Performance Indicator
LSA	License Shared Access
MCR	Master Control Room
MEC	Multi-access Edge Computing
MME	Mobility Management Entity
mMTC	massive Machine-Type Communications
MNO	Mobile Network Operator
MPEG	Moving Picture Experts Group (formally, ISO/IEC JTC 1/SC 29/WG 11)
MTC	Machine Type Communications
Near-RT RIC	Near Real-Time Intelligent Controller
NFV	Network Function Virtualisation
NMOS	Network Media Open Specifications
NPN	Non-Public Network
NSA	Non-standalone
OIPF	Open IPTV Forum
OPNFV	Open Platform for NFV
O-RAN	Open Radio Access Network
PCRF	Policy and Charging Rules Function
PDCP	Packed Data Convergence Protocol
PGW	Packet Data Serving Gateway
PLMN	Public Land Mobile Network
PMSE	Programme Making and Special Events

PNI-NPN	Public Network Integrated NPN
QoE	Quality of Experience
RAN	Radio Access Networks
RRS	Reconfigurable Radio Systems
RU	Radio Unit
SA	Standalone
SDN	Software-defined networking
SDO	Standards Developing Organization
SGW	Serving Gateway
SLA	Service Level Agreement
SME	Small and medium-sized enterprise
SMPTE	Society of Motion Picture and TV Engineers
SDR	Software Defined Radio
TSG	Technical Specification Groups
UC	Use Case
VIAPA	Video, Imaging and Audio for Professional Applications
VQEG	Visual Quality Experts Group
vRAN	Virtualized RAN

1 Introduction

5G-RECORDS (see Figure 1) is about the design, develop, integrate, validate and demonstrate specific 5G components (see Section A) for professional AV production into end-to-end 5G infrastructures. The validation through different use-cases (live audio production, multiple camera wireless studio, live immersive media services) will help to maximise the impact of the project results and influence standardization and regulation.

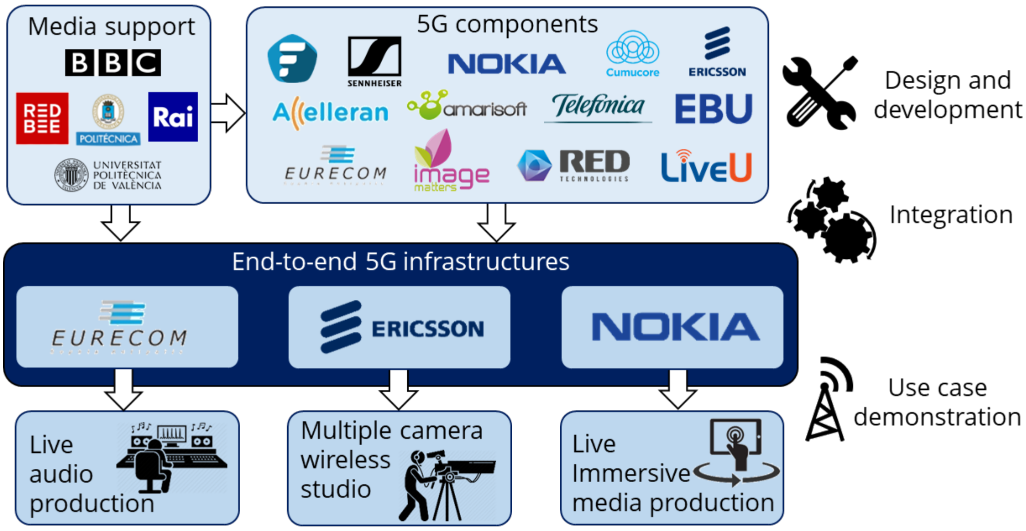


Figure 1. 5G-Records overview

1.1 Objective of the document

This deliverable summarises the standardisation, regulation, exploitation and dissemination plans in the 5G-RECORDS project.

Partners in the consortium are making use of the project to develop core solutions and integrate them into the 5G ecosystem supported by professional media production. We are increasing our competitive advantage and improving our products and services. The objectives depending on the type of partner (industry or research), its activities (technology, operator, broadcaster) and size (from SMEs to large enterprises) include the following:

- Enhance 5G-enabled products and services focused on content production and media verticals.
- Expand their IPR (Intellectual Property Rights) portfolio.
- Increase knowledge and know-how to be leveraged for future projects as well as practical deployments and alternative selections.
- Influence the standardisation bodies for adoption of the new features.
- Socialise results with verticals and telecom operators.
- Disseminate scientific findings in major research and academic events.

The project aims at having a wide impact on the on-going standardisation effort in the field of 5G wireless and other media-related technologies. Building on the partners' experience in European and global standard organisations, the project will ensure that results and findings will reflect in corresponding impact globally. This impact will either correspond to direct contributions into existing or emerging standards related to researched areas, as well as will ensure that project partners are in an advantageous position towards steering and guiding the activities of the standardisation community.

1.2 Structure of the document

The document is structured as follows. Firstly, the standardization plan is addressed in Section 2, including the introduction of the Standards Developing Organizations (SDOs) as well as the project partners' membership in those SDO and the individual standardization plan of each partner.

Then, Section 3 aims to present the regulation plan whereas Section 4 addresses the exploitation plan according to the role of each partner (i.e. SMEs providing 5G components, cellular network infrastructure providers, media industry, broadcasters or research).

Furthermore, the dissemination and communication plan is addressed in Section 5.

Finally, a brief definition of the use-cases (live audio production, multiple cameras wireless studio and live immersive media services) is presented in Annex A alongside the components' description.

2 Potential Standardization Plan

2.1 Standards Developing Organizations (SDOs)

In this Sections the selected SDOs are explained, they have been chosen in order to help ensuring not only project's impact and usefulness, but also serve to validate the quality and relevance of the project outputs.

Standardization activities are a key factor to ensure long term sustainability and the widest possible use of the 5G RECORDS results.

3GPP

The 3rd Generation Partnership Project (3GPP) unites [Seven] telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), known as "Organizational Partners" and provides their members with a stable environment to produce the Reports and Specifications that define 3GPP technologies.
The project covers cellular telecommunications network technologies, including radio access, the core transport network, and service capabilities - including work on codecs, security, quality of service - and thus provides complete system specifications.
The specifications also provide hooks for non-radio access to the core network, and for interworking with Wi-Fi networks. 3GPP specifications and studies are contribution-driven, by member companies, in Working Groups and at the Technical Specification Group level.
The three Technical Specification Groups (TSG) in 3GPP are; Radio Access Networks (RAN), Services & Systems Aspects (SA), Core Network & Terminals (CT).

ETSI

ETSI is the European Telecommunications Standards Institute. It reduces globally-applicable standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, broadcast and Internet technologies. ETSI standards enable the technologies on which business and society rely. For example, standards for GSM™, DECT™, Smart Cards and electronic signatures have helped to revolutionize modern life all over the world. ETSI is a not-for-profit organization with more than 800 member organizations worldwide, drawn from 67 countries and five continents. Members include the world's leading companies and innovative R&D organizations. ETSI is at the forefront of emerging technologies and address the technical issues which will drive the economy of the future and improve life for the next generation.

HbbTV

Hybrid broadcast broadband TV (or "HbbTV") is a global initiative aimed at harmonizing the broadcast and broadband delivery of entertainment services to consumers through connected TVs, set-top boxes and multiscreen devices. The HbbTV specification is developed by industry leaders to improve the video user experience for consumers by enabling innovative, interactive services over broadcast and broadband networks. The specification uses elements of existing specifications from other standards including OIPF, CEA, DVB, MPEG-DASH and W3C.
In June 2014, the activities of the Open IPTV Forum (OIPF) were transferred to the HbbTV Association. This broadened the HbbTV Association's mandate to include defining specifications for service providers and technology suppliers that streamline and accelerate deployment of IPTV services.

ITU

The International Telecommunications Union (ITU) is an organization based on public-private partnership since its inception, ITU currently has a membership of 193 countries and almost 800 private-sector entities and academic institutions. ITU is headquartered in Geneva, Switzerland, and has twelve regional and area offices around the world. ITU membership represents a cross-section of the global ICT sector, from the world's largest manufacturers and telecoms carriers to small, innovative players working with new and emerging technologies, along with leading R&D institutions and academia. Founded on the principle of international cooperation between governments (Member States) and the private sector (Sector Members, Associates and Academia), ITU is the premier global forum through which parties work towards consensus on a wide range of issues affecting the future direction of the ICT industry

O-RAN Alliance

O-RAN Alliance members and contributors have committed to evolving radio access networks around the world. Future RANs will be built on a foundation of virtualized network elements, white-box hardware and standardized interfaces that fully embrace O-RAN's core principles of intelligence and openness. An ecosystem of innovative new products is already emerging that will form the underpinnings of the multi-vendor, interoperable, autonomous RAN, envisioned by many in the past, but only now enabled by the global industry-wide vision, commitment and leadership of O-RAN Alliance members and contributors. The O-RAN Alliance was founded by operators to clearly define requirements and help build a supply chain eco-system to realize its objectives. To accomplish these objectives, the O-RAN Alliance's work will embody two core principles: openness and intelligence

SMPTE

Since its founding in 1916, the Society of Motion Picture and TV engineers (SMPTE) has developed more than 800 standards, recommended practices, and engineering guidelines, that are currently in force; and it continues to innovate at a rapid clip, generating an average of 50 new standards annually focused on film and digital cinema, television, and internet video. By providing structure, organization, and interoperability, SMPTE has assisted in advancing the motion-imaging industry through all of the major transitions, from the advent and integration of sound and color to the shift from celluloid and analog to digital formats, including digital cinema, high-definition TV (HDTV), and 3D TV. SMPTE standards touch nearly every piece of motion-imaging content consumed by billions of viewers around the world, ensuring that content is seen and heard in the highest possible quality on any display screen. Our standards also enable repeatable workflows for content creators and distributors, as well as the manufacturers who support them. With more than 100 years of motion-imaging standards leadership, SMPTE is the innovator of some of the most iconic standards for high-quality content, as well as those that are facilitating the transition to an IP-based multiscreen world.

SMPTE Standards are recognized across the world. SMPTE is accredited by the American National Standards Institute (ANSI) and recognized by the International Standards Organization (ISO), the International Electrotechnical Commission (IEC), and the International Telecommunications Union (ITU) as an Approve Referenced Organization. Among its many roles on the international stage, SMPTE provides the Secretariat for the ISO Technical Committee on Cinematography, TC-36

MPEG

MPEG stands for "Moving Picture Experts Group" and is the informal name of ISO/IEC JTC 1/SC 29/WG 11, which means, once decoded, that MPEG is a Working Group of a Sub-Committee of the Joint Technical Committee between ISO and IEC. As such, the standards developed by MPEG are published by ISO and follow its rules. Since it was established in 1988, MPEG has produced an impressive portfolio of standards to help industry offer end users enjoyable digital media experiences in an efficient way, especially thanks to media compression techniques, but also by means of several other technologies. MPEG's task force consists of thousands of highly qualified researchers from private companies and academia, of which several hundreds attend its regular meetings. MPEG is divided into Subgroups dealing specifically with the different aspects covered by its standards: Requirements, Systems, Video, Audio, 3D Graphics, etc. Very recently (during the summer of 2020), MPEG has formally evolved from being WG 11 of ISO/IEC JTC 1/SC 29, to being split into seven separate WGs, corresponding to the previous Subgroups, that have been created within SC 29.

AMWA

With worldwide representation from both media companies and their suppliers, the AMWA currently focuses on the industry move to IP based architectures. To enable software based systems to recognize and exploit devices, the AMWA has developed the Networked Media Open Specifications (NMOS). These have been created in practical workshops by the Networked Media Incubator project. This activity complements the work of other well established technology associations, such as the Audio Engineering Society (AES), the European Broadcasting Union (EBU), the Society of Motion Picture and Television Engineers (SMPTE) and the Video Services Forum (VSF).The AMWA continues its support for the Media Exchange Format (MXF), the Advanced Authoring Format (AAF) and the Framework for Interoperable Media Services (FIMS).The organization maintains open membership and committee participation.

VQEG

VQEG (Video Quality Experts Group) was born from a need to bring together experts in subjective video quality assessment and objective quality measurement. The general motivation of VQEG is to advance the field of video quality assessment by investigating new and advanced subjective and objective methods for assessing quality. VQEG brings together experts from different organizations, including industry, academia, government organizations, and SDOs around several projects, to develop subjective assessment methodologies as well as objective metrics that can model the user Quality of Experience (QoE).

VQEG organizes its work around several workgroups or projects. Particularly relevant for 5G-RECORDS is the VQEG project 5GKPI, whose mission is to study the relationship between the Key Performance Indicators of new communication networks (namely 5G, but extensible to others) and the QoE of the video services on top of them.

2.2 Project partners' membership in SDOs

Standardization activities are a key factor to ensure long term sustainability and the widest possible use of the 5G-RECORDS results. Successful contributions to standards not only help to ensure a project's impact and usefulness, but also serve to validate the quality and relevance of the output. Building on the consortium expertise, partners will push results and findings in individual or joint collaborations, aiming at guiding or influencing the activities of the European and global standardisation community. Moreover, this will enable the consortium to address the most advanced and up to date use cases, requirements and baseline technologies
The project partners have very strong presence in European and global SDOs, in particular:

Table 1. Partners in different SDOs

	3GPP	DTG	ETSI	HbbTV	VQEG	MPEG	ITU	ORAN	SMPTE	AMWA
NOK										
EDD										
CMC										
RED										
RAI										
ACC										
EUR										
SEN										
EBU										
BBC										
UPM										

2.3 Potential Standardization - Individual plans

Table 2. Individual standardization plan

Partner	5G Component	SDOs
UPV	OpenAirInterface	**3GPP** Follow the 3GPP Release 17 activities, particularly within the context of the “Study on support of reduced capability NR devices” and “Study on NR coverage enhancements” study items.
NOK	E2E 5G deployment	**VQEG** Presentation of 5G-RECORDS in VQEG plenary meeting, as part of 5GKPI VQEG project, which is currently chaired by Nokia. The results of the project will also be contributed to help in the definition of Quality-of-Experience-based KPIs for 5G networks and beyond. **ITU-T** Presentation of 5G-RECORDS project to ITU-T SG12 on Quality of Service measurements. Potential contribution to work item G.QoE-5G (Q13/12).
EDD	5G components on mid- and high-bands as well as NPNs	**3GPP** Support on-going 3GPP studies around VIAPA requirements in FS IIoT and FS_eNPN.
	Higher Layer protocols & procedures between 5G Devices and ST2110-GW	**3GPP** Drive the definition of protocols and procedures between 5G PMSE devices and a 5G<->2110 Gateway.
CMC	5G network functions	**3GPP** Support on-going 3GPP proposal for UPF service description
RED/SEN	Spectrum sharing management technologies/5G-enabled	**ETSI** TC RRS; Presentation of 5G RECORDS to WG1 in their November 2020 meeting; more presentations / contributions to be done as seemed appropriate. **CEPT**

	microphones and wireless IEM (in-ear monitoring)	WG FM; Presentation of 5G RECORDS in their January 2021 meeting; possibly combined with an ETSI TC RRS presentation of eLSA.
ACC	dRAX near-RT RIC, CU CP, CU UP and xApps	**O-RAN Alliance** If any of the enhancements done in dRAX to support the live audio production use case can have an impact as contribution to the O-RAN Alliance architecture, interfaces or specifications, Accelleran can articulate contribution or project related presentation within the O-RAN Alliance
EUR	OpenAirInterface	**3GPP** Follow and contribute to the 3GPP Release 17 activities, particularly within the context of the “Study on support of reduced capability NR devices” and “Study on NR coverage enhancements” study items
EBU	Non-public Network support	**3GPP** The FS_eNPN Study Item is covering use cases and requirements for the support of non-public networks, non-public networks as private slices, related security implications as well as UE onboarding. Enhancements in the 5GS would enable the support for standalone NPN along with subscription / credentials owned by an entity separate from the SNPN (e.g. a service provider); UE onboarding and provisioning for non-public networks; service continuity aspects for media production scenarios; several optimisations and customisations when NPNs are supported by PLMNs; among others.
	Support of time sensitive communications	**3GPP** The study item FS_IIoT is evaluating the integration of time sensitive communications (TSC) support in the 5GS which may be beneficial for professional production applications requiring synchronization. In the scope of this study are the support of uplink synchronisation with IEEE TSN or support of deterministic applications using the same UPF or by exposure of network capabilities to support TSC.
BBC/EBU	Gateway and media orchestration layer	**SMPTE/AMWA** While the gateway and the media orchestration layer will be utilizing the existing SMPTE ST 2110 suite of standards and the AMWA NMOS specifications, the development of the gateway and the interfaces may lead to the exploration of the effect of a wireless 5G network on the performance of these existing solutions. Depending on the outcomes, a further investigation may need to happen in SMPTE and AMWA and the results of the projects will be contributed towards possible further development or adaptation of these standards and specifications
UPM	FVV Live 5G	**MPEG** All activity related to MPEG-I carried out within the Requirements, Systems, Video and 3D Graphics subgroups (now WGs 2, 3, 4 and 7, respectively: see Section A) will be closely followed, including regular

		participation in their meetings during 2021 and 2022. These meetings will also be taken as an opportunity to showcase and disseminate the results of the 5G-RECORDS project in front of a highly qualified and influencing audience. If and whenever possible, the research results of the project will be presented as technical contributions for their potential adoption in MPEG standards. **VQEG** Presentations of 5G RECORDS Project, progress and outcomes in the general meetings (2 per year), within the Immersive Media group (IMG) and the 5G Key Performance Indicators (5GKPI) group. The possibility to launch a common test plan involving other laboratories will be explored, addressing QoE issues related to immersive media over 5G.
RAI	All components	**MPEG:** contribution to joint effort to start an Exploration in MPEG (ISO/IEC JTC1 SC29) about standard components for distributed production (codecs, transport, signalling) . This effort could ideally produce a new part in MPEG-A family of standards.
TV2		As an EBU member, contribute and support all work for standards and interoperability in workflows, related to content production. Presenting outcome and results from 5G-RECORDS in national and international forums for broadcast and media professionals.

Currently,Universitat Politècnica de València (**UPV**), Telefonica (**TID**), LiveU (**LU**), Fivecomm (**5CMM**) and Image Matters (**IM**) do not have plans for standardisation.

3 Regulation Plan

Regulatory issues will be dealt with in WP2 which aims to define the overall ecosystem of the project and how it will be impacted by the regulatory aspects. Furthermore, WP2 will define the regulatory requirements stemming from the project use cases.

Specifically, regulatory issues will be dealt with in Task 2.2 - *Regulatory framework and business models*. Task 2.2 will provide guidance to the project to ensure that the use cases are carried out in compliance with the applicable regulation.

Furthermore, the analysis of the regulatory framework will seek to identify those regulatory issues that are relevant for professional content production, such as:

- licensing conditions for non-public networks, including access to spectrum;
- roaming between different networks, including between public and non-public networks;
- conditions for access to network slicing;
- cross-border operations.

Two project milestones:

Table 3. Project milestones

Milestone	Description	Due date
MS6	*Regulatory frame and business models identified* with the corresponding deliverable D2.2	October 2021
MS10	*Final analysis of regulatory and business models* with the corresponding deliverable D2.3	August 2022

Both deliverables D2.2 and D2.3 will be publicly available.

Should the analysis of the regulatory framework reveal that some requirements of the use cases are not appropriately covered by the current regulation, these will be clearly identified in the deliverables. This will allow the project partners to bring these issues to the attention or their respective regulatory authorities. If appropriate, the project will bring these issues to the attention of the European Commission services and, with respect to spectrum related issues, to CEPT.

4 Exploitation Plan

The consortium members will target some or all, depending from the partner's type (e.g., university, research centre, small and medium-sized enterprise (SME), broadcaster, network operator, media industry of the objectives listed in the following:

1. Enhance products and services portfolio
2. Speed-up the development
3. Validation and improvements of the current products and services
4. Influence business strategy decisions
5. Scaling up business and revenues
6. Planning alternative services related to content production complementing the existing workflows
7. Engaging with the industry partners and the regulators on issues beyond the technical aspects, i.e., 5G deployment models, business arrangements and regulatory conditions.
8. Developing software and hardware for future (public-domain) collaborative projects and by industry and academia around the world

The table below lists for each partners the objectives from the list above they would like to achieve.

Table 4. Objectives versus partners

	1	2	3	4	5	6	7	8
UPV								
Nokia Spain SA								
Ericsson GmbH								
Telefonica								
Cumucore OY								
RED Technologies								
Image Matters								
RAI								
Accelleran NV								
LiveU Ltd.								
Fivecomm								
Sennheiser								
EBU								
BBC								
UPM								
Eurecom								
TV2								
Red Bee Media								

4.1 SMEs providing 5G components

4.1.1 Accelleran

Accelleran brings dRAX, a cloud native and O-RAN aligned 5G SA vRAN solution consisting on a near-RT RIC, CU-CP, CU-UP and xApp framework components. dRAX will be enhanced to support the requirements of the live audio production use case. Accelleran plans to exploit the enhancements done in 5G-RECORDS as part of the dRAX product offering in general customer opportunities, and in particular in any audio production opportunities using 5G private networks (Figure 31).

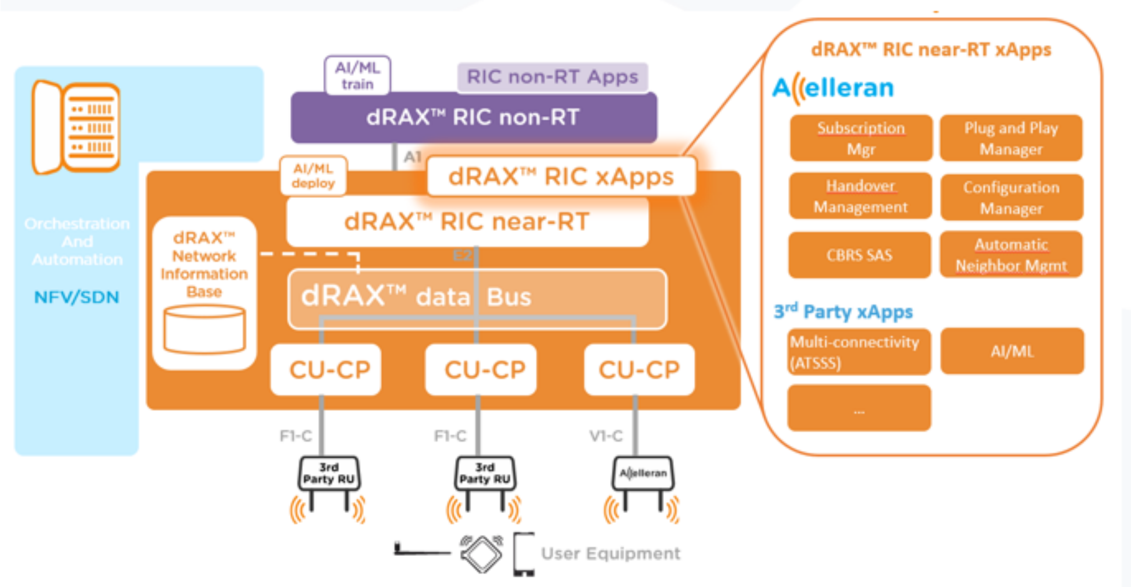


Figure 2. Accelleran dRAX component.

5G-RECORDS will enhance that opportunity whilst also developing market specific experience and credibility in the AV transmission domain. The stringent requirements and KPIs of the use cases are expected to be directly applicable to the needs of additional verticals, expanding the market addressability of future commercial offerings of Accelleran. As shown in other H2020 projects, the networking and joint exploitation opportunities with other 5G-RECORDS consortium partners is expected to benefit Accelleran in growth to scale-up the business and revenues.

4.1.2 Cumucore

Cumucore brings a compact 5GC Non-Standalone (NSA) and Standalone (SA) with new integrated network functions for private mobile networks for rapid deployment on-site. Cumucore integrates 3GPP standard network functions in a micro-mobile packet core targeted to content production and delivery deployments in private networks. Cumucore enables deployment for media production on-site or on-cloud for ingesting media content from production to be processed locally with edge computing-based applications or delivered to the cloud for post-processing (Figure 32). Cumucore intends to strengthen its role as provider of micro-mobile packet core, targeted to industrial deployments, private LTE, small or medium MNOs. The project will help Cumucore to extend its current expertise on SDN networking and mobile core into the radio interface and cooperate with other partners to deliver end-to-end system.

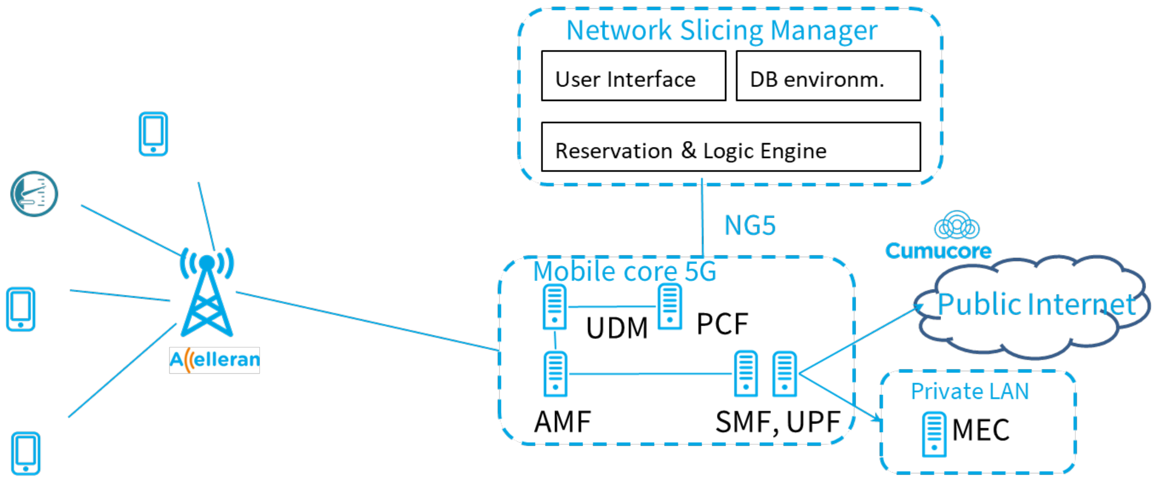


Figure 3. Cumucore architecture

4.1.3 Fivecomm

Thanks to 5G-RECORDS, Fivecomm aims to expand its portfolio in 5G and professional media production with a clear business-to-business (B2B) perspective, helping end-users, broadcasters, and customers on selecting the optimum media solutions for their needs.

Fivecomm aims at developing, under the 5G-RECORDS umbrella, a *5G gateway for cameras* to be used on UE wireless cameras, and to be integrated as part of use case 2 (multiple camera wireless studio) in the context of the project. The aim is to develop, integrate and technically validate a compact final solution that provides 5G wireless connectivity to end-users in an easy and flexible way. The product can be particularized for the connection link between the cameras and the 5G network, depending on the specific needs and requirements of the media vertical.

4.1.4 ImageMatters

Thanks to 5G-RECORDS, Image Matters will create a generic Camera platform for 5G Broadcast exploiting its System-on-Module products.

This platform will be offered to Camera vendors as a basis for their development. It will also be available to academic projects for further collaborative projects.

On the way to develop the whole platform firmware and software multiple point will be discussed with standardization committee to conform as well as possible to their actual and future standard. The validation during the 5G test beds will enable IM to provide a commercial version of the module to camera manufacturers.

4.1.5 RED Technologies

RED Technologies will integrate the functional blocks supporting temporary license creation (leasing) within its Spectrum Sharing solution.

RED Technologies will enhance its expertise and contribute to the standardisation of spectrum sharing, including eLSA, as standardisation is critical for the industry to ensure spectrum sharing products are multivendor. The results of 5G-RECORDS will strengthen the position of the company in the standardisation of spectrum sharing and its product development. The project will speed up the development of the spectrum sharing interfaces, with different implementations being tested on the field. Indeed, experimentations under real-life conditions give an undeniable advantage RED Technologies for future deployments in Europe and abroad and constitutes a competitive advantage over competitors.

In addition, RED Technologies will perform the following dissemination related activities:

- Share the results of this project within research/scientific and academic events, along with other consortium partners.

- Influence ETSI and CEPT standardization work on spectrum sharing, including within ETSI RRS and CEPT FM, on the following topics:
    - Local licensing.
    - Temporary licensing.
    - Licensing conditions (e.g., first come first served).
    - Moving away from secondary assignment for PMSE.

4.2 Network providers

4.2.1 Telefonica

Telefonica I+D (TID) is the innovation company of the Telefonica Group. It contributes to the Group's competitiveness and modernity through technological innovation. To achieve this, the company applies new ideas, concepts, and practices in addition to developing advanced products and services.

Telefonica plan to use 5G-RECORDS project and its approach to improve their solutions towards Media customers, leveraging our edge and network. Participation in the 5G-RECORDS project will allow Telefonica to improve the portfolio of products and services as it is a technological trend that will generate new opportunities in the coming years.

Thanks to the automation of the deployments we will be able to accelerate the developments and reuse code. As 5G marks a new era, technology will influence the decisions of the company, leading us to a market blue sea, with a new range of new 5G-related use cases.

Future research projects will benefit remarkably from all the teachings of this project.

4.3 Cellular network infrastructure providers

4.3.1 Ericsson

Ericsson provides access to a commercial-grade 5G System to project partners for tests and demonstrations. The 5G System is capable to operate as Stand-Alone Non-Public Network (SA-NPN) or as integrated NPN (PNI-NPN). During the project time, optimized system configurations for Media Production use-cases will be identified and tested in the system.

Ericsson’s objective is to work with media producers to jointly explore the 5G system capabilities, the integration of the 5G System into existing media production workflows and identification of key pain-points with existing 5G Systems. The intention is to bring identified technology gaps into 3GPP standardization.

Ericsson will support the definition of the protocols and procedures between the Wireless Camera (and other devices) and the 5G<->SMPTE Gateway, focusing on the full protocol stack via 5G. Control Plane (orchestration) and media plane aspects may be separately studied. It is expected that different protocols should be used on-top-of the 5G System than in a SMPTE 2110 based Media Production environment. When needed, Ericsson will support the standardization of the higher layer protocol stack for Media Production, e.g. in 3GPP or other SDOs. Other research results will be published via scientific conferences.

4.3.2 Nokia

Nokia Spain will use 5G-RECORDS to deploy and validate a portable 5G end-to-end solution based on millimeter wave (mmW) technology. It is envisioned that this solution is exploited at three different levels: as a blueprint design for smart venues and similar venue-oriented deployments, as a test bed for 5G in mmW for several Nokia business units, and as a research platform for Nokia Bell Labs.

5G-RECORDS will pioneer the experimentation with mmW 5G in Spain, building a novel design which combines high-throughput mmW RAN, Fixed Wireless Access CPEs and GPU-powered MECs. The resulting blueprint design will support high throughput (with special focus in the uplink), low latency and high processing power, as well as flexibility for the deployment. This design is suitable for several use cases which include real-time video capture and processing workloads, such as smart venues, and it can be applied both to MNOs and NPNs.

Nokia has already shown that venue-tailored 5G deployments can bring significant benefits to industry and operators. The use of 5G technology in the Nokia Oulu factory contributed to more than 30% productivity gains, 50% savings in time of product delivery and millions of annual costs savings. New 5G smart stadium services like premium video can bring revenue in the order of 20-25 MUSD per venue, which is a 40% return on investment for the service provider.

The portable platform built in 5G-RECORDS can also be used as test bed by several Nokia Spain units, allowing them to experiment with solutions in field trial conditions. This means having early access to a functional end-to-end mmW deployment, which can be used to test new solutions that can be offered to Nokia customers.

Finally, it will be used as research platform for Nokia Bell Labs. Nokia Bell Labs in Spain, through its Distributed Reality Solutions department, is creating technology for the end-to-end delivery of Virtual and Augmented Reality communications and other video-based real-time solutions. For this purpose, a platform like 5G-RECORDS end-to-end solution can be used to research on several problems requiring high bandwidth, low latency, and offloading video processing to the edge cloud, including: immersive video capture, 360 video bidirectional communications, remote operation of vehicles, or advanced mixed reality interaction patters for training and industrial operation. The result of this research is exploited by feeding back the results to other business units, support Bell Labs Consulting in customer engagements, and generate industrial and intellectual property rights.

An important area of exploitation of the results is the end-to-end evaluation of the impact of the network design in user Quality of Experience, for each of the considered use cases. This analysis is fed into VQEG to be consolidated with other academic and industrial stakeholders. VQEG collaborates actively with ITU-T to jointly create new international recommendations (e.g. the recently approved ITU-T P.919 for subjective evaluation of immersive video).

4.4 Media Industry

4.4.1 Sennheiser

Today's professional wireless audio devices in high-end studio or live stage environments require custom RF technology to meet artist's requirements for latency, reliability and audio quality. 5G has the potential to enable such audio use cases with standardized technology. Furthermore, current trends show an increasing use of wired IP-based workflows in A/V productions, due to its wide distribution and easy infrastructure deployment and operation. 5G could enable the seamless integration of wireless audio devices into IP-based A/V production.

Sennheiser's goal in 5G-RECORDS is to explore the possibility of deploying 5G technology for wireless ultra-low latency audio applications. 5G-RECORDS will generate knowledge on the technical feasibility and resulting constraints and implications for a potential subsequent implementation and integration of wireless 5G audio devices.

4.4.2 LiveU

LiveU brings its huge across-the-board knowledge and leadership of mobile video contribution in the global media market. LiveU will enhance its products with 5G capabilities that will be validated over 5G-RECORDS 5G test platform such as SA and NPN, in the wireless studio use case. Integration with leading broadcasters in such NPN and cloud production are also important for our solutions improvements.

LiveU will enhance capabilities and various features, such as aim for higher UL bandwidth for its reliable video transmission and for lower uplink latency, return IP channel to support remote control of devices, delivery/transport of various other signals besides the A/V such as control of robotic cameras and similar low bit rate devices, potentially timing signals from the center, integrate and validate these with other vendors' products such as the robotic cameras, SMPTE 2110 and perhaps NMOS gateways etc. When the use case evolves and requirements are clear, LiveU may address additional capabilities.

LiveU intends to use its newest platforms such as LU800 and/or potential others. The intention is to use both its integrated real time HEVC video encoder and video capturing as well as its video transmission engine and other capabilities. On the other side, a receiving software (on standard processing platform with standard physical video output cards), will be used to interface the wireless studio A/V production system. Depending on the Use Case requirements such as for ultra-low end-to-end latency, an alternative solution may be selected by LiveU for this UC. In this alternative, the video encoder will be provided outside the LiveU device, provided by the broadcast partners. The LiveU device will handle the transmission of the various IP traffic, including that of the external video encoder, so to try and reduce the latencies. At the other side there will be a LiveU layer2 unicast Data Gateway that connects to the public internet or intranet and distribute the packets according to their IP addresses.

LiveU LU-Central (LUC) will be used to manage the LiveU unit and server. Both single modem usage and multi-link (multi-modem) “bonding” will be tested over these 5G connections to support BW and reliability.

The figure below shows the alternative in which the LiveU unit includes the video encoder.

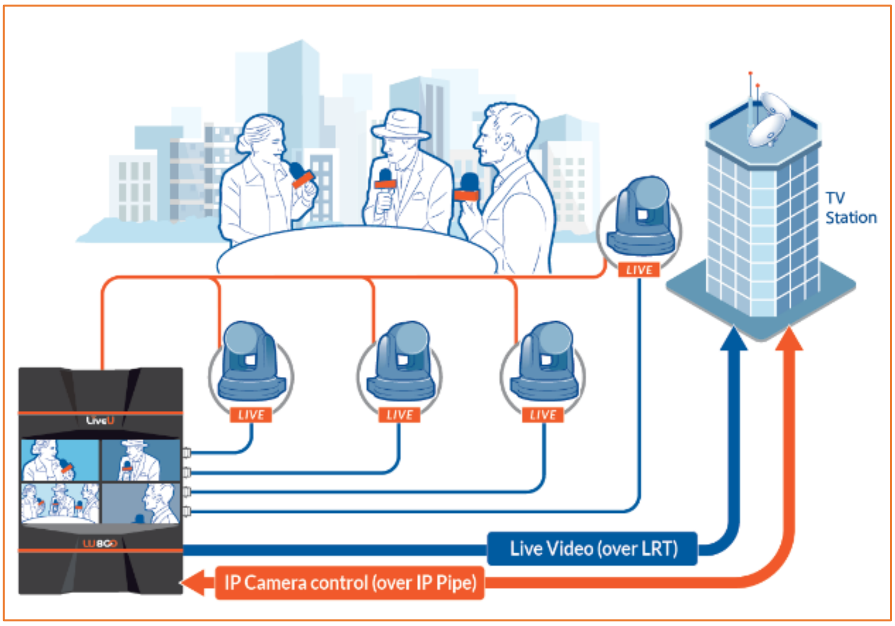


Figure 4. LiveU unit including a video encoder.

4.4.3 RedBee Media

Red Bee Media is the world's leading managed service provider to the media industry. Red Bee Media is trusted to manage and transform complex, mission-critical services with superior expertise for managed content providers aiming at high quality media experiences. Red Bee Media can optimally deliver customers' content to their audience on every device. Through their involvement in 5G-RECORDS, Red Bee will work to develop and test standards for content acquisition through remote production in a live environment. The results will feed into our service delivery and allow us to test technical and commercial models for how remote production could work particularly for tier 2 and 3 events. The outputs will have significant impacts for the sector as live events are more easily, sustainably and efficiently enabled, invigorating linear schedules and supporting smaller content owners to deliver DTC services.

4.5 Broadcasters

4.5.1 BBC

The BBC is one of the world's leading producers of live content in partnership with many facilities providers. We have nearly 100 years of experience in developing technology to improve how we create and distribute media to our audiences.

We have recently opened a state of the art IP based production facility in Cardiff, Wales and this is built on the specific technologies that 5G records seeks to interface with. There is a growing need to service the IP based technology with wireless connectivity to improve mobility, flexibility and reliability of production services.

In 2022 we aim to enhance the facilities in Cardiff by fitting out a studio that to date with enhanced radio technology. There is a desire to use this as flexible space and the project team are open to exploiting suitable technologies emerging from 5G records.

Co-located at this site is a major sporting facility that hosts international rugby and if possible technologies will be extended to provide coverage in this stadium using the same principles established during this project.

The aim will be to leverage local development funds from the UK Government based on knowledge and practical deployments of this technology. BBC will also have a direct exploitation route within 5G-RECORDS by means of contribution to standards, providing a voice for public and private sector media production companies to ensure that content production can remain world class as we move to an IP based world. It will strengthen the competitiveness of the European media sector, ensuring that the results of European leading researchers and innovators in the 5G community can reach end users.

4.5.2 RAI

5G will bring network performance enhancements and agility in the network characteristics, and with that, will play an important role in supporting the growth and development of many industries, the broadcasting and media factories included.

For RAI the 5G technology is expected to build on and integrate the previous generations of wireless networks supporting the expected broadcasters' mobile data growth, outdoor events coverage, and at the same time will allow new services for final users and advertisers.

RAI radiotelevisione Italiana will leverage the 5G-RECORDS project to gain knowledge about new features offered by 5G technology in the area of distributed television production. By using the 5G network and features, RAI will in particular:

- Gain knowledge in IP-end-to-end highly distributed broadcast production workflow, cloud/edge-based video and audio processing and delivery, in 5G era.
- Achieve integration of the media company production workflow with new distributed edge network and computing technologies.
- Define technical and business strategies for procurement of telecommunication infrastructures and services for distributed production

More in general, RAI will leverage the 5G-RECORDS project to gain knowledge about 5G service layer, that will be precious also for future works (research and industrial) in the environment of new generation networks and to study the impact of these technologies in the broadcaster production workflow.

4.5.3 TV2

TV2 thanks to the outcomes of the 5G-RECORDS project will improve their operation and broadcast production. In addition, 5G-RECORDS outputs are expected to have significant impacts for TV2, as live events are more easily, sustainably and efficiently enabled, invigorating linear schedules and supporting small niche output. In this sense, the 5G-RECORDS project will help TV2 to increase their knowledge on 5G components for multiple cameras and remote production.

4.5.4 EBU

The EBU is an association of public service media providers, and facilitates collaboration between its members as well as with wider industry, SDOs and academia. The use cases related to content production are well aligned with a number of ongoing EBU activities such as the 5G for Content Production evaluation group and the work conducted on IP studios, including PTP for synchronisation and in particular the definition of a **ST2110-Gateway and media services orchestration layer currently not existing on the market**. Technical results and the experience gained from this project will also be used to assist its members in their strategic decisions for the adoption of 5G and the interaction with SMPTE 2110 IP based implementation projects. 5G-RECORDS will help to develop innovative 5G-enabled use cases and applications, to identify priorities for further R&D and standardisation efforts and to assist in engaging with the industry partners and the regulators on issues beyond the technical aspects, i.e. 5G deployment models, business arrangements and regulatory conditions. Moreover, the EBU will disseminate the activities carried out by the EBU Members involved in this project (BBC, RAI and TV2) within the EBU working groups and the 5G-MAG association.

4.6 Research

4.6.1 Eurecom

Being a research and teaching institute, EURECOM is situated at a unique place to both follow and apply the state-of-the-art 3GPP standards into the live audio production use case it is involved with, and also contribute the novel methods which will be researched and developed within the project to the relevant standardization activities. In fact, since the beginning of the project proposal activities, EURECOM has already created and been regularly updating its dissemination plan, and started working on that plan following the official acceptance of the project by the European Commission.

EURECOM is an individual member of the 3GPP, and has been monitoring the study items (SIs) “Study on support of reduced capability NR devices (FS_NR_redcap)” and “Study on NR coverage enhancements (FS_NR_cov_enh)” of the ongoing 3GPP Release 17 activities within the context of the project. In fact, EURECOM has contributed the documents “R1-2006880” titled “Limitations of NR short block-length codes for PUCCH coverage enhancement” to the 3GPP Technical Specification Group (TSG) Radio Access Network (RAN) WG1 (Working Group Radio Layer 1) meeting number 102-e in August 2020, and “R1-2008938” titled “Low-PAPR Sequence-Based Approaches for PUCCH Coverage Enhancement” 3GPP TSG RAN WG1#103-e in October 2020, both for the agenda items 8.8.2.2 “PUCCH coverage enhancement”. As the project progresses, EURECOM will start contributing to the FS_NR_redcap SI too.

The equipment and software developed by EURECOM in the context of the 5G-RECORDS project will be made available in the public-domain for future use in collective initiatives. In particular, the software generated during the project will be contributed to the OSA to allow for its use in future collaborative projects and by industry and academia around the world. EURECOM will also publicize the development through official communications in the context of OSA events and publications as well as industry-driven events (Mobile World Congress, NGMN Conference and Exhibition, ETSI-sponsored events, ITU conferences). Moreover, developments in the context of 5G-RECORDS will be followed as official projects within the OSA and regularly communicated on the OAI developer meetings and mailing lists.

4.6.2 UPM

Universidad Politécnica de Madrid, besides its teaching, R&D activities, is highly interested in participating in the exploitation of the outcomes of R&D projects in which it is involved. UPM expects to further improve its understanding of the new possibilities that 5G offers to alleviate deployment, interconnection and transmission challenges associated with the stringent latency and data rate requirements of FVV systems.

UPM will also exploit the experience obtained during the deployment and operation of the FVV system in actual scenarios with a twofold objective of improving the performance and quality of the FVV system and widen its portfolio of scenarios where FVV broadcasting is of interest to final users. In that sense, UPM foresees to include in its portfolio of exploitable technologies, under its Innovatech Program, an enhanced version of its current FVV system. These results and knowhow will be adapted and included to enhance its research activities and used as background knowledge for new project proposals, copyright and patent issues.

4.6.3 UPV

Universitat Politècnica de València will exploit the results and experience gained from the project in further expanding their knowledge base in the field and staying competitive for future wireless research initiatives, in enhancing their teaching scope and quality by introducing new project findings and cutting edge technologies into the teaching and research syllabus at undergraduate, postgraduate teaching and research. UPV plays a central role in expanding the knowledge, teaching and training future engineers working in the fields of telecommunications. They also have the leading role in disseminating research results in major scientific venues. To remain competitive for future research project calls, universities need also to expand their circle of competence and deepen their understanding of future broadcast and multimedia challenges.

5 Dissemination and Communication Plan

5.1 Objectives

The dissemination and communication plan aims to ensure that the outcomes of the project reach all the communities active in the technologies, systems, and services targeted by the project. Thus, the plan seeks:

- Establishing and maintaining a communication link with different parties using the public website where the consortium will be presented, project objectives explained, and public deliverables made accessible. Other means of promoting the project include the use of social media as well as printed communication as appropriate.
- Maximizing the scientific impact by publishing papers in major IEEE conferences and high impact journals. Visibility will also be guaranteed by providing open access to the published versions of the paper on the project webpage and open repositories in compliance with the EC open policy.
- Publishing white papers to describe the project as a whole and to highlights the final results and use of partners' business networks to spread and discuss project progress and results.
- Organizing workshops and tutorials.

Besides, the plan defines quantitative targets for measuring the success of these activities along the lifespan of the project:

Table 5: Minimum project targets for the dissemination and communication activities.

Category	Type	Target
Dissemination	Journal and conference papers	20
	Keynotes and panels	15
	Participations in events and forums	10
	Workshops	4
	Tutorials	2
Communication	Website	1
	Social networks	3
	Audiovisual resources	6
	Press releases	15
Others	Patents	5
	Open source repositories	2

As stated, the key of the plan is to disseminate all aspects of the project among the scientific community, professionals in the 5G sector and the general public. Given the innovative nature of the project, the leader of the dissemination/communication task will request the rest of the project partners to update the project repository with the necessary and updated information for the publication of the activities, articles of interest, and news. The periodicity of these publications will be determined by the progress and news of the project as well as by the progressive achievement of the abovementioned objectives.

5.2 Dissemination Plan

All partners in the project will disseminate project results internally within their organisations and via established networks. Industrial project partners will disseminate through their strong links to industrial events and regulatory bodies where their products, prototypes, development platforms can be shown and ideas for 5G technologies, applications, and infrastructures can be presented. Research and academic project partners will disseminate the project visions and results to educational staff and students, so project ideas can be integrated in different training activities like student projects, incorporation into lectures, etc.

5.2.1 Industrial community

The dissemination plan seeks that the project will be present in major industrial events, for the industry in general and for the 5G and media industries:

- **5G Industry events**: Mobile World Congress (MWC).
- **European Administrations**: CEPT workshops.
- **5G-PPP**: EuCNC conference and ICT conference.
- **Media industry events**: IBC show, EBU Production Technology Seminar, EBU Network Technology Seminar, Forecast and BroadThinking.

All partners will have to show the advances achieved in the project at major international exhibitions and tradeshows, as well as participating in 5G events and fora to publicize those results among industrial research peers and the regulatory community.

The partners will organize demos will be conducted at the most important EC events regularly organized by them in order to be visible in other sectors such as security or e-health.

5.2.2 Scientific community

The dissemination plan has as objective to promote the participation the academic and research partners in international scientific conferences, the organization of workshops, presentations, keynotes, Info days, training and tutorials:

- **High quality scientific publications**: EuCNC, BMSB, VTC, ICC, Globecom, WCNC and ICME. Targeted journals include the IEEE Transactions on Broadcasting, IEEE Transactions on Communications, EURASIP Journal on Wireless Communications and Networking and EBU's Technical Review.
- **Workshops, presentations and keynotes**: IEEE 5G summits, the IBC show, innovation seminars, relevant technical assemblies, telecom and EU policy making events or international scientific symposia.
- **Info days, training and tutorials**: Tutorials will be organized in conjunction with IEEE conferences and EC's Marie Curie European Training Networks (ETN) such as JOLT. The project will also organize info days in parallel with major IEEE workshops and tutorials.

5.3 Communication Plan

To help reach out the general public, 5G-RECORDS has designed four action lines that will ensure that the work within the project will be exposed to a wide range of communities for their interest and their participation.

- Designing **public website** where the project target and deliverables will be presented.
- Creating **audiovisual resources** to promote the project.
- Drafting **press releases** where the partners will exhibit their results.
- Opening three **social networks** accounts to spread the project advances and outcomes.

The communication activities will be coordinated by the task leader who will provide the consortium partners the project advances and will guarantee their access and encourage their active participation.

5.3.1 Website

A project website has already been set up at www.5g-records.eu and will be regularly updated with all public information that will also facilitate contacts and exchanges with other research and industrial initiatives on the relevant topics. Videos will be available for high-speed download and streaming, and some project tools may be made available for download by the public. The project will also distribute its own newsletter.

The project website contains static contents (e.g. main project objectives, consortium, use cases, infrastructure, etc.) and dynamic contents (e.g. partners' news, videos, events, etc.). The website also includes a section where dissemination activities will be collected together with their respective references (e.g. scientific publications, presentations, public deliverables, etc.).

To support the ongoing population of the website, all of project partners will have to provide with up-to-date and public information related by the project to the task leader.

All the partners will promote the website using information and links through their own websites, company events, social networks, etc.

5.3.2 Press Releases

In order to disseminate the results and the partial scope of the project, as well as a better understanding of it, a publications plan of press releases related to the main activities or milestones of the project has been designed.

The project aims to deliver a large number of releases to be published along the project lifetime. All partners are committed to public a press release within 2021. The minimum list of press releases, together with their drafting partners, is listed in the table below.

Table 6: Minimum list of press releases.

Type	Name	Leader	When
Overview	The key challenge of 5G-RECORDS	UPV	2020
Components Definition	5G microphones and In-Ear-Monitoring (IEM) systems	Sennheiser	2021
	Spectrum sharing management technologies	RED Technologies	
	Compact 5G Core	Cumucore	
	Dynamic Profile Controller		
	dRAX platform	Accelleran	
	5G-enabled cellular bonding	LiveU	
	OAK module	Image Matters	
	Edge computing platform	Telefónica	
	Free Viewpoint Video	UPM	
Use Cases	Live audio production	Sennheiser	2021
	Multiple camera wireless studio	BBC/EBU	
	Live immersive video production	NOKIA/UPM	
Outcomes	Achieved goals	UPV	2022

	Results	Nokia / Eurecom / Ericsson	

In addition of these assigned press releases, each project partner shall deliver, at least, a general press release per year concerning its work for the project, which shall be published on its own website and upload to the repository of the project.

5.3.3 Social Networks

As online media are very effective, its use will be adopted by the project. Thus, results and updates should appear on social networks, and, therefore, pages will be opened on Twitter and LinkedIn as well as an account on YouTube.

Social networks, mainly Twitter and LinkedIn, will be automatically fed as soon as some content is published on the website. Social networks require their own narratives and visual languages, as well as assiduity in publications, so the participation of all partners in this task is essential. In this sense, once the social networks of the project have been opened, the partners should inform the task leader of each of the news, providing texts and visual content and the community manager of the package will be in charge of publishing.

All the project's own publications on social networks will be accompanied by the following hashtag: # 5grecords, however, more hashtags may be added according to the content of the publication. Mentions to the project coordinators and funding agencies should also be added: @UPV, @5GPPP and @EU_H2020.

5.3.4 Audiovisual resources

5G-RECORDS considers that audiovisual content delivery is a must for the project outreach. Thus, a strategy for video content creation has been designed to be able to show in a friendly and compact way the objectives, the use cases and the outcomes of project.

The table below lists the videos that will be produced throughout the project with the partners who will have to create them.

Table 7: Videos.

Type	Name	Leader	When
Overview	The key challenge of 5G-RECORDS	EBU/UPV/UPM	2020
Components Definition	5G microphones and In-Ear-Monitoring (IEM) systems	Sennheiser	2021
	Spectrum sharing management technologies	RED Technologies	
	Compact 5G Core	Cumucore	
	Dynamic Profile Controller		
	dRAX platform	Accelleran	
	5G-enabled cellular bonding	LiveU	
	OAK module	Image Matters	
	Edge computing platform	Telefónica	
	Free Viewpoint Video	UPM	
Use Cases	Live audio production	Sennheiser	2021
	Multiple camera wireless studio	BBC/EBU	
	Live immersive video production	NOKIA/UPM	

Outcomes	Achieved goals	EBU/UPV/UPM	2022
	Results	Nokia / Eurecom / Ericsson	
Media	Media services orchestration	BBC/EBU	2021
Broadcasters	RAI and 5GRecords	RAI	2021
	TV2 and 5GRecords	TV2	2021
	Red Bee and 5GRecords	Red Bee	2021

Each video duration should not exceed three minutes and all of them should be subtitled for a wider scope, thus enlarging the project outreach.

It is expected that the number of the produced videos will increase as the project advances progress.

5.4 Procedure related to publications by consortium partners

All communication and dissemination activities shall be recorded in the project repository, where all project information will be gathered for the communication and dissemination plan.

The procedure for uploading the information is detailed below:

1. The partner should go to the project repository and choose the option on the menu where the information will be uploaded.
2. There is a procedure within each section to upload the information, documents and/or links required for the publication.
3. After uploading, the partner should send an email to the WP6 reflector mail informing about the new publication.

'The WP6 task leader will put the relevant publications, or the links to them, on the project public website and/or social networks as appropriate to foster the dissemination and communication of the project outcome.

This procedure will also help the elaboration of the forthcoming deliverables of WP6 as an structured and updated information is gathered along the lifespan of the project.

6 Conclusions

This deliverable summarizes:

- Potential standardization individual plans
- Exploitation individual plans
- Regulatory issues that will be addressed in the forthcoming months
- Dissemination and communication plan

In terms of standardization, major contributions are expected to 3GPP, ETSI, VQEG, MPEG, ITU, O-RAN Alliance, AMWA and SMPTE

The individual exploitation plans will target different objectives depending from the nature of the partner and in particular will allow to enhance products and services portfolio to increase the knowledge, to scale up business and revenues, to influence strategy decisions and to integrate hardware and software to develop new components currently not existing on the market.

The dissemination and communication plan has defined a set of objectives to ensure the success of the dissemination activities along the lifespan of the project. In this way, the plan will maximize the scientific and industrial impact of the project, guaranteeing its visibility in all the communities active in the technologies, systems, and services.

A Use-cases and components description

A.1 UC1: live audio production

In a typical live audio production setup for e.g. music concerts, music festivals, TV shows or theatres the artists are equipped with Programme Making and Special Events (PMSE) equipment, such as wireless microphones and wireless IEM systems.

The term PMSE equipment is used to describe radio applications used for broadcasting, newsgathering, theatrical productions and special events and applications used in meetings, conferences, cultural and education activities, trade fairs, local entertainment, sport, religious and other public or private events for perceived real-time presentation of AV information.

Professional PMSE applications fall into three broad categories: (i) audio links, e.g. wireless microphones, in-ear monitors, talk-back systems; (ii) video links, e.g. cordless cameras; and (iii) service links, e.g. telemetry and remote control.

This use case will concentrate on 5G wireless microphones, IEM (In-Ear monitoring) systems, monitoring, control tools and gateways between 5G and traditional audio infrastructure domain.

The latency of the audio signal from the microphone to the IEM system is the most critical parameter and if it exceeds a certain threshold (e.g., 4 ms) the artist will not be able to perform anymore. An additional challenge is to accurately synchronise all audio sources over the network to produce a combined audio mix.

Wireless live audio productions require high communication reliability as well as ultra-low signal delay. In particular, the most important KPIs to be met are the round-trip latency from analogue input at microphone side to analogue output at IEM side, also called mouth-to-ear latency, the time synchronicity at application layer, and reliability. This use case contains 4 main areas of a wireless scenario: capturing live audio data, temporary spectrum access, automatic setup of wireless devices and local high-quality network.

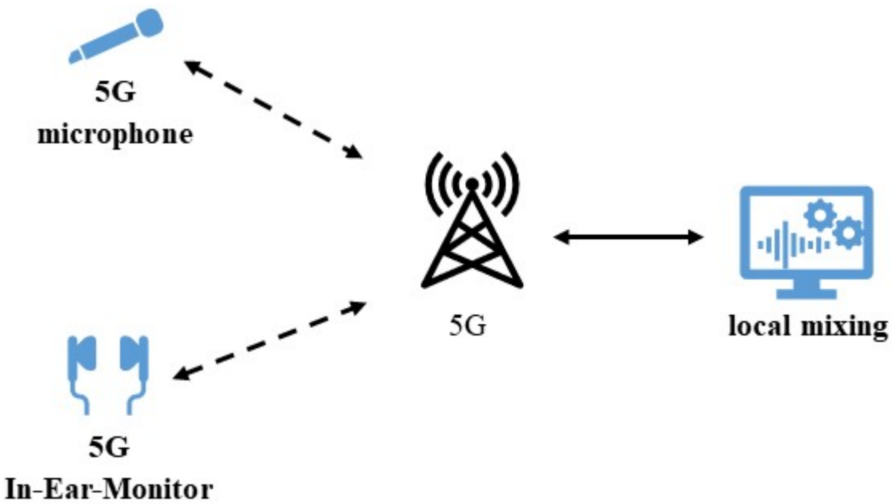


Figure 5. Live Audio Production use case.

A.1.1 UC1 Components

The 5G components of the live audio production use case are shown in Table 8.

Table 8. Main 5G components of UC1 Live Audio Production.

Partner	5G Component
Cumucore	A compact 5GC with new integrated network functions
Accelleran	Accelleran dRAX is a cloud native 4G and 5G vRAN solution with a near-RT RIC, CU CP, CU UP and xApp framework components. One of the xApps will enable spectrum sharing client functionality.
RED Tech	Spectrum sharing management technologies.
Eurecom	Completely open source 5G modems to connect media specific devices to the 5G network.
Sennheiser	5G-enabled wireless microphones and wireless In-Ear-Monitor (IEM) systems

- **Cumucore**

Cumucore 5GC will be integrated in UC1 (see Figure 3) and will provide the 5G Core functionalities needed for this use case and integrate them into a new combined module.

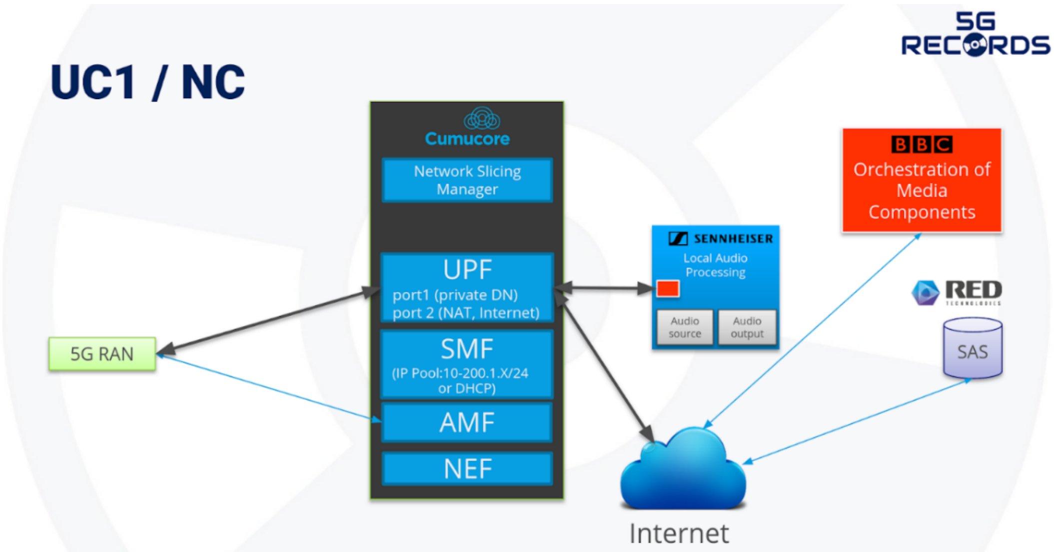


Figure 6. Cumucore in UC1.

Cumucore 5GC is 3GPP Rel15 compliant and includes the modules depicted in Figure 4.

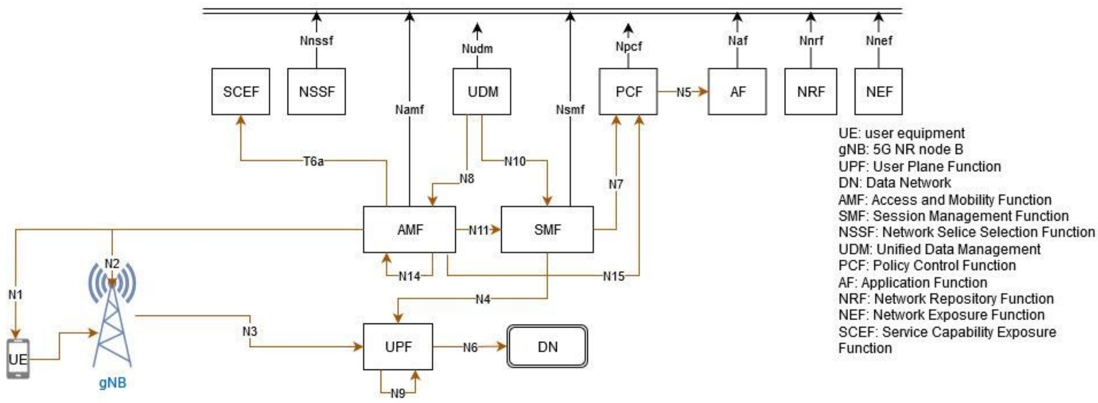


Figure 7. 5GC architecture and interfaces.

5GC includes all the required functionality for interoperability with 3GPP Rel 16 and has been tested with different RAN (Radio Access Network) vendors. The current release of 5GC includes the network functions from Service Based Architecture (SBA) required for supporting network slicing i.e. Network Slice Selection Function (NSSF) and discovery of Multi-Access Edge Computing (MEC) through the Network Repository Function (NRF).

Cumucore's proprietary Software-defined networking (SDN) Mobile Backhaul Orchestrator (MBO) integrates SDN to dynamically manage network resources in the backhaul to deploy network slices. The MBO provides SDN component connected directly to eNB/gNB to encapsulate GTP-U into Ethernet, MPLS or GRE. The MBO manages the SDN switches in the backhaul as shown in Figure 5. It registers into the NRF so it can be discovered by AMF that will indicate the TEIDs to be encapsulated into specific VLAN or MPLS tags for routing the traffic as part of selected slices.

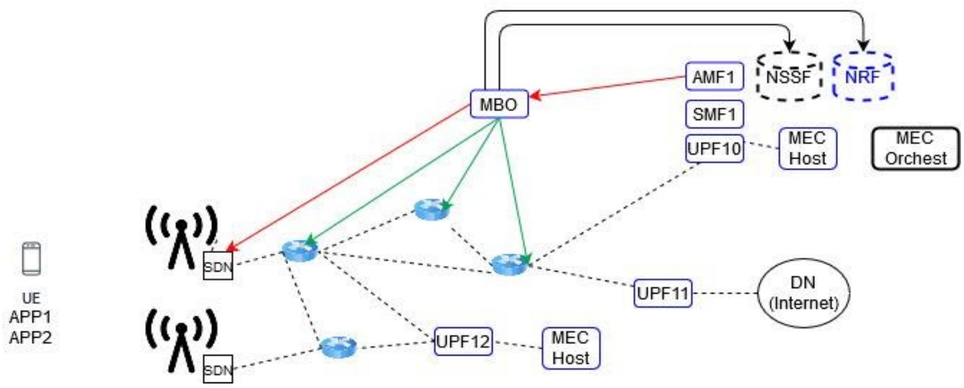


Figure 8. 5GC architecture integrated with SDN Mobile Backhaul Orchestrator.

The MBO includes a machine learning function that based on user data collected through LLDP from SDN switches will calculate disjoint paths using Dijkstra. The MBO takes into use the disjoint path when congestion or link break is detected to deliver reliable and low latency communication for selected users i.e. IMSI/TEIDs. The graph in Figure 6 shows that 5GC architecture integrated with SDN MBO including NRF and NSSF for network slicing delivers Ultra Reliable Low Latency Communications despite broken links or network congestion.

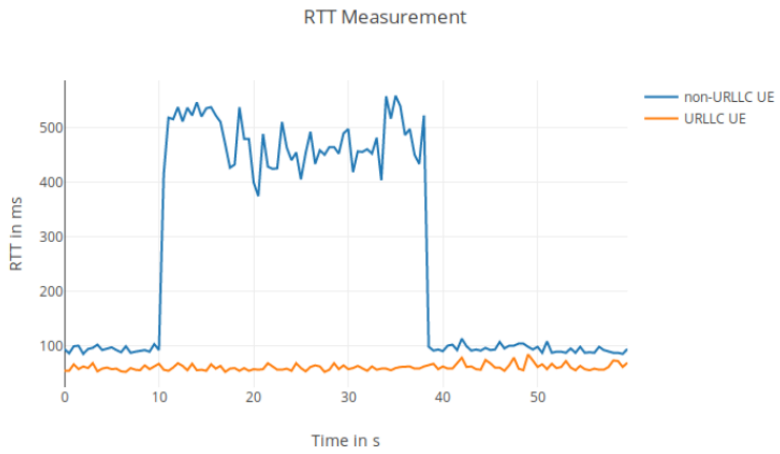


Figure 9. Round Trip Time (RTT) results of network congestion impact to URRLC traffic with MBO managed slices.

Delivering several virtual networks from one physical network is enabled by Network Slicing Manager. Network Slicing Manager can define slice sizes, different quality of service per slice, traffic rules per slice including prioritization and pre-emption rules. Through Network Slicing Manager you can manage access right to the network slices in the multitenant use case.

The 5GC can be configured with IPSec to secure the connection between RAN and Core network elements.

The 5GC security includes the following levels of authentication.

Primary authentication: This is mandatory and currently implemented in 5GC for mutual network and device authentication. 5GC includes the 5G Authentication and Key Agreement (5G-AKA) and Extensible Authentication Protocol (EAP)-AKA. 5GC uses EAP-AKA for device authentication in non-3GPP technology such as IEEE 802.11 WLANs. The EAP-AKA is also used for device provisioning for devices with eSIM e.g. Apple devices.

Secondary authentication: This is optional and used for authentication with data networks outside the mobile operator domain. This feature is not currently implemented by Cumucore.

Service Based Architecture (SBA): The 5GC is based on a service-based architecture using TLSv2 with OAth.

Supported features are:

NG signalling transport (3GPP release version R15.2.0 (2019-07), Data link layer, Ethernet,IP layer, Support of IPv4, Support of IPv6, Support of Diffserv Code Point marking ,Transport layer, SCTP (IETF RFC 4960), configuration with a single SCTP association per NG-RAN node/AMF pair, configurations with multiple SCTP endpoints per NG-RAN node/AMF pair

Data transport (3GPP release version R15.2.0 (2019-07), Data link layer, Ethernet, DPDK, NG Interface user plane protocol, GTP(General Transport Protocol)-U protocol over UDP over IP, GTP-U, UDP/IP, support of fragmentation and assembly of GTP packets at IP layer, Support of IPv4, Support of IPv6, Diffserv code point marking

NG Application Protocol (NGAP) (3GPP release version R15.3.0 (2019-03), PDU Session Management Procedures, UE Context Management Procedures, UE Mobility Management Procedures, Paging Procedures, Transport of NAS Messages Procedures, Interface Management Procedures, Warning Message Transmission Procedures, NRPPa Transport Procedures, Trace Procedures, Location Reporting Procedures, UE TNLA Binding Procedures, UE Radio Capability Management Procedures, Data Usage Reporting Procedures, PDU Session User Plane protocol, 3GPP release version R15.1.0 (2018-09) and R15.2.0 (2018-12), Elementary procedures, Transfer of DL PDU Session Information, Transfer of UL PDU Session Information, Elements for the PDU Session user plane protocol, General, Frame format for the PDU Session user plane protocol, DL PDU SESSION INFORMATION (PDU Type 0), UL PDU SESSION INFORMATION (PDU Type 1), Coding of information elements in frames, PDU Type, Spare, QoS Flow Identifier (QFI), Reflective QoS Indicator (RQI), Padding, Paging Policy Presence (PPP), Paging Policy Indicator (PPI))

➢ Accelleran

Accelleran brings dRAX™, a cloud native and O-RAN aligned 5G SA vRAN solution consisting of a near-RT RAN Intelligent Controller (RIC), CU-Control Plane (CU-CP), CU-User Plane (CU-UP) and xApp framework components.

Accelleran dRAX™ is the marketing name for Accelleran´s virtual RAN product line. dRAX™ is engineered to provide an open and extensible software framework for the control plane functions of 4G and 5G RAN and aligns with Open RAN architecture principles defined by both 3GPP and the O-RAN Alliance.

dRAX™ is a genuinely cloud-native architecture based on containerised microservices communicating with each other via an asynchronous messaging framework. Each of the major components of the RAN (CU-CP, CU-UP, near-RT RIC) are themselves disaggregated into a fine-grained set of service entities. For example, the CU-CP is composed of a set of collaborating services handling:

- F1AP connections to DU
- E1AP connections to CU-UP
- NGAP connections to AMF
- RRC connections to UEs

The lifecycle (deployment, upgrade, scaling requirement) of these components are managed independently and they are unaware of location since the dRAX™ messaging framework handles routing of all messages between services.

The near-RT RIC is a key component of dRAX™. It supports the deployment of xApps (again as microservices) and provides them with a number of services in the context of the dRAX™ environment.

dRAX™ leverages Accelleran field-proven RAN software and is compatible with Accelleran 4G CE certified carrier-grade small cells and supports 5G gNB using standards-based DU/RUs from the developing ecosystem of 5G Open RAN.

To summarise, the key features of dRAX™ are:

- O-RAN aligned vRAN: The Accelleran dRAX™ vRAN platform delivers a true multi-vendor, disaggregated and open virtualized RAN Intelligence aligned with the O-RAN Alliance. Implementing 3GPP Control User Plane Separation (CUPS), the user and control planes are fully decoupled. Support for 3rd party DUs, RUs & e/gNB encourage an open disaggregated eco-system to bring innovative 4G/5G products to the commercial market at very competitive price points.

- Open Orchestration & Data APIs: dRAX™ is open. Orchestration supports the industry preferred Network Function Virtualization (NFV)/SDN framework APIs above and the NIB (Network Information Base) data APIs support industry standards and best practices (NFV/SDN, O-RAN, OAM, 3GPP, Netconf/Yang, …).
- 4G and 5G SA support: dRAX™ is field proven today for LTE and is being integrated with 5G SA support, leveraging standards-compliant Distributed Unit (DU)/ Radio Unit (RUs).
- Extensible RIC xApps: dRAX™ provides an open platform for the development of customised RAN intelligence, either by the customer, Accelleran or 3rd parties.
- Scalability: dRAX™ can be implemented on a single microserver for the smallest edge cloud. At the other end of the scale, dRAX™ is designed to scale to clusters of hundreds of cells.
- Mission Critical Reliability: All dRAX™ code is written to Accelleran's unique set of SW development standards based on established practices from safety critical industries.

Accelleran dRAX™ (Figure 7) will be enhanced to support the requirements of the live audio production use case and will be integrated with the other needed 5G components on the associated use case testbed, namely the 5GC from Cumucore, DU/RU from Eurecom and Shared Access Spectrum server from RED Technologies.

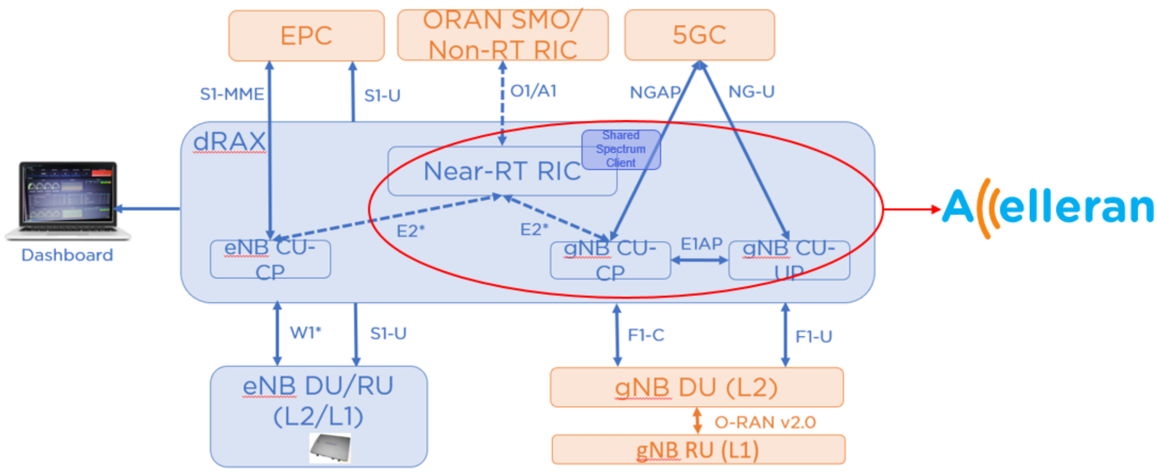


Figure 10. Accelleran dRAX™ in UC1 Live Audio Production

Near-RT RIC

The near-RT RIC (Near RealTime RAN Intelligent controller) shown in Figure 8 is a key component of dRAX™. It has been developed as a true open development platform where 3rd parties can leverage dRAX™ open data and control knobs.

It supports the deployment of containerized xApps and provides them with a number of services in the context of the dRAX environment:

- xApp on-boarding and lifecycle management
- Access to real-time RAN measurements and events
- Configuration of RAN components
- Real-time commands to direct RAN behaviour (eg force a handover, sub band masking)
- Real-Time state database
- Inter xAPPS communication
- API-driven xAPP configuration and policy management

CU-CP and CU-UP

Figure 8 shows the internal CU-CP and CU-UP components.

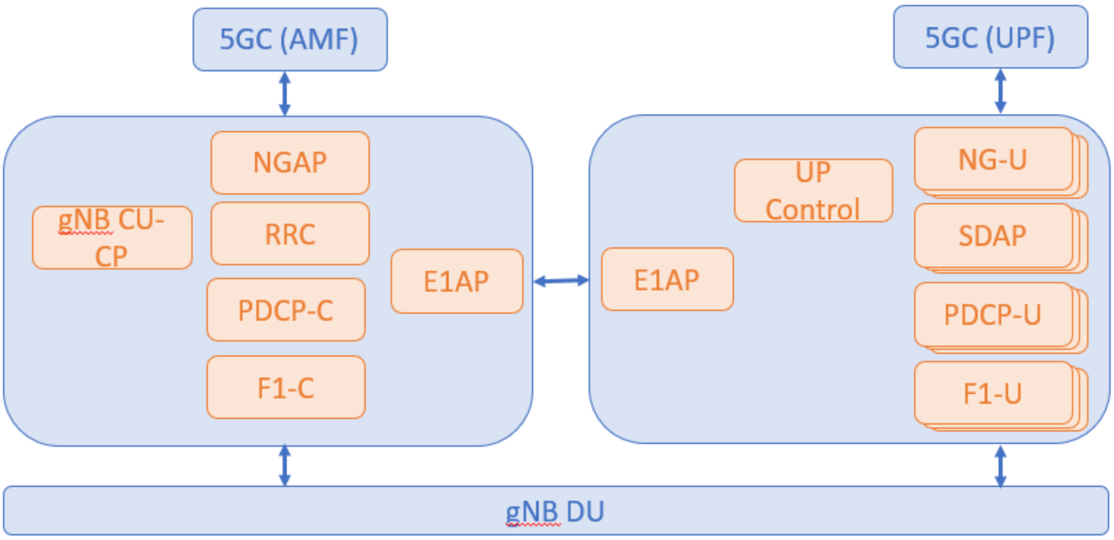


Figure 11. Accelleran CU components

The gNB-CU-CP is a logical node hosting the RRC and the control plane part of the Packed Data Convergence Protocol (PDCP) protocol of the gNB-CU for a gNB. The gNB-CU-CP terminates the E1 interface connected with the gNB-CU-UP, the F1-C interface connected with the gNB-DU and the NG-C (N2) interface connected to the AMF in the 5GC.

The gNB-CU-UP is a logical node hosting the user plane part of the Packed Data Convergence Protocol (PDCP) protocol and the Service Data Adaptation Protocol (SDAP) protocol for a gNB. The gNB-CU-UP terminates the E1 interface connected with the gNB-CU-CP, the F1-U interface connected with the gNB-DU and the NG-U (N3) interface connected to the UPF in the 5GC.

xApp Framework (Shared Spectrum Access xApp)

The Accelleran xApp framework will be used to enable and enhance Accelleran´s CBRS Shared Spectrum Access client based on LTE to support the 5G-NR functionality needed to communicate with RED Technology Shared Access Spectrum server for the acquisition of 5G shared spectrum dynamically.

➢ RED Technologies

RED Technologies brings the spectrum sharing component. The SAS server is responsible for determining the maximum allowed transmission power of each device.

The architecture of the SAS server is envisioned as shown below:

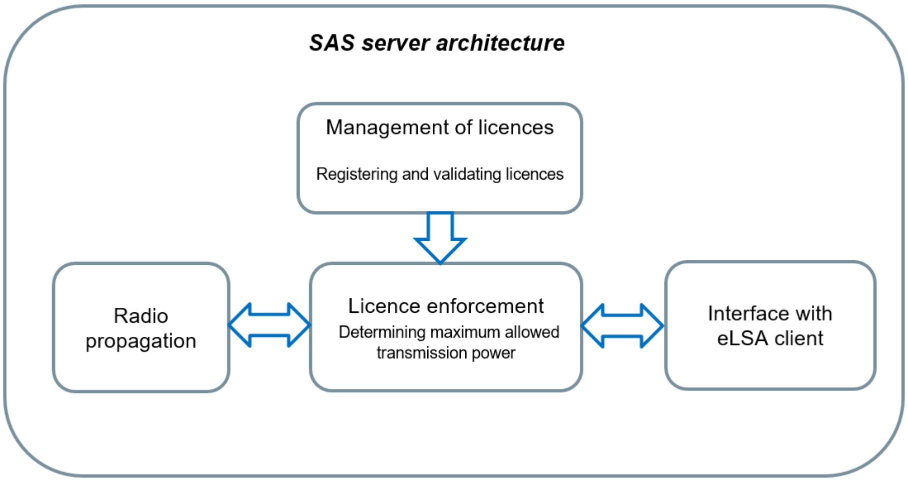


Figure 12. SAS server architecture.

Interface with eLSA client

1. **Device registration** (e.g., 5G Small Cell): During registration, parameters required for interference protection shall be provided to the SAS server, including the localization and the antenna related parameters.

2. **Handling of requests to access spectrum:** Prior to begin transmissions, each device shall provide to the SAS server the frequency range and transmission power over which it wishes to operate.

3. **Real-time control of spectrum grants**: The SAS server shall receive heartbeats from devices at regular intervals. This would enable to move a device to another frequency when a more suitable frequency is identified and to update the transmission power as needed (e.g., to give a higher maximum allowed power).

Management of licenses

1. **Identification of an area to be licensed** (both frequencies and zone): Based on the planned deployment, desired transmission power, and radio environment the SAS server shall determine the license contour and identify the most suitable frequencies.
2. **Permanent license creation / activation**.
3. **Temporary license creation / activation** (lease).

License enforcement / protection from interference

For each license area, the SAS server shall make sure that the aggregation of emissions from all devices (e.g., all 5G small cells) located outside this area is below a pre-defined threshold.

This could be ensured by (i) computing the path loss between each device and each point within the license area; (ii) verifying that the aggregation of transmissions from all devices (based on the requested transmission power) is below the pre-defined threshold and, if needed, (iii) reducing the maximum allowed transmission power of some devices.

- **Eurecom**

EURECOM will supply and support the OpenAirInterface (OAI), which is the first and only open source project that provides fully working 3GPP Rel-15 compliant reference implementations of the 5G New Radio (NR), gNodeB (gNB) and core network (5GC). The user equipment (UE) in the Live Audio Production (LAP) use case are microphone and in-ear-monitors that are to be provided by Sennheiser, and connected to the off-the-shelf and modern Ettus Research Universal Software Radio Peripheral (USRP) software defined radio (SDR) platforms through IP gateway devices and over the Ethernet protocol. Experimental radio hardware instead of a commercial product is deliberately chosen in order to be able implement and experiment with the relevant subjects of the constantly evolving 3GPP Rel-17, and also to research and develop novel techniques within the project that are to be patented and contributed to the 3GPP standardization activities simultaneously. On the software side, OAI will communicate with Accelleran's dRAX over F1-U and F1-C interfaces.

- **Sennheiser**

Goal of 5G-RECORDS UC1 is to research the feasibility of utilizing 5G as technology for wireless ultra-low latency audio devices. For this purpose, Sennheiser will contribute rapid-prototyping audio IP gateway devices. The gateways will allow to connect conventional analog audio devices, such as wired microphones and In-Ear-Monitors, to a 5G system and provide sufficient flexibility and processing power to achieve highly optimized low latency interfacing with 5G modems / SDRs and 5G core (see Figure 10).

A wired microphone and a gateway device will act as a 5G-enabled microphone. The combination with a 5G modem / SDR acts as a rapid-prototyping 5G microphone UE. The corresponding 5G IEM UE consists of a wired In-Ear-Monitoring, an audio IP gateway and a modem / SDR. A third audio IP gateway will be connected to the local audio processing for low latency mixing and the 5G core.

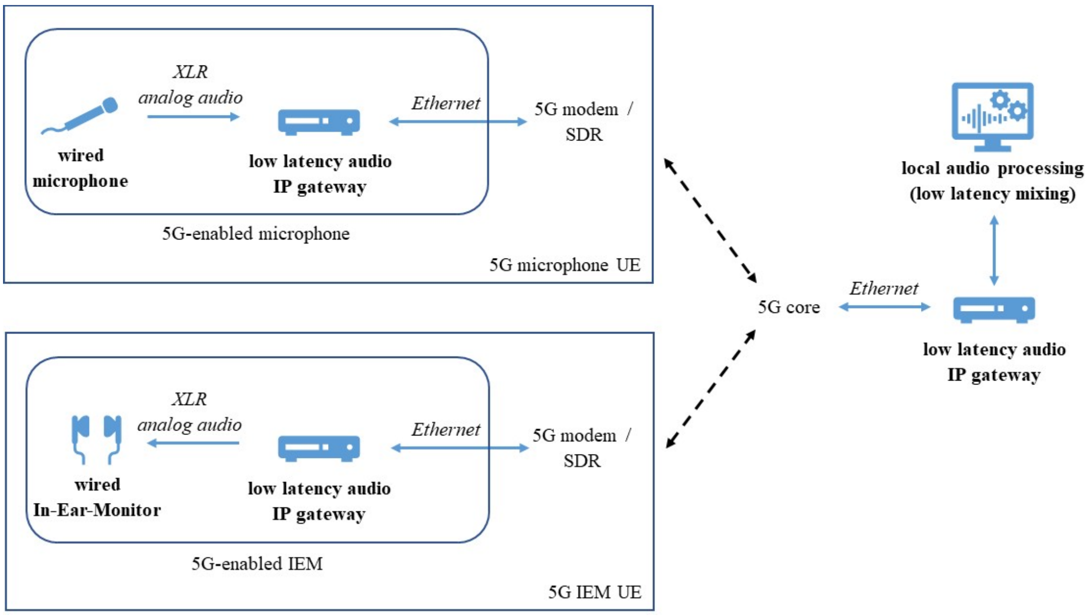


Figure 13. 5G-enabled microphone and in-ear-monitor

A.2 UC2: multiple camera wireless studio

This use case (Figure 11) contemplates the deployment of an outdoor production scenario with two or more 5G-enabled cameras and sound capture devices connected to a Non-Public Network (NPN) in a remote location, which acts as an appendix of the indoor TV studio. In here, remote cameras will be controlled from the broadcast centre located in the studio. Multiple TV cameras, microphones, intercom systems and monitoring devices will be connected over radio links to the 5G gNB or using device to device direct communications.

A wide range of resolutions and compressions will be used. The studio will be established in Aachen (Germany) and controlled remotely by the director to test multiple video and audio feeds, talkback, autocue, and vision mixing. In addition, the director will use incoming data feeds or sensor information from the performers at the event to create augmented user experiences. The remote cameras will be tested on both UHD and HD resolutions and synchronised audio and video will be returned to the broadcast centre for processing. On the return path camera control and communications data will be carried.

This use case can be tested and optimised for both private and public networks with a likely scenario being 5G NPN at both the broadcast centre and remote location connected via a Public Land Mobile Network (PLMN) with a dedicated network slice. On location, some device to device communication services will be deployed such as connection of a radio mic to a camera.

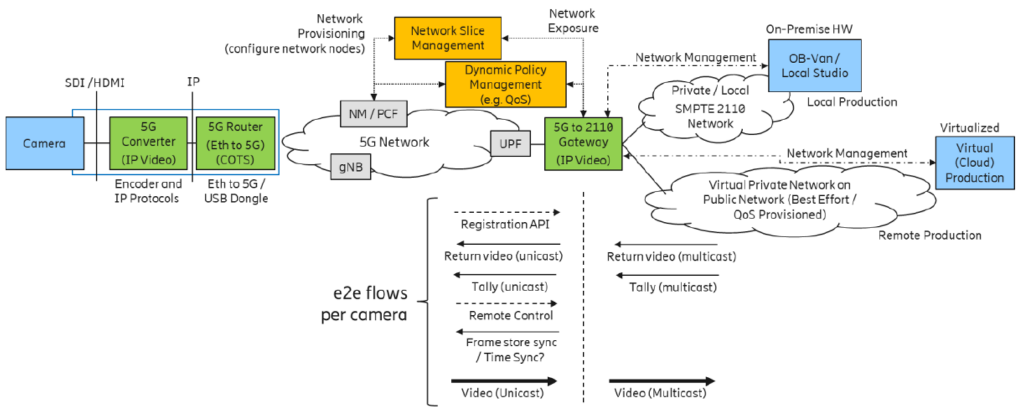


Figure 14. Multiple wireless cameras scenario

All Camera and OB van content destined for Virtual Cloud Production will be routed via an IP defined broadcast master control facility (Red Bee Media MCR) that provides contribution, processing and onramp to virtual cloud production.

A.2.1 Components

The 5G components of the multiple camera wireless studio use case are shown in Table 9.

Table 9. Main 5G components of UC2 Multiple Camera Wireless Studio.

Partner	5G Component
Ericsson	5G components on mid- and high-bands as well as NPNs Support functional specification of the protocol and procedures between 5G PMSE devices and SMPTE2110 – 5G Gateway.

Cumucore	Network slicing and management systems based on software defined networks
LiveU	5G-enabled single modem and bonded modems dynamic video encoding & transmission, or multi-IP transmission without video encoder – depending on UC evolution. Software for the receiving side server/Gateway with interface to SMPTE. The solution will support delivery of additional signals/IP signals to serve the Wireless Studio UC
Image Matters	O²-Galena is a camera platform for 5G Broadcast. O² Galena receives video and audio signals either from sensors or from external devices. It encodes and packages them for 5G-transport toward non-public 5G network and, further, toward a remote location (studio). O² Galena is locally connected to human and machines enabling a remote communication and control with and by the remote studio.
EBU, RAI	An *SMPTE ST2110 – 5G Gateway* to enable professional production 5G wireless studios and support the integration of a *media orchestration layer.* In particular, the gateway will get unicast RTP streams from the 5G Core, perform decoding and transmission of the uncompressed stream as ST2110 into a local IP network. From the local IP network, the gateway will subscribe to the local multicast uncompressed video/audio streams, compress them using H.264 and send them as RTP unicast streams to the 5G Core. The gateway will also send the compressed streams with SRT/RIST protection on top to a remote location or to the cloud
Fivecomm	5G gateway development for video cameras at the UE side. The gateway includes two modules, i.e. the video encoder that translates SDI/HDMI inputs into IP video, and the 5G modem that provides connectivity to the network.
BBC	Media Orchestration layer
RedBee	Cloud based MCR development and operational feasibility validation

- **Ericsson**

The 5G system is initially based on 5G Non Stand Alone (NSA) setup (Figure 12) and will be migrated during the project to an SA (Stand Alone) setup (Figure 13). The 5G system includes RAN nodes and core network nodes. For the NSA 5G system, the RAN nodes include eNBs (for LTE anchor) and gNBs. The core network nodes include Serving Gateway (SGW), Packet Data Serving Gateway (PGW), Mobility Management Entity (MME), Home Subscriber Server (HSS) and Policy and Charging Rules Function (PCRF). The PGW is the entry for an external content server into the mobile system. The content server is the ST 2110 / 5G Gateway for the Multi-camera wireless studio use-case. For the standalone system (SA) setup, the core network nodes are migrated to UPF, AMF, SMF, UDR and PCR. The ST 2110 / 5G Gateway connected to a UPF.

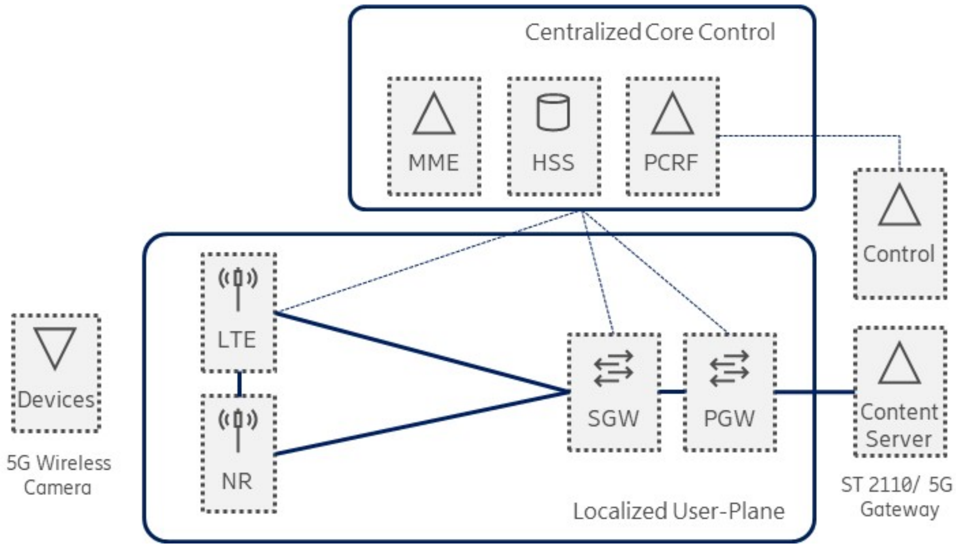


Figure 15. Ericsson Non-Standalone (NSA) setup

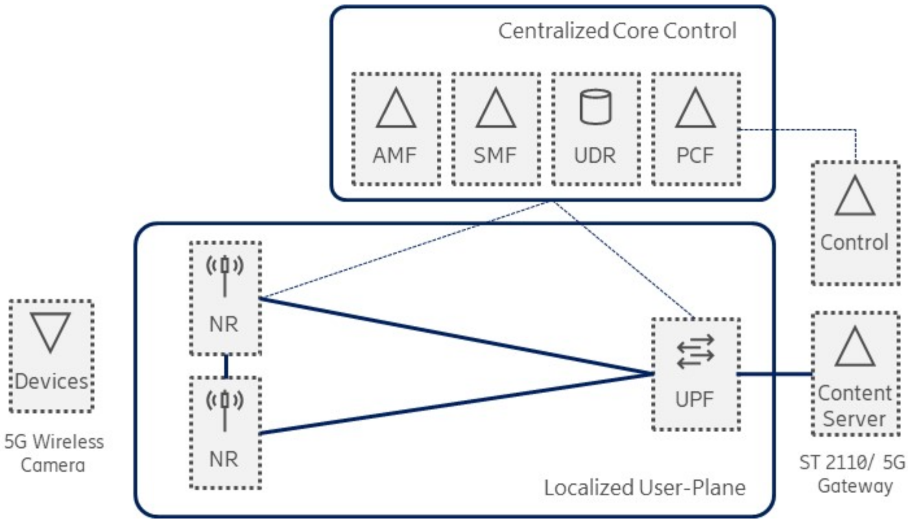


Figure 16. Ericsson Standalone setup

The lab test system can be operated with different radio carriers. The prime focus is on the 3.8GHz industry band (mid band). Support for high band radio carriers need to be coordinated.

To configure different traffic handling policies such as QoS flows, etc, a PCF is provided in the setup. Support for QoS flows is needed to separate IP flows from each other, e.g. to configure a higher priority for the program video flow than for the interactive intercom. For each QoS flow, a traffic priority, a packet delay budged (PDB) and a packet error rate (PER) are defined. When the QoS flow is a GBR QoS flow, then also a Guaranteed Bitrate (GBR) is configured. The PCF exposes the Npcf API which can be used to create QoS flows dynamically. Note, one or more QoS flows can be carried within a Network Slice.

The test system is configured as a Standalone Non-Public Network (SA-NPN). It is expected that Network Slices are more relevant for Public Network Integrated NPNs (PNI-NPNs).

For the trial system, the plan is to work with the 5G Industry Campus Europe (ICE) at the RWTH Aachen Campus and to leverage the outdoor coverage. The architecture for the Industry Campus Europe Network is very similar as the lab setup. The outdoor coverage is realized using 3.7GHz tp 3.8GHz NR carrier (Industry spectrum).

Ericsson supports the functional specification of the protocol and procedures between 5G PMSE devices and SMPTE2110 – 5G Gateway, focusing specifically onto network usage aspects. This includes the need for different (static of dynamic) QoS flows or the need for different Network Slices or PDU Sessions.

➢ Cumucore

For this use case, Cumucore will provide Network Slicing functionality. Network Slicing means that one physical network can deliver several logical networks that has no dependency between themselves. If one Network Slice has reached its capacity limit it has no impact on the other slices.

Network slicing can be used to provide different slices per application type, e.g. video and voice. Another way to organize slices is per organization, e.g. HR and production, or per type of devices, e.g. machine type communications (MTC) or personnel communications.

Network slices can have different service characteristics, downlink capacity, uplink capacity, delay and jitter. Network Slicing Manager provides an easy to use user interface to manage Network Slices and it ensures that data streams can meet the Service Level Agreement it has been assigned.

The Network slicing manager architecture and interfaces are represented in Figure 14.

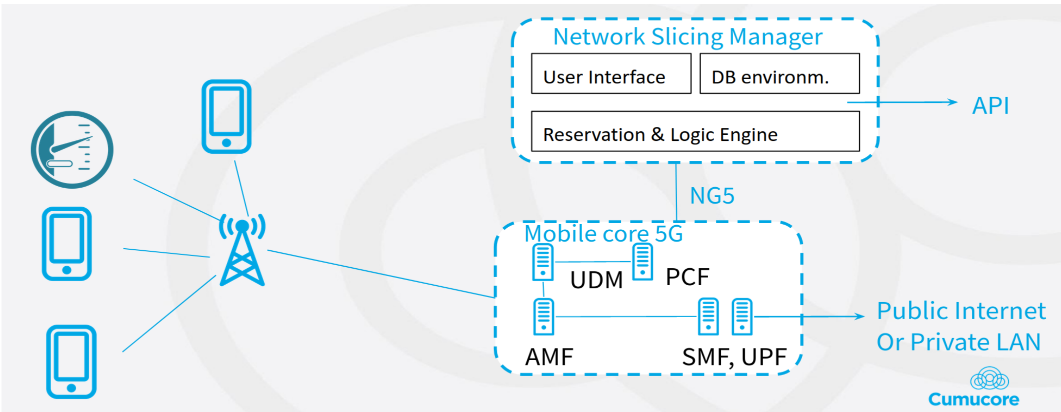


Figure 17. Network Slicing Manager architecture and interfaces.

Available capacity (Mbps) depends on the used frequency bandwidth and what kind of modulation can be used for a data stream. By ensuring that resource allocation demand in a slice will not exceed the resource supply, Service Level Agreement (SLA) for a single data stream can be delivered. If a mobile device is moving in a cell the resource allocation for that data stream needs to compensate for the changes in the modulation.

Delay (ms) = transport time (constant) + queuing (variable). Low delay SLA data streams need to be assigned queuing privilege inside the delay budget, e.g. only a certain number of data streams can have a delay SLA.

Network slices can be run according to two business models:

Production company operated NPN:

Private mobile networks are using licensed frequency. In this case the production company needs to manage the frequency licence. Production companies are the only users of the network and they would like to use the same network on temporary bases in different locations. This will set a requirement for a frequency regulation in the country. From the Network Slicing point of view in this scenario Network Slices can be organized per data stream

Facility company operated NPN:

If the facility owner is running the Private Mobile Network, frequency license can be permanent and network slices can be organized based on the organizations. In the media use case this means that different media production companies would buy their own Network Slice. When defining Network Slices you can define (i) the capacity by resource blocks and transport per virtual network; (ii) the QFIs available per virtual network; (iii) MCI based traffic light; (iv) the number of users per virtual network; (v) the number of dataflows per virtual network. Furthermore, you can create users and deliver SIM/eSIM as well as set the price and time for a virtual network. On the other hand, when using Network Slices you can (i) make capacity reservations; (ii) name users and data flows; (iii) create/remove profiles by selecting the UL/DL capacity and delay; (iv) attach profiles to data flows; (v) set priority for data flows; (vi) see resource load status per flow/user both UL/DL capacity and delay; (vii) see block error rate per data flow; (viii) save configurations; and (xix) activate configuration.

- **LiveU**

The LiveU solution will be used in UC 2, wireless studio – remote production, as a tool to transmit live video into the remote studio, over 5G. These components enable the UC2 remote production. The transmission of the camera(s) feed(s) from the Aachen 5G test-field into the RAI studio in Italy will be made using this solution and integrated into this workflow and facilities. Synchronized multi-cam remote production will be enabled when capturing two feeds in the same field device, encoding them and transmitting them over the 5G network. At the RAI studio, the signals will be transcoded within the solution into SMPTE2110 video and fed/output into the RAI studio systems. Additional capabilities such as SMPTE2110 transcoding, audio/intercom/party-line calls, Tally light support and data channel for field equipment control (such as robotic cameras), will be added to support the UC best-practices. Bonding multiple 5G modems will be demonstrated in order to enhance the reliability of the transmission in various scenarios and network conditions.

Here is the description of the main components of the solution:

The solutions are comprised of the following components:

1. Video encoder and transmitter/production unit – the LU800 (or future derivative). Hardware and software
2. Receiving server that receives the video packets streams, decodes it, outputs it and also communicates with the LiveU field unit – either the LU2000-SMPTE2110 version or the LU4000 version, or their similars
3. LU-Central – the cloud service that manages the LiveU components and transmissions, including via APIs for 3rd parties.
4. LiveU Tally light sub-system: controller and field light device

Here is a high level short-handed description of these components:

The LU800 video encoder & transmitter/production unit

This new device (Figure 15) is designed for remote production. It can capture video feeds from up to 4 SDI cameras and transmit them simultaneously and synchronously up to 1 frame over single 5G modem/connection or multiple 3G/4G/5G modems bonded together. It can transmit single 4K or multiple 1080p60 cameras.
The encoding is adaptive HEVC H.265, changing its output with no loss according to the commands of the LiveU SW according to its algorithms of evaluation and prediction of the performance of the available links.
Current max per single 4K stream transmission bandwidth is 20 mbps and we intend to develop it to 30 mbps and even try to go as high as 50 mbps. For multicam, the current total transmission rate of a single LU800 is about 60mbps at 15mbps per HD 1080p60 stream. The main limitation being the HW platform capacity.

The unit contains up to six 5G modems, based on 3rd party vendors for the modems and a LiveU RF/board design. We will be working with new 5G modules as vendors release them (they have been much delayed), test them and ensure the right module is being selected. Multi-modems/connections/operators etc are used to provide reliable and sustainable high-quality live video over long period of times.

The unit is self-contained – having a rechargeable battery, backpack, and touchscreen operation. It can also be operated fully from remote, via the LU-Central, once at least one of its connections is made.
The unit, and solution, support numerous features and capabilities which we cannot describe in this space and focus.

Additional specific capabilities are planned in the timeframe of the project include IP channel to allow remote control of any IP device (with overall limited capacity as is being the case for such remote control purposes), Tally light support, "party-call" to enhance IFB with return audio and with multi-party team calls, video switcher to allow local or remote switching of the transmitted video stream if more than one are captured, and more.

Figure 18. LiveU LU800

A look at the LU800 physical interfaces/connectors (Figure 16):

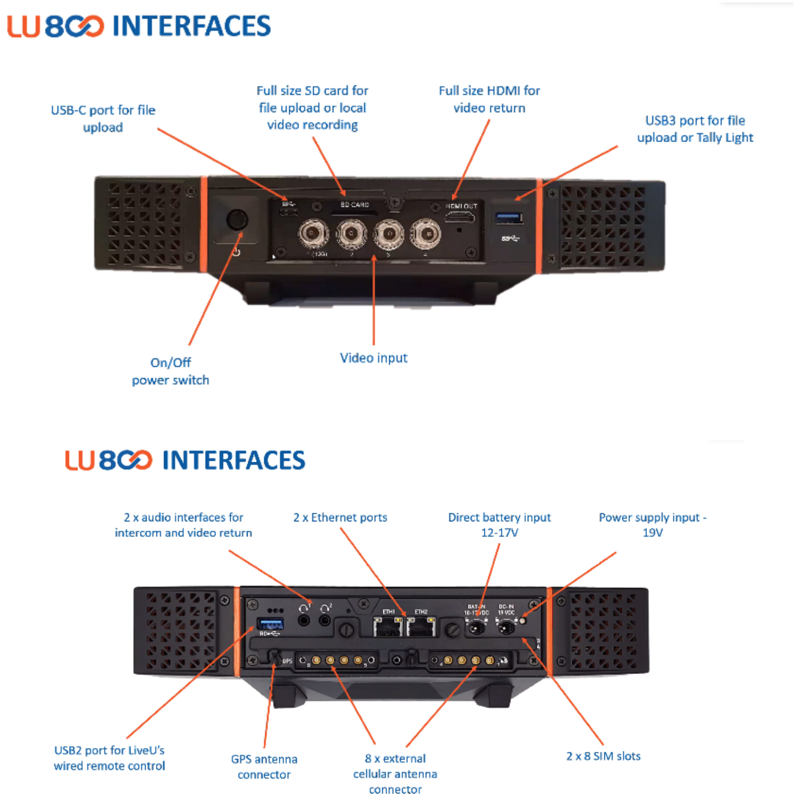


Figure 19. LU800 physical interfaces/connectors

Receiving server / video decoder-transcoder

This server is placed at the studio side.

The LU2000-SMPTE2110 bonded video decoder is used to receive, decode and playout any HEVC bonded video streams sent by LiveU's field units. The 1U rackmount decoder can simultaneously output two full HD streams (up to 1080p) over SMPTE 2110 Ethernet ports, sending them to selected IP destinations.

The LU2000-SMPTE2110 includes two 25 Gigabit Ethernet SMPTE 2110 ports, with one of the ports used for redundancy, ensuring the highest level of reliability and giving you peace of mind when dealing with live content. As it acts as a LiveU to SMPTE2110 video transcoder, transcoding the LiveU video protocol (called LRT) received from the LU800 into SMPTE2110 format, there are limitations due to platform processing capabilities. Hence at the moment this server does not support 4K incoming feeds. We will evaluate adding it.

We are also evaluating developing support for feed synchronization through the Precision Time Protocol (PTP).

Integrating seamlessly with LiveU's multi-layered live video ecosystem, the LU2000-SMPTE2110 allows operators to monitor and control live streams via LiveU Central, the unified management platform for LiveU's field and studio units.

Depending on final requirements and trade-offs, we may use the LU4000 or similars to receive the LU800 4K stream (the LU2000-SMPTE receives only 1080 streams). This will allow testing higher bit rates, yet without the SMPTE gateway functionality. This model requires a much stronger hardware and should be equipped with a Blackmagic 8K Pro SDI video output card. This server can take-in the studio IFB/audio from the audio interface box connected via a USB.

LU-Central management and monitoring

Cloud based, is being used in the project but not part of the deployment. The LiveU Central management platform (Figure 17) allows full control and monitoring of the entire LiveU ecosystem and content via any modern browser, from anywhere around the world. Using the LiveU Central web interface you can remotely control and manage your LiveU field units and channels. Main capabilities:

- Manage unit streaming settings: mode, delay, channel selection and start/stop streaming
- View and manage unit's network interfaces and their current performance: Ethernet ports, WiFi & cellular modems
- Manage IP streaming to social media or CDNs – one click streaming to Facebook
- File Management – preview files, play to SDI or download
- Manage metadata before and after streaming
- Group & user management
- Service management (some are future, expected to be supported within the project timeframe): LU-Smart, Video Return, Tally Light, Audio Connect, IP Pipe, etc

In addition, we will provide RESTful APIs to the LU-Central (potentially not a commercial deployment but a lab deployment). These APIs will support monitoring the LU800 and video server, their status, the transmission itself, and even start/stop of transmissions. The LU-Central communicates transparently with the LU800 and the video servers to execute these APIs.

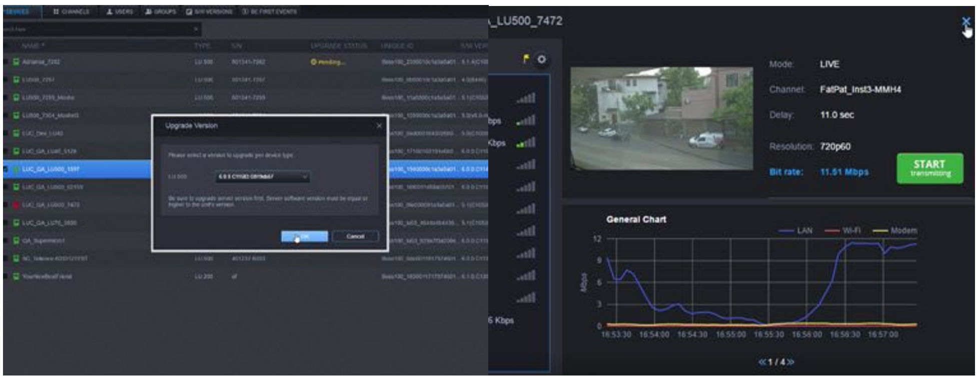


Figure 20. LU-Central screenshots examples

The Tally light sub-system

This subsystem is comprised of a controller and the Tally light device itself (Figure 18) The controller is placed in the remote studio, connected to the production switcher on one side and onto a LiveU server on the other. Mapping of the controller to the connected system is done via the LU-Central cloud management. The Tally light itself connects to the LU800 via USB.

Figure 21. LiveU Tally light device prototype

➢ Image Matters

For this use case, Image Matter will provide the O² Galen, which is a camera platform for 5G Broadcast. It remotely connects a professional camera to a central studio enabling full communication with local operator (display, intercom, etc.) and control of local machines (lens, robot, etc.).

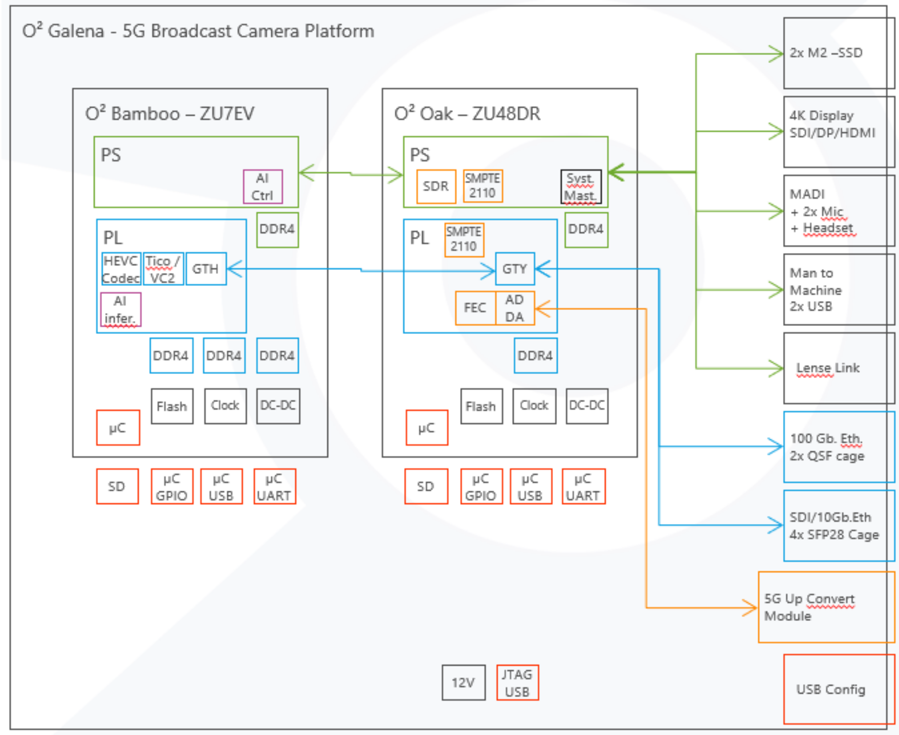


Figure 22. Image Matters – O² Galena block diagram

The O² Galena platform is based on two FPGA based systems on module:
O² Bamboo and O² Oak.
The O² Oak is responsible for central system control, for all inputs and outputs, for video transport packaging, for software defined radio 5G modulation, for 5G communication control and for 5G analogic interfaces. The video transport layer would be based on SMPTE 2110 standard. Alternatively, to 5G medium, the O² Oak will also handle redundant 100Gb. Ethernet links for wired transport.

The O² Bamboo is a co-processor responsible for video processing, analysis, and compression. Video compression could be based on HEVC, JPEG 2000, JPEG-XS, VC2, or any other feasible compression scheme validated by broadcaster to achieve the expected quality and latency mix. The O² Bamboo can address content up to 4K UHD definition @ 60 frames per second.

The O² Galena does target a glass to glass latency below 20ms and allows also a local storage of content on SSD.

The O² Galena is essentially a hardware platform. Most of the processing and communication IP-Cores shall be provided by 5G-RECORDS Project partner or acquired from external IP-Core vendors.

➢ Fivecomm

Fivecomm brings to the use case 2 a “*5G gateway for cameras*”. It is integrated into the complete end-to-end system at as part of the user equipment (UE). The objective for 5G-RECORDS is to develop, integrate and validate a compact and flexible module solution that provides 5G wireless connectivity and can be customized. In other words, it will be particularized for the connection link between the cameras and the 5G network, depending on the specific needs of the use case.

The full integration of this 5G component into the use case is shown in Figure 20. As it can be observed, the module is divided into two main parts, i.e. the '*video encoder*', which translates the camera inputs (SDI/HDMI video and audio, control, tally, etc.) into IP signals; and the '*5G modem*' that provides 5G connectivity through the network to the production studio.

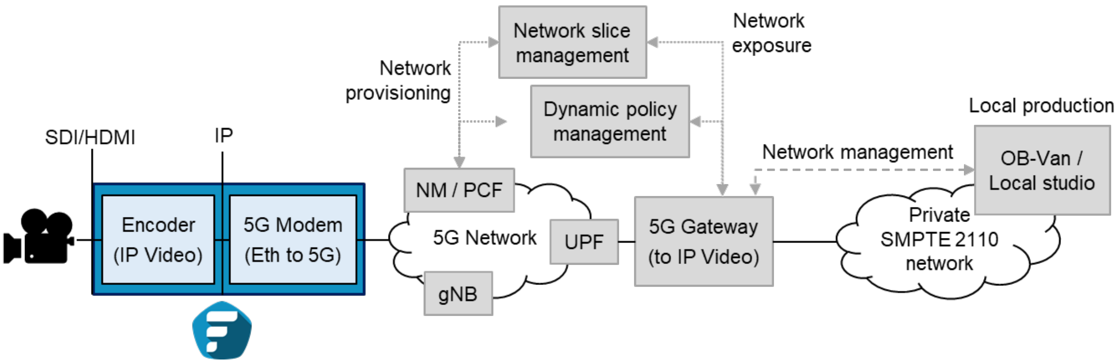


Figure 23. Fivecomm solution for 5G-RECORDS: the 5G gateway for cameras

There is a series of key performance indicators (KPIs), with their associated requirements, that need to be fulfilled in the context of the multiple camera wireless studio. Some examples are the glass-to-glass latency, the video codecs to be used, bitrate, battery lifetime for continuous real-time transmission, development cost, or size. The "*5G gateway for cameras"* will be specifically designed (both encoder and modem parts) to fulfill such requirements, specified in WP2.

Although some of these aspects are still under discussion, Fivecomm is exploring alternatives to provide, among others, the following features:

- *Video encoder:*
    - H.264/H.265 codecs (other alternatives are possible).
    - Glass-to-glass latency of below 20 ms. Encoding latency (from UE wireless camera to the network) down to 8-10 ms.
    - Infrastructure agnostic (LTE/5G/Satellite/LAN).
    - Variable resolution and frame rate.
- *5G modem:*
    - 5G New Radio (NR) Rel-15 support.
    - Sub-6 GHz frequency bands: n28 (700 MHz, FDD) and n78 (3.5 GHz, TDD).
    - Both non-standalone (NSA) and standalone (SA) modes supported.
    - Option 3x, 3a and 2 network architectures.
    - Up to 2.5 Gbps in the DL and 900 Mbps in the UL.

As an alternative, Fivecomm could bring to the consortium the "*5G modem*" part as a single component. This allows for collaboration with other partners that plan to provide the video encoding to the use case, increasing synergies and enhancing component integration.

BBC

For this use case, BBC will provide the orchestration layer. Whilst the current Rel16/17 standardisation has focused on improving the QoS parameters in terms of latency and bandwidth and timing, the application of professional media production functionalities requires the definition and development of an additional orchestration layer above the 5G infrastructure capabilities. The minimum functionalities required comprise (i) automatic discovery and registration of professional media devices, (ii) automatic resource management and provisioning, (iii) control and monitoring functionalities, (iv) timing and genlock capabilities, management and performance management, and ideally (v) the orchestration layer is compatible with similar functionalities developed in wire SMPTE 2110 – IP based infrastructures. In order to facilitate an industry wide support of these functionalities the development should seek for an open systems approach that can be supported by a wide industry through standardisation, open APIs and open micro-service architectures including open source code development.

Red Bee Media

The Red Bee Media Master Control Room (MCR) functionality is positioned between the gateway and cloud.

Source / camera feeds are terminated locally and aggregated in one local setup and then routed in order to be compressed before the connection into cloud is made. The goal is to feed multiple signals into cloud.

The cloud MCR provides signal processing and routing to and from the gateway, supporting project partners in the project to handle content and to deliver to remote locations, using either public networks or direct connectivity.

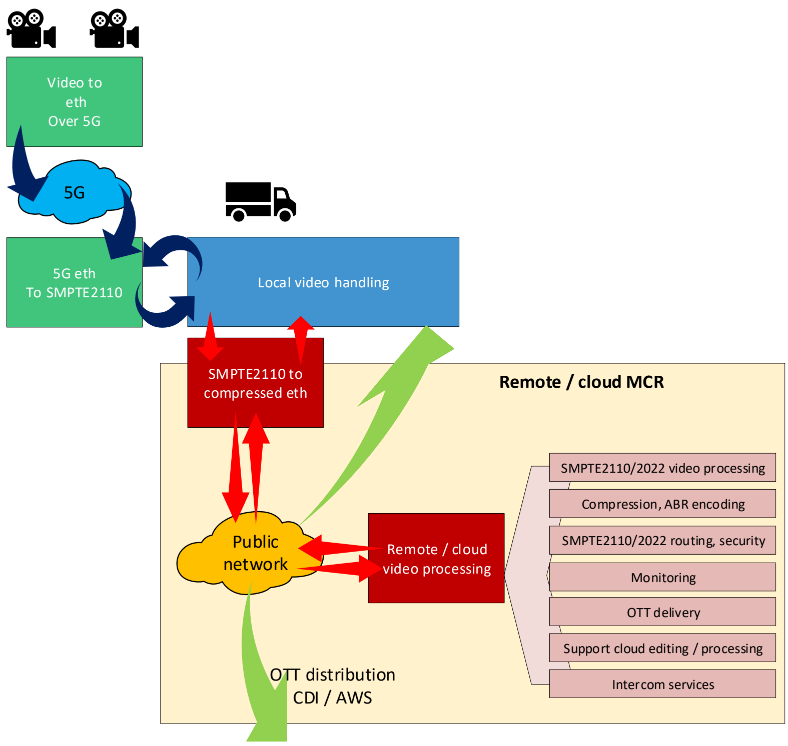


Figure 24. Cloud MCR

<u>Contribution into MCR, originating from gateway</u>

- Contribution Camera / OB van content feeds into cloud / remote MCR

<u>Processing Services (multitenant)</u>

- Remote processing of raw video, preparation of content for virtual (cloud) production

<u>On Ramp to Virtual Cloud Production</u>

- Playout of content, feeding into IP gateway, OTT distribution
- Compression, ABR
- SMPTE2110 / SMPTE2022 routing
- Transmission

While technical, operational and commercial feasibility is investigated, the aimed for solution includes:

- Solution design, workflows
- Latency, reliability, security
- Scenario validation, deployment constraints, operational considerations

Building on long term experience in on-prem processing, cloud based MCR services will be explored, evaluating main aspects of such a service. Booking services is done with remote MCR staff. On-ramp permanent processing capacity is available to support cloud services with add-on processes.

Cooperating with a public cloud provider, the dedicated start setup in the study will be moved into cloud following a step-wise approach.

A.3 UC3: live immersive media production

This use case considers a real-time, end-to-end, Free Viewpoint View (FVV) system that includes capturing, 5G contribution, virtual view synthesis on an edge server, 5G delivery and visualization on users' terminals.

The system will generate in real-time a synthesized video stream from a free-moving virtual position. As shown in Figure 22, an FVV system generates synthetic views of a 3D scene from a virtual viewpoint chosen by the user by combining the video information from several real reference cameras. The envisaged use case targets, among other possibilities, the real-time immersive capture of sport events such as a basketball game. It will be possible to reproduce content both live and offline (replay) of free-viewpoint trajectories around one basket of the court. The content can then be distributed not only to people attending the event (local delivery), but also to third parties. The most innovative part of this use case is the fact that each user can access a specific selected angle live, since *all possible angles are available at any time*.

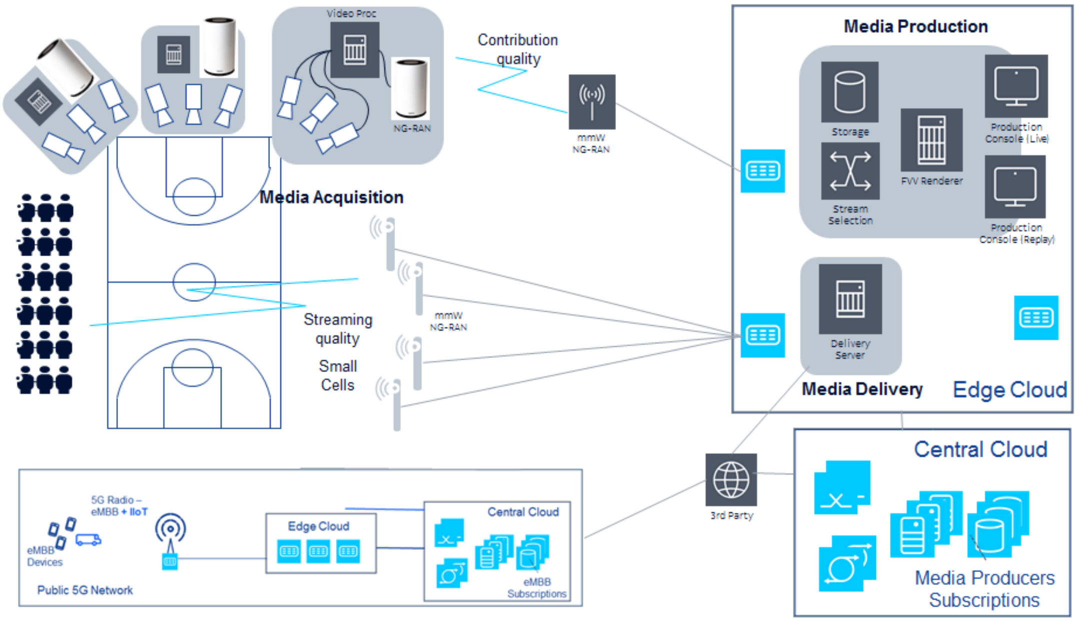


Figure 25. Live immersive media services: use case overview.

A.3.1 Components

The 5G components of the live immersive media production use case are shown in Table 10.

Table 10. Main 5G components of UC3 Live Immersive Media Production

Partner	5G Component
Nokia	End-to-end 5G solution for immersive media production, including RAN (AirScale mmWave Radio), CPE (FastMile 5G FWA) and Edge Cloud (AirFrame MEC).
Telefonica	Edge computing to allocate processing, storage and central processing unit capacity
UPM	FVV live system for immersive video capturing of real-time events, connected to the 5G network

➢ Nokia

5G transformation is much more than a radio network upgrade challenge. While 5G New Radio is clearly important to the network buildout, 5G requires a much more comprehensive approach. 5G involves end-to-end technology (radio, core, cloud, high bandwidth and programmable transport, management, automation, BSS, security, and more), business and people capabilities.

In 5G-RECORDS, Nokia will blueprint an end-to-end solution for advanced media production and delivery, which can be applied to both NPN and MNO deployments in Smart Venues, either permanent or ad-hoc, where high capacity is demanded (e.g. concerts, festivals, sport stadiums, etc.). Venue locations have been focus areas for 4G optimization for a long time. The need and desire to share our entertainment experience has been evolving for a while now. Stadium owners and operators have been lacking the motivation to fulfill the needs of the audience, as very few locations offer proper downlink (DL) and uplink (UL) quality just to mention the basics. But as stadium/venue operators compete more fiercely, onsite and remote entertainment solutions will play a growing role in their strategy. By considering the content production (with stress on uplink) in an integrated manner with the services to fans (which will mostly demand downlink), 5G-RECORDS will study a solution valid for massive events both from technical and business perspectives.

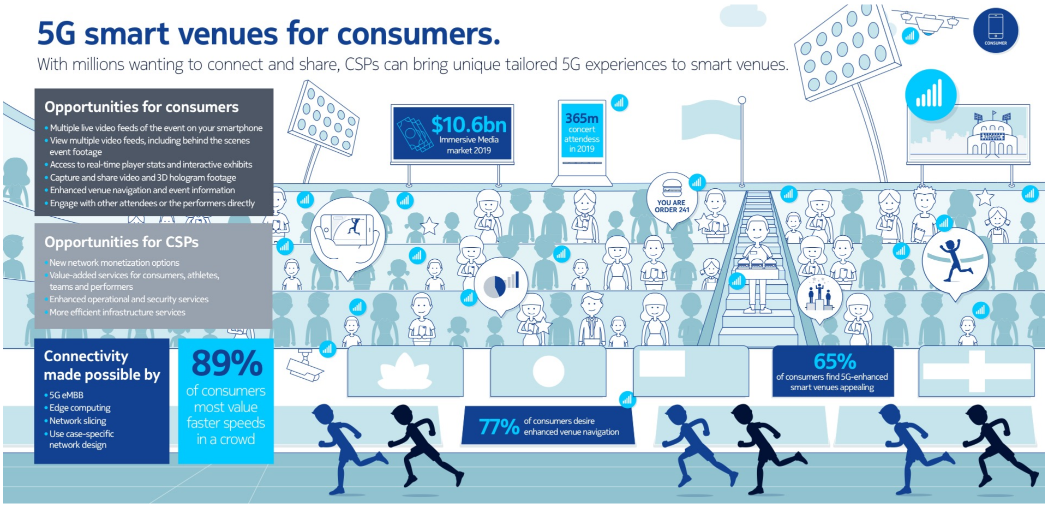


Figure 26. 5G Smart venues for customers.

Three elements are key in the end-to-end solution provided by Nokia: RAN (AirScale mmWave Radio), Customer Premise Equipment (CPE) (FastMile 5G FWA) and Edge Cloud (AirFrame MEC):

The **AirScale mmWave Radio (ASMR)** provides extreme capacity for the busiest enhanced Mobile Broadband localities. This compact, high-power small cell offers a wide range of deployment options to ease installation considerations. These options include 180-degree and 360-degree coverage and multi-band deployments to provide flexibility in ensuring service continuity in a wide variety of environments. ASMR is ideal for extreme capacity 5G connectivity, such as stadiums, airports and pedestrian areas.

The **Nokia FastMile 5G Gateway** is a fully self-contained gateway that uses 5G NR for the network connection. It is a Fixed Wireless Access (FWA) CPE, designed for use in homes and businesses. Its optimized design includes higher gain antennas driving higher speeds than conventional cell phones, as it uses radio resources in a more efficient way. This additional efficiency can consistently boost peak rates at a given location by up to 180 Mb/s when compared to omni antenna designs. This added performance pays significant dividends in revenue and customer satisfaction.

The **Nokia AirFrame** open edge server, is an x86 solution built and tailored to fully support edge and far-edge cloud deployments. The ultra-small footprint provided by the solution is complemented with a real-time, Open Platform NFV (OPNFV) compatible, OpenStack distribution built to provide the performance and low latency required by solutions like Cloud RAN. AirFrame open edge server is fundamental to distributing computing capacity in the network and driving the implementation of Cloud RAN, Multi-access Edge Computing (MEC) as well as 5G.

➢ UPM

FVV Live 5G component

FVV technology is able of providing immersive video experiences which allows the user to freely move around the scene, navigating along an arbitrary trajectory as if there were a virtual camera that could be positioned anywhere within the scene. This is possible thanks to a multi-camera capture of the scene that allows to estimate its geometry and thus, FVV technology is able to render other points of view of the scene despite there are no actual cameras on them (virtual views). Figure 24 shows an example where the synthetic view corresponding to a virtual camera (yellow one) is generated from 3 actual reference cameras (blue, red and green).

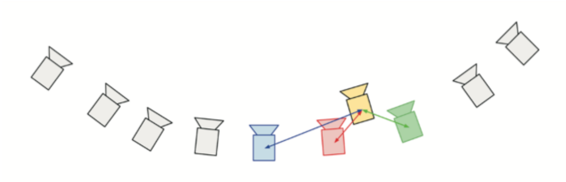


Figure 27. Free Viewpoint Video: generation of synthetic views from virtual cameras.

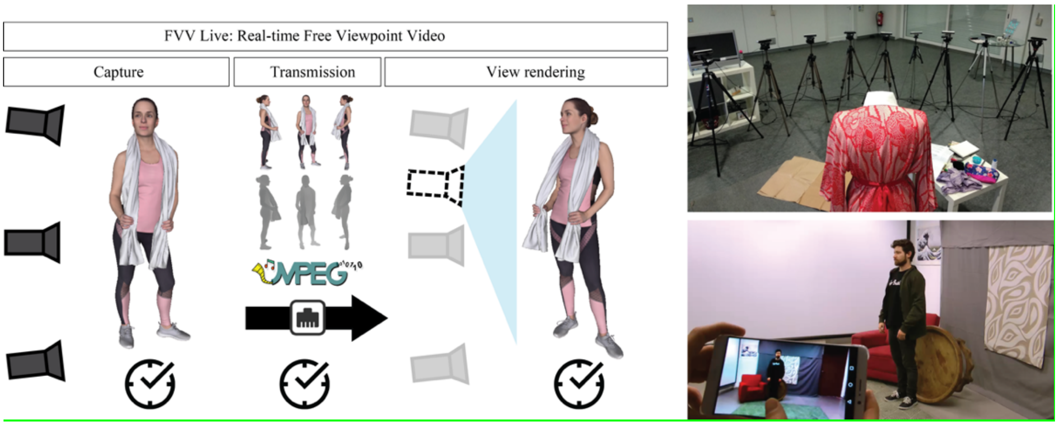


Figure 28. FVV functionality and set up

FVV Live 5G is based on an existing FVV prototype, called FVV Live (see Figure 24). It is a novel end-to-end real-time FVV system that has been designed to provide high virtual video quality using off-the-shelf hardware, thus enabling low-cost and easy deployment. FVV Live 5G will extend the previous prototype to be able to operate in 5G networks. Its key elements, depicted in Figure 25, are the following:

- A **media acquisition module** comprised of a sparse array of consumer electronics stereo cameras, managed by a set of capture servers (CSs), which yields a multi-view plus depth (MVD) format. The acquisition module includes a depth post-processing sub-module that deals with depth estimation errors due to slight calibration errors typical in stereo-based depth cameras. In addition, it includes a compression and transmission sub-module based on standard video coding schemes and transmission protocols. This sub-module will be connected to a 5G network which will allow to transmit the media captured data targeting contribution quality. Besides, cameras and capture servers will be synchronized and remotely controlled through the 5G connectivity. To limit the overall bitrate, the transmission module will be able to adaptively enable/disable the data stream from each real camera depending on the position of the virtual one.

- A **view synthesis module** providing high-quality video with real-time constraints. This module uses a layered approach, merging background (BG) and foreground (FG) layers projected from several reference cameras in the virtual view. The view synthesis module will be placed on the Virtual Media Production server thanks to 5G-virtualization functionalities.

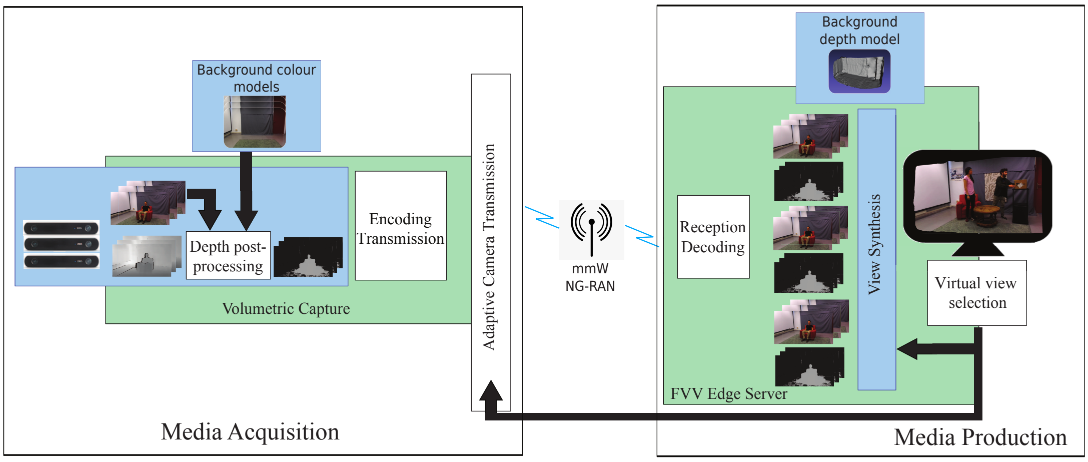


Figure 29. FVV Live 5G block diagram.

FVV Live 5G aims at taking advantage of 5G features and functionalities in order to take a step forward in terms of flexibility and portability. 5G connectivity will allow a portable FVV system to operate in real time with a very reduced deployment cost and high flexibility. The incorporation of 5G into the FVV pipeline will allow the distribution of the computational load, thus paving the way for possible future service virtualisation.

Moreover, the extensive use of 5G for subsystem interconnection will allow the synchronization of all involved elements and the remote control and operation of the live immersive service. Besides, all system interfacing and control aspects will be handled by the 5G network.

➢ Telefonica

5G networks will not live in isolation. As new technology evolutions emerge, they will need to be integrated in existing and complex networks where an array of technologies, users and services co-exist.

In most of the scenarios, as it will eventually happen with Live Immersive Media Productions, use cases will interact with users that are in other mobile networks, FTTH networks, WiFi networks, etc. It is crucial for 5G use cases to succeed to understand how this complexity impacts real network performance and to try to ensure network behaves as need it end to end.

In 5G-RECORDS, Telefónica will provide Edge Infrastructure to host Delivery Servers. This Edge Infrastructure will not be co-collocated with the 5G Radio infra but close enough (around 100km) to allow proper service performance. This kind of Edge Computing (that considers Edge up to a distance close to 100km) is similar to what several telcos (including Telefónica) are currently deploying.

Additionally, Telefónica will provide Network Slicing capabilities to explore how Live Immersive Media Productions requirements match crowded Transport, FTTH Access and WiFi capabilities. Based on that we will understand how network behavior should adapt to perform as the use case needs in and end to end scenario.

Regarding the edge platform is based on having a network architecture that supports end-to-end programmable services, and at the same time allows to deploy processing capacity at the edge of the access network.

Enable innovative services

Edge platform as a center of programmable services must enable a wide range of services, not limited to access services, nor must it constrain without the need to implement new services. Specifically, the Edge must enable services extracted from these vertices:

- Both services, access and conventional cloud
- Services deployed both in the data plane (NFV) and services implemented in the control plane.
- Our services that are always reliable and the not so reliable third parties

Extendable and controllable

The edge is a configurable platform and is not a closed solution, it provides the means for the operator to specify the desired portfolio of services and the dependencies between those services. This allows the Edge platform to be configurable for different markets and access networks: residential, business and mobile. It must also provide the mechanisms to provision and parameterize these services in accordance with our business and operational objectives.

Open infrastructure efficiency

The Edge platform is conceived to use white label infrastructure, relying on the knowledge acquired in the Marco Polo project, we extend it to the servers, switches and optical terminals of the central; with the consequent cost savings and proven robustness of these devices specified by the Open Compute Project. The Edge platform must run on white label servers and switches, working directly with microcircuit manufacturers

Operational robustness

The Edge platform must take into account the partial and intermediate failure scenarios, therefore it has been designed taking into account the possibility that the behavior in the operation of the system is not always synchronized with the desired state of the system.

Multipurpose security

Edge platform security should not be limited to distinguishing between system managers and users, but it should be capable of ensuring access to the system by various actors, such as global and local operators, service developers, service managers and service subscribers

For this scenario, Telefonica will provide the edge infrastructure (Figure 27):

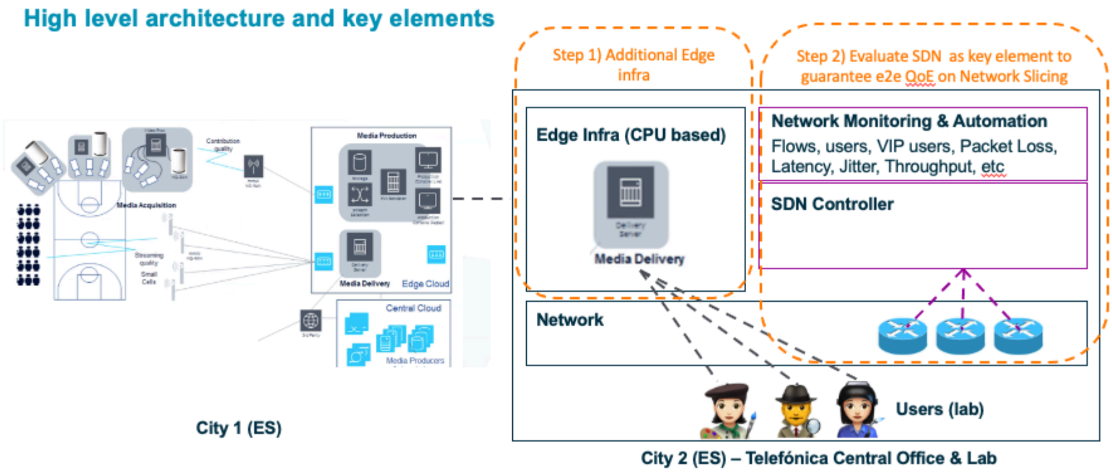


Figure 30. High level architecture and key elements of UC3 Live Immersive Media Production

Edge Compute resources will be available at Telefonica Central Office (Figure 28).

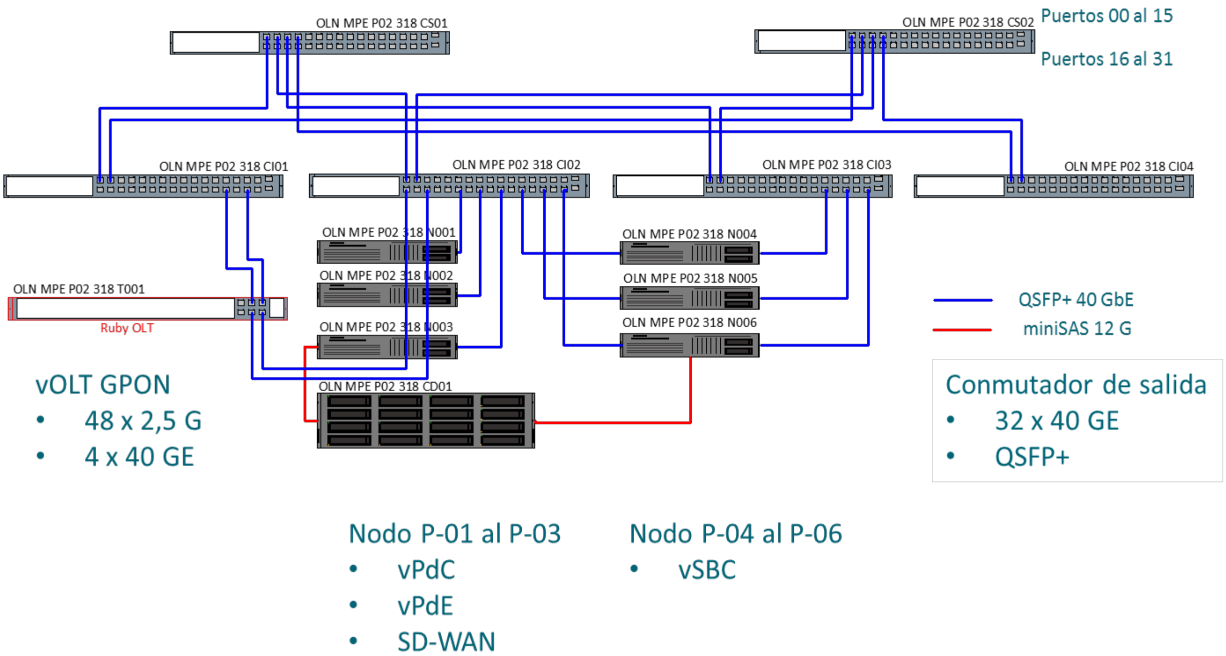


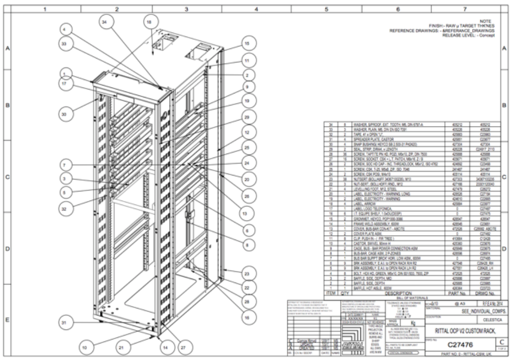
Figure 31. Edge compute - logical architecture

Edge computing components in UC3 are listed in Table 4 and Figure 29:

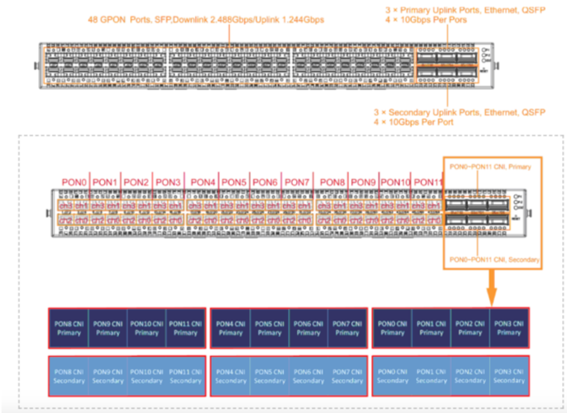
Table 11. Description of components Edge computing UC3

Component	Description
Rack OCP 2.0	Powered at -48DC. Separate in two zones. With one central Bus bar at 12V. Public specification available in [1].
Celestica Pebble E1050.	Management switch. With 48 RJ45 ports and 4x SFP+ ports.
OLT Ruby S1010 vOLT	48 GPON ports. 48xSFP ports - 2.488 Gbit / s - 6xQSFP ports - (4x10GbE).

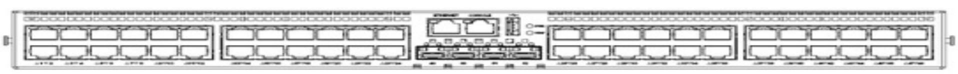
Smallstone Celestica WhiteBox switches	6 x Smallstone Celestica WhiteBox switches. Chipset Broadcom BCM56850 Trident II, and 32xQSFP 40G ports.
Relion OCP1930g Server	3 x Relion OCP1930g Server • Dual Socket Motherboard, w/ Dual GbE/RJ45. • Dual Intel Xeon E5-2680 v4. • 128GB RAM, DDR4-2400. • NVMe Kit (consumes Mezz). • 500GB SSD, 2.5", NVMe. • IC, Mellanox ConnectX 4 QSFP 40GbE.
Tundra Valkre 1030c - ARM	3 x Tundra Valkre 1030c - ARM • Dual Cavium ThunderX CPUs · 128GB RAM, DDR4-2133. • NIC, Intel I350T2V2, PCIE2 x4, 2x RJ45/1000BASE-T. • 2 x Hard Drive, SATA 6Gbps, SSD, 2.5, 480GB. • Integrated NIC, 2x QSFP/40GbE.
Storage	JBOD. 45 SAS SDD. Storage server. ByceCanyon, up to 72 HDD



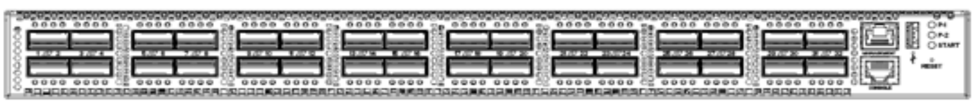
(a) Rack OCP 2.0



(b) OLT. Ruby S1010 vOLT



(c) Celestica Pebble E1050

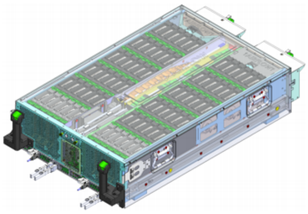


(d) Smallstone Celestica WhiteBox switches

(e) Relion OCP1930g Server

(f) Tundra Valkre 1030c - ARM

(g) JBOD. 45 SAS SDD.



(h) ByceCanyon, up to 72 HDD

Figure 32. Telefonica 5G Edge computing components

The physical view of the edge rack is the following:

Figure 33. Telefonica Edge Rack

References

[1] Open Rack/SpecsAndDesigns (http://www.opencompute.org/wiki/Open_Rack/SpecsAndDesigns).