5G-SOLUTIONSfor European Citizens

D1.1A - Definition and analysis of use cases/scenarios and corresponding KPIs based on LLs (v1.0)

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Glossary of terms and abbreviations used

Abbreviation / Term	Description
3GPP	3rd Generation Partnership Project
5G	Fifth Generation (mobile/cellular networks)
5G-PPP	5G Public Private Partnership
5GC	5G Core
5QI	5G Quality Indicator
AGV	Automated Guided Vehicle
API	Application Programming Interface
AR	Augmented Reality
B2B	Business to Business
B2B2X	Business to Business to Everything
B2C	Business to Consumer
B2H	Business to Household
BBF	Broadband Forum
BSS	Business Support Systems
CCTV	Closed-Circuit Television
CI/CD	Continuous Integration / Continuous Development
CMAF	Common Media Application Format
CN	Core Network
CSC	Communication Service Customer
CSP	Communication Service Provider
CU	Central Unit
DASH	Dynamic Adaptive Streaming over HTTP
DL	Downlink
DU	Distributed Unit
E2E	End-to-End
eMBB	Enhanced Mobile Broadband
eMTC	Enhanced Machine Type Communications
EPC	Evolved Packet Core
ETSI	European Telecommunications Standards Institute
FoF	Factories of the Future
GST	Global Slice Template
HD	High Definition
HTML	Hypertext Markup Language
eNB	Evolved Node B
ETF	Internet Engineering Task Force
gNB	5G Node B
HLS	HTTP Live Streaming
IMS	IP Multimedia Subsystem
IoT	Internet of Things
IIoT	Industrial Internet of Things
KPI	Key Performance Indicator
L2VPN	Layer 2 Virtual Private Network
L3VPN	Layer 3 Virtual Private Network
LTE	Long Term Evolution
MANO	Management and Orchestration

MEF	Metro Ethernet Forum
MES	Manufacturing Execution System
mIoT	Massive Internet of Things
mMTC	Massive Machine-Type Communications
MPEG	Moving Picture Experts Group
MVNO	Mobile Virtual Network Operator
NaaS	Network as a Service
NBI	Northbound Interface
NEST	Network Slicing Task Force
NETCONF	Network Configuration Protocol
NFV	Network Functions Virtualisation
NFV-NS	NFV Network Service
NFVIaaS	NFVI as a Service
NGMN	Next Generation Mobile Networks
NOP	Network Operator
NR	New Radio
NSA	Non standalone
NSaaS	Network Slice as a Service
NSD	Network Service Descriptor
NSI	Network Slice Instance
NSSAI	Network Slice Selection Assistance Information
NST	Network Slice Template
ODA	Open Digital Architecture
ONAP	Open Network Automation Platform
OSM	Open Source MANO
OSS	Operation Support Systems
PLC	Programmable Logic Controller
PPDR	Public Protection and Disaster Relief
QoS	Quality of Service
QoE	Quality of Experience
RAN	Radio Access Network
RRH	Radio Remote Header
SA	Standalone
SB	Service Blueprint
SC	Service Component
SD	Service Descriptor
SDO	Standards Development Organisation
SLA	Service Level Agreement
SOF	Service Orchestration Function
SRTP	Secure Real-time Transport Protocol
SST	Slice Service Type
TaaS	Testing as a Service
TBD	To Be Defined
TCP	Transmission Control Protocol
TMForum	Tele Management Forum
TOSCA	Topology and Orchestration Specification for Cloud Applications
UAV	Unmanned Aerial Vehicle
UDP	User Datagram Protocol

UHD	Ultra-High Definition
UL	Uplink
uRLLC	Ultra-Reliable Low Latency Communications
V2X	Vehicle to Everything
VNF	Virtualised Network Function
VNFaaS	VNF as a Service
VNFD	Virtualised Network Function Descriptor
VPN	Virtual Private Network
VR	Virtual Reality
VSB	Virtual Service Blueprint
ZOOM	Zero-touch Orchestration, Operations and Management
ZSM	Zero-touch Network and Service Management

1 Executive Summary

The scope of this document is to provide a detailed analysis of the use cases, the conditions under which the trials will be executed, the requirements and the target KPIs that will set the benchmarking for the actual measurements in the Living Labs.

The first important step is the definition of the methodology, followed by the performance evaluation, the identification of the use case requirements and the relative KPIs. The second step is the analysis of the use case scenarios and the usability needs in order to capture the requirements from the end-user stakeholders, as well as the relevant target technological and business KPIs which will be validated in the Living Labs. This outcome will feed other critical tasks and point out the technological enablers for facilitating the execution of the field trials. To this end, the use cases will be validated towards their conformance to target 5G KPIs, as well as their business potential, ethical and social acceptance. This deliverable defines in a clear and solid way the initial version of the KPIs, their target values and the measurements that have to be provided, in order to prove and validate that the 5G technology can provide prominent industry verticals with ubiquitous access to a wide range of forward-looking services with orders of magnitude of improvement over 4G.

The project is going to setup several living labs in order to cover the majority impact of 5G revolution. Each of said living labs will be organized in different use cases.

The main use cases identified in the context of the **Factories of the Future** (FoF) LL are as follows:

- Use Case 1.1: Time-critical process optimisation inside digital factories;
- Use Case 1.2: Non-time-critical communication inside factories;
- Use Case 1.3: Remotely controlling digital factories;
- Use Case 1.4: Connected goods:
- Use Case 1.5: Rapid deployment, auto/re-configuration and testing of new robots;

To enable the execution of representative FoF use cases, the approach will involve both horizontal and vertical slicing. Horizontal slicing involves computational off-loading, e.g. multi-access edge computing. It addresses the diverse network capacity and latency requirements e.g. 10,000x capacity at the edge with <1ms latencies ("factory floor") due to the huge numbers of sensors, other networked devices and time-critical applications. It requires over-the-air resource sharing across network nodes and as such, the 5G air interface will be an appropriate enabler. Portable 5G RAN nodes will be installed inside each one of the factory premises of GLAN (Ireland), PBGS (Brussels), and NTNU (Norway), with the first two acting as stand-alone private 5G networks for validating the relevant field trials requiring URLLC class service type. This will ensure that the results obtained during the validation of these use cases will be as realistic as possible and that the URLLC requirements can be met. For vertical slicing, on the other hand, which entails separate virtual networks within the 5G network, technologies at the air interface, RAN and NGC levels will be setup and configured. At the RAN level (i.e. at base station) access point and depending on factors such as traffic type, traffic load and QoS requirement, the RAN architecture of each of the slices can be dynamically configured. The 5G node will allocate radio resources for the slice and enable all radio and network functions associated with the slice.

The **Smart energy** living lab will target three use cases referring to the broad area of *Demand Side Management* (DSM). DSM refers to the changes in electricity use by consumers from their normal consumption patterns in response to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardised. In a broader sense, DSM also embeds the topic of overload avoidance and optimal self-consumption, in those scenarios where the peak power affects the energy bill, and local RES have an impact on the net power withdrawn from the grid.

The use cases to be validated in this **Smart City and Ports** LL include the following:

- Use Case 3.1: Intelligent street lighting;
- Use Case 3.2: Smart parking;
- Use Case 3.3: Smart city co-creation sounds;
- Use Case 3.4: Smart buildings – smart campus;
- Use Case 3.5: Autonomous assets & logistics for smart port;
- Use Case 3.6: Port safety: monitor & detect irregular;

Through the use of digital and telecommunication technologies, traditional networks and services become more efficient for the inhabitants, business' and ports benefit. It is estimated that 50 billion devices will be connected to mobile networks by 2020, while a large proportion of communications will occur between machines and not humans. In this respect, 5G supporting mMTC, eMBB, URLLC, virtualisation and slicing will be able to respond to the smart cities and ports of the future.

The main uses cases identified in the media & entertainment living lab are the following:

- Use Case 4.1: Ultra High-Fidelity Media;
- Use Case 4.2: Multi CDN selection;
- Use Case 4.3: On-site Live Event Experience;
- Use Case 4.4: User & Machine Generated Content;
- Use Case 4.5: Immersive and Integrated Media and Gaming;
- Use Case 4.6: Cooperative Media Production.

Taking into account that the media traffic is the main, volume-wise, traffic type being delivered by the networks, the new 5G networks will play a major role in media distribution. The solution must be transparent in different levels, from the media delivery protocol perspective to be universally adopted and from the networking efficiency to avoid overheads with extra messaging. This can become a reality by using content delivery analytics to measure the speed and availability of different delivery paths over the network. 5G slicing, Multi-access Edge Computing (MEC), Fog and Mist Computing architectures can make the difference in order to exploit in an isolated and scalable way geo-based network and QoS analytics with almost zero latency. In this regard, SDN over NFV virtualisation technologies bring new possibilities to make an efficient and dynamic setup and provision of the infrastructure. The use of multiple IP-based connections bonded together, enables higher bandwidth, higher reliability and lower delay. An inherent multicast and broadcast mode with support for large cells and a single-frequency mode provides a highly efficient mean for distribution of high-quality and/or immersive content to many concurrent users. Target devices include regular smartphones, VR/AR glasses, TV sets, public displays as well as in-car entertainment systems (which are expected to gain an increasing role in the advent of automated driving).

An additional living lab, named **Multi-vertical concurrent usage of eMM, mMTC & URLLC**, leverages, combines and executes **in a combined and concurrent manner a subset of use cases previously described whose target KPI requirements** (i.e. high throughput, low latency, high density of devices) **fall under such classes of service.** In particular, each of the service classes SC5.1-SC5.3 will incorporate the parallel execution of a number of use cases in each of the LLs.

Vertical industries address their connectivity and communication requirements with dedicated specific solutions. 5G technologies, slicing and virtualization will provide a common base that delivers an open, cost-efficient and interoperable eco-system enabling a solution platform for the different verticals. 5G must also cater in an economical way the diverse requirements and business needs of a multitude of verticals. In addition, 5G infrastructure and architecture will integrate heterogeneous technologies and enable network slicing, so that the multiple concurrent execution of vertical operational services is performed regardless of their diverse requirements.

The requirements' captured in this deliverable, documents the end-users (stakeholder) needs about the new innovative vertical use cases that require 5G performance capabilities in the domains of Factories of the Future, Smart Energy, Smart Cities, Internet of Things (IoT), Media & Entertainment. These use cases and the relative scenarios have been mapped to specific target Key Performance Indicators (KPIs) and Service Level Agreement (SLA) values (e.g. throughput, mobility, latency, density, reliability, positioning accuracy, coverage, service provisioning time, Quality of Service (QoS), Quality of Experience (QoE), etc.), which set the baseline for conducting the actual measurements during the field trials.

Besides the extraction of the KPIs of interest for the use cases, this deliverable also analyses the requirements for the infrastructure, the technological enablers and the stakeholders which will be necessary for the next steps of the project, i.e., the execution of the field trials and the evaluation of the use cases with regards to their business potential and the need to be served by a 5G network. Finally, the key elements of the envisaged visualisation infrastructure are presented aiming at the representation and analysis of the KPIs measured during the trials.

2 Introduction

This deliverable aims to analyse all those use cases that are expected to shape the future of 5G networks and applications, in order to identify:

- The stakeholders and their roles in each use case;
- The objective of each UC;
- The requirements from the stakeholders;
- The technical and business KPIs;
- The required target KPIs and the measurements that have to be taken;
- The gap between current and future definitions, needs and KPIs aiming at driving 5G usage.

The definition of the scenarios and KPIs will contribute to other deliverables so that the use cases will be field trialled separately with real end-user actors through ICT-17's 5G-EVE and 5G-VINNI facilities. To this end, the use cases will be validated towards their conformance to target 5G KPIs, as well as their business potential, and ethical and social acceptance. Furthermore, through the use cases and scenarios analysis, we extract the requirements that will point out the technological enablers for facilitating the execution of the field trials.

In other words, this deliverable will be the corner stone for the 5G field trials, by defining in a clear and solid way the KPIs, their target values and measurement procedures that need to be provided, in order to prove and validate that the 5G technology can provide prominent industry verticals with ubiquitous access to a wide range of forward-looking services with orders of magnitude of improvement over 4G.

2.1 Mapping Projects' Outputs

Purpose of this section, is to map 5G-SOLUTIONS Grand Agreement commitments, both within the formal Deliverable and Task description, against the project's respective outputs and work performed.

Table 1: Adherence to 5G-SOLUTIONS GA Deliverable & Tasks Descriptions

Project GA Component Title	Project GA Component Outline	Respective Document Chapter(s)	Justification
TASKS			
Task 1.1 - Definition and detailed analysis of vertical use cases/scenarios, baseline and corresponding target KPIs	*The aim of this task is to capture requirements from the end-user stakeholders, including the articulation of detailed use case scenarios and usability needs, and relevant target technological and business KPIs which will be validated in the Living Labs. Specifically, this task will be divided into two key sub tasks: (a) systematic compilation of current use cases features and capabilities (b) requirements analysis. A requirements' capture will involve the documentation of end-users needs and opinions about new innovative vertical use cases that require 5G performance capabilities in the domains of Factories of the Future, Smart*	*Section 4, Section 5, Section 6*	*Sections 4 and 5, following the DoA analysis of Sections 2 and 3, includes a thorough analysis of all the Use Cases (UC), in terms of UC objectives, requirements and target KPIs (technical and business KPIs). These sections provide details about the scenarios that have to be investigated for each use case, in order to validate the target KPIs and demonstrate the UC applicability and necessity. Furthermore, the technology requirements are discussed. Furthermore, for*

	Energy, Smart Cities, IoT, Media & Entertainment. Such use cases will be mapped to specific target KPI and SLA values (e.g. throughput, mobility, latency, density, reliability, positioning accuracy, coverage, service provisioning time, QoS, QoE, etc.), which will set the baseline for conducting the actual measurements during the field trials.		*each KPIs the target values as well as the required measurements are provided. Section 6 discusses the infrastructure and technology requirements for the UC evaluation.*
DELIVERABLE			
D1.1A: Definition and analysis of use cases/scenarios and corresponding KPIs based on LLs *Interim (v1.0) version of report containing the detailed analysis of the use cases, the conditions, requirements and the target KPIs that would set the benchmarking for the actual measurements in the Living Labs*			

2.2 Deliverable Overview and Report Structure

5G technology is advancing at a fast pace, making the careful and thorough review of the state-of-the-art a necessary task for every research project on 5G. To this end, Section 3 of this deliverable provides a review of the most recent recommendations on the 5G use cases and KPIs from the 5G-PPP perspective. The classification of the use cases based on the 5G-PPP recommendations is taken into account in Sections 4 and 5, where the methodology and the use cases analysis are provided. More specifically, Section 5 provides a thorough per use-case analysis, aiming at identifying all the key requirements that are necessary for the successful deployment and execution of the trials. Moreover, the technical and business KPIs are extracted, which will be used for proving and validating that the 5G technology can provide prominent industry verticals. Finally, Section 6 provides the visualisation system enablers towards the realization of the 5G trials.

3 5G-PPP Perspective

The 5G research and industry are going to deliver important improvements in network capacity, boosts in spectral efficiency, reduced End-to-End latency, increased reliability and more. These enhancements are determined by key performance requirements defined by the International Telecommunications Union (ITU). [3] reports in a graphic way the performance improvements for the International Mobile Telecommunications IMT-2020 (target for 5G) over IMT-Advanced (current situation represented by 4G advanced). The required improvements are really impressive: e.g., 20x increase in peak data rate, from 1 Gb/s to 20 Gb/s, user-experienced data rate that increases 10x, from 10 Mb/s to 100 Mb/s and reduced latency by a factor of 10, from 10 ms down to 1 ms.

As opposed to the legacy networks, including 4G, for which all the activities related to development and commercialisation (comprising requirements and specifications definition, design, standardisation and deployment activities) were based on an abstract, application/service-agnostic definition of the network Quality of Service (QoS) requirements, the respective 5G development activities are based on a more stakeholder/application/service requirements-aware approach.

With respect to IMT-advanced, 5G targets the following numbers as new network characteristics:

- 1 ms End-to-End latency.
- 100 times higher mobile data volume per geographical area.
- 10 times more connected devices.
- 10 times to 100 times higher typical user data rate.
- 100 times lower energy consumption.

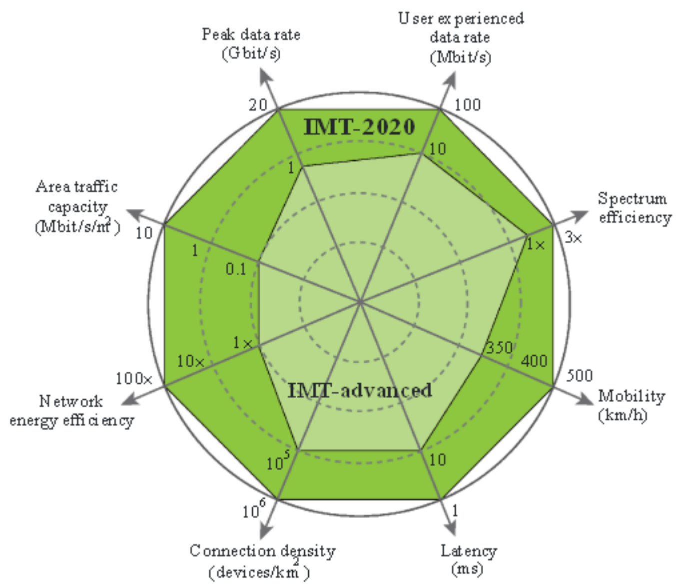

Figure 1 -: Radar diagram reporting 5G requirements (source ITU-R).

Ubiquitous 5G access including low-density areas. The KPIs defined by the 5G community ([1]-[4]) are not only related to performance. Business and societal objectives are identified as well. In particular, business KPIs are related to the involvement of small medium enterprises in the research and to reach a global market share for 5G equipment & services delivered by European headquartered ICT companies at, or above, the reported 2011 level of 43% global market share in communication infrastructure.

On the other hand, five KPIs related to societal aspects have been identified:

- Reduction of energy consumption per service up to 90% (as compared to 2010).
- Enabling advanced user-controlled privacy.
- European availability of a competitive industrial offer for 5G systems and technologies.
- Stimulation of new economically-viable services of high societal value like U-HDTV and M2M applications.
- Establishment and availability of 5G skills development curricula.

3.1 5G Vertical Requirements

Besides the general technical QoS KPIs and target values for 5G technologies, the 5G network deployments and operation will be tailored to support the requirements of a range of stakeholders and services in an all-inclusive manner. For this purpose, 5G-related activities are converging to address the following major vertical industries:

- Automotive, focusing on services provided in high mobility scenarios, IoT applications/services, etc.;
- eHealth, especially focusing on remotely provided health services with high latency and reliability requirements;
- Energy, especially focusing on IoT based energy monitoring, management and network control scenarios;
- Smart cities and smart ports,
- Media & Entertainment, especially focusing on next generation applications/services provisioning such as Ultra High Definition (UHD) content, Crowdsourced/multi-user created content, highly interactive services, etc., and
- Factories of the future, referring to Industry 4.0 setups.

It becomes evident that these vertical industries involve large service groups, which can be provided by various business stakeholders, depending on the specific market/social environment, and can include various applications/services. Following the top-down approach, the vertical use cases can be broken down to services falling in the 5G (3GPP, ITU) identified categories: enhanced Mobile Broadband (eMBB), massive Machine Type Communications (mMTC), Ultra-Reliable and Low Latency Communications (URLLC) and Network Operation services, as depicted in Figure 2.

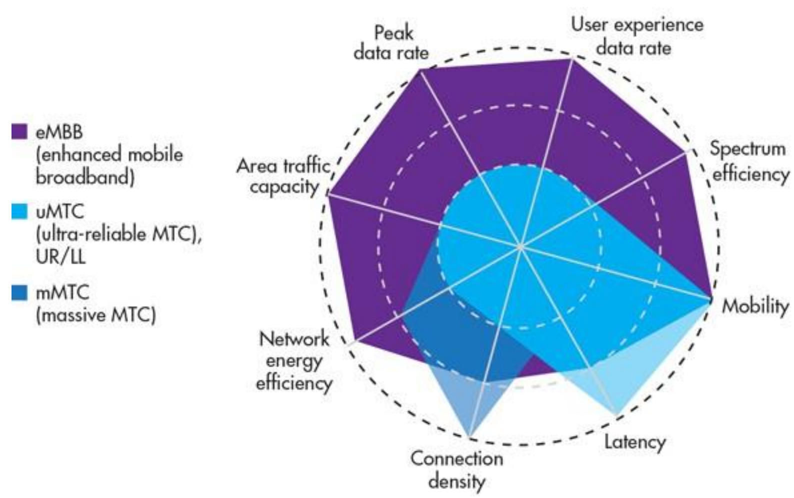

Figure 2: 5G use cases defined by the ITU Vision for 2020.

Furthermore, 3GPP's work on 5G services and their requirements has resulted in an almost identical classification corresponding to enhanced Mobile Broadband (studied in 3GPP TR 22.863), massive Internet of

Things (studied in 3GPP TR 22.861) and Critical Communications (studied in 3GPP TR 22.862) services. On top of this, Network Operation Services (studied in 3GPP TR 22.864) are distinguished as a separate class with a number of functional requirements such as multi-tenancy, energy efficiency, etc. 3GPP has already started consolidating the four Technical Reports into a single Technical Specification (TS 22.261), where specific system requirements are reported.

3.2 Enhanced Mobile BroadBand (eMBB) Service Class

eMBB includes bandwidth intensive services/applications, i.e., with (very) high data speed requirements such as streaming, video conferencing and virtual reality. The bandwidth requirements of this type of services are expected to be about 100 Mb/s per user, while in some cases it can be in the order of some Gb/s, reaching even 10 Gb/s. Table 2 reports the main KPIs target values for eMBB vertical needs, as identified in previous 5G-PPP projects or result of main satiation bodies (3GPP or ITU-R) discussions.

Table 2: eMBB Main KPIs Identified in Main Research Projects and Standardization Bodies

Service Class	KPI		Ref.	Target Values	
eMBB	eMBB.1	Peak Data Rate. NOTE: the data rate is a time-variable function. It might be important to define some parameters (e.g. peak, burst, average) in order to better describe the data rate	ITU-R report	**Downlink:** 20 Gbps	**Uplink:** 10 Gbps
	eMBB.2	End-to-End latency: the time it takes to transfer a given piece of information from a source to a destination, measured at the communication interface, from the moment it is transmitted by the source to the moment it is successfully received at the destination.	3GPP TS22.261	4 ms	
	eMBB.3	Traffic density	TBD	~7,5Mbit/s/m^2	
	eMBB.4	DL/UL data rate for mega-event. Considering the peak data rate and the total, bearing in mind the statistical multiplexing	5G-PPP 5G-PICTURE	20-100Mbit/s/user, (Total ~135 Gbps over the bowl area)	

3.3 Enhanced Machine Type Communication (eMTC) Service Class

eMTC extends LTE IoT capabilities – for example, Narrow Band-IoT – to support huge numbers of devices with lower costs, enhanced coverage and long battery life. This type of services implies the provisioning of connectivity to thousands of end-devices. Table 3 reports the main KPIs target values for eMTC vertical needs, as identified in previous 5G-PPP projects or result of main standardization bodies (3GPP or ITU-R) discussions.

Table 3: eMTC main KPIs Identified in Main Research Projects and Standardization Bodies

Servic e Class	KPI		Ref.	Target Values
eMTC	eMTC.1	Coverage. The improved coverage is expected to be needed by some MTC/IoT devices with challenging coverage conditions, for example	5G-PPP project 5G-MONARCH	Max coupling loss 164

		water/gas/electricity metering devices installed in basements. The coverage enhancement is mainly achieved through repetition techniques.		dB
	eMTC.2	Max Battery Life. time of battery duration	H2020 Project SCOTT	10 years
	eMTC.3	Jiiter. the **short-term variations** of a digital signal's significant instants from their ideal positions in time	Project METIS II	500 us
	eMTC.4	Position accuracy	5G-PPP 5GCAR Project	0.1 m

3.4 Ultra-Reliable, Low-Latency Communications (URLLC) Service Class

URLLC refers to "mission-critical" communications, including latency-sensitive ones, i.e. services with extremely short network traversal time requirements, such as applications/services enabling industrial automation, drone control, new medical applications and autonomous vehicles. The latency requirements for this type of services are expected to range between 1 ms and 2 ms for the user plane and less than 10 ms for the control plane. Table 4 reports the main KPIs target values for URLLC vertical needs, as identified in previous 5G-PPP projects or result of main standardization bodies (3GPP or ITU-R) discussions.

Table 4: URLCC main KPIs Identified in Main Research Projects and Standardization Bodies

Service Class	KPI		Ref.	Target Values
URLCC	URLCC.1	User plane latency: the time it takes to transfer a given piece of information from a source to a destination, measured at the edge of the user-plane.	5G-PPP project 5G-MONARCH	0.5 ms
	URLCC.2	Reliability, as **percentage value of the amount of sent network layer packets successfully delivered** to a given node within the time constraint required by the targeted service, divided by the total number of sent network layer packets. The reliability rate is evaluated only when the network is available	3GPP TS 22.261 V16.1.0 (2017-09	10^{-5} success probability for 32 bytes within 1 ms
	URLCC.2	**Connection availability**: the percentage of available time (w.r.t. total time) in a generic observation period of the connection across the transport network. A bidirectional path or connection is in the unavailable state if either one or both directions are in the unavailable state.	5G-PPP 5G-PICTURE	99.999%
	URLCC.3	**Communication service availability**: percentage value of the amount of time the End-to-End communication service is delivered according to an agreed QoS, divided by the amount of time the system is expected to deliver the End-to-End service according to the specification in a specific area.	5G-PPP 5G-PICTURE	99.999%
	URLCC.4	**Packet loss or frame loss ratio**: defined as the percentage of frames that should have been forwarded by a network but were not.	5G-PPP 5G-PICTURE	10^{-4}

4 5G-SOLUTIONS Methodological Framework

The scope of the project is to run multiple innovative trials from various business domains in order (a.) to verify the feasibility to meet currently defined 5G KPIs, and (b.) to identify through the trials and the respective analysis standardization areas what needs to be further investigated from various perspectives, i.e. technological, applications & business.

In this chapter, the methodological framework for main objectives of this project is defined. This framework is later used in chapter 5 to collect definitions, requirements and KPIs from use cases in five Living labs related to different business domains as mentioned above.

4.1 Framework

In this section we provide a framework to map collected requirements and KPIs from use cases arising in five Living Labs into consolidated 5G-PPP service classes. Accordingly, we follow the 5G-PPP Service Classes Triangle introduced in previous 5G-PPP projects. Beyond the previously defined KPIs (e.g., from previous projects), new KPIs are defined and tested within 5G-SOLUTIONS according to different business needs.

The steps for this mapping are:

- define each field trial element as a tuple of uniquely identified definitions for Use Case (UC), Key Performance Indicator (KPI) and Requirement (i.e. <UC, KPI, Requirement>);
- by using definitions of 5G-PPP service classes, locate each use case (UC) in the spectrum between edges of this triangle;
- map Use Cases (UCs) to Living Labs and then position them into the 5GPPP Service Classes Triangle;
- KPIs in each element (i.e. <UC, KPI, Requirement>) have to be characterized by key information such as:
    - How to measure
    - Where to measure (testbed/LL)
    - Relative/Absolute evaluation
    - Scope of measurement

The framework actions will be completed in the Deliverable D1.1B. In the deliverable D1.1A we mainly focus on describing the UCs, identifying stakeholders and putting the ground for the DoA KPIs validation.

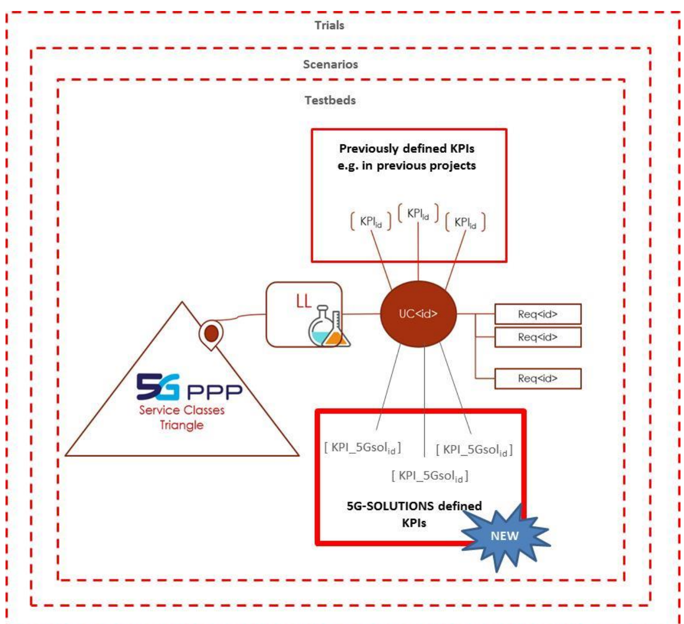

Figure 3: KPIs Definition Framework.

5 Use Case Description and Detailed Analysis

According to general methodology illustrated in Section 4, in this section we describe the use cases (UCs), related requirements and KPIs/SLAs. The "5G end to end Key Performance Indicators (KPI)" is be used for KPIs definitions [1].

5.1 Factories of the Future Living Lab

This Living Lab covers sensor data gathering in heterogeneous environments, plant monitoring and massive payload data offloading, plant real-time monitoring and control, with the final aim of process optimization. By optimizing the production process, it will be possible to increase the whole production line efficiency and the quality of the produced goods. From a maintenance point of view, Living Lab 1 (hereafter LL1) wants to create a solid baseline to enhance the interaction between the human operator and the plant components.

5.1.1 UC1.1: Time-critical process optimization inside digital factories

This Use Case consists of leveraging 5G technology to enable a real time product and process control. P&G products are manufactured 24/7 at a large production rate i.e. thousands of product units per minute. The only way to assess the quality of the product is through digital visual inspection, which translates into a need for very high data transfer rate (images to be transferred quickly) and a low latency (to be able to analyze the images and feedback the process for control).

5.1.1.1 UC objectives and scenario

The main objective of this Use Case is to mark a sensible improvement in the quality control system in industrial production chains. By implementing digital hyperspectral monitoring systems in-line with the production chain it is possible to detect defects and non-conformity in the products that were not possible to be detected before, such as chemical discontinuity in the product's components. The product inspection happens directly into the production chain, when the product is, for instance, still moving on a conveyor belt. Such technology, however, requires a high data rate and a consistent reliability level, other than (depending on the speed of the production line) stringent latency requirements. For these reasons this type of monitoring solutions need an elaboration unit close to the sensor with a wired connection. Such a configuration proved to be not suitable for the industrial production lines that often cannot host powerful processing units and cables close to the production machine. Replacing the cables with a wireless connectivity, would allow moving the processing unit in a safe and adequate space, leaving the production machine free from impediments. Moreover, a wireless connection allows gathering information about the monitoring progresses, collecting statistics with the aim of improving the whole system.

Table 5: UC1.1 Objectives

Test Objectives	Requirements	Participants
Verify the suitability of wireless connections in a high data-rate and low-latency context	Adequate source of data, performance monitoring system	PGBS and IRIS providing the source and user of the data, UOP providing the network infrastructure
Evaluate network orchestration and monitoring system	Real high data-rate traffic and its application. Connection with Patras facility.	UOP providing the infrastructure cooperating with NOKIA
Evaluate the reliability feature of a 5G wireless connection	Extensive tests in a continuous production line	PGBS providing the production line

For this UC IRIS will install its Hyperspectral Imaging (HSI) monitoring system in-line with the production line for product inspection and quality assurance. The HSI allows discovering defects in the produced goods that are not visible using visual cameras, increasing the overall quality of the product and reducing waste.

Nowadays, diverse inline monitoring technologies, based in photonic approaches such as Ultra Violet/Visible (UV/Vis), Near infrared (NIR) and Raman, have been developed and applied for the monitoring of different products in the food, chemical, pharmaceutical and consumer goods industries.

A basic hyperspectral imaging system, shown in Figure 4, includes in its set-up, a sensitive NIR- sensor, a broadband illumination source (often a tungsten lamps), a spectrometer, which separates the backscattered/transmitted light in its different wavelengths.

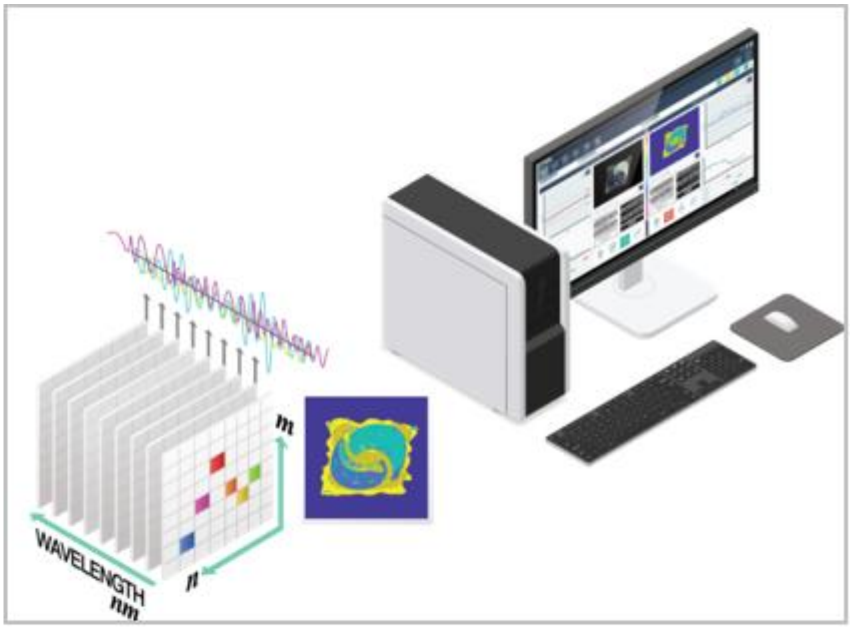

Figure 4: Left: Graphic representation of a hyperspectral cube. Each hyperplane (slide) of the cube corresponds to a spectral channel or wavelength band. Right: HYPERA® software Interface.

The output of an HSI system is a multispectral image of the sample under test, containing the spatial localization of the features under interest and its chemical composition. This set of data is generically organized in a hyperspectral data cube. Such a set of data has to be processed using advanced machine learning tools, also known as chemo metric techniques (multivariate analysis and statistical methods) to extract the most relevant and significant information from the spectral dataset. In this regard, chemo metric methods allow the analysis of large amount of data, identifying the most significant spectral features for discrimination & classification/prediction purposes.

In this regard, IRIS has developed the HYPERA® system, schematized in Figure 5. This system is configurable to be adapted to the specific in-line process requirements (resolution, conveyor speed etc.).

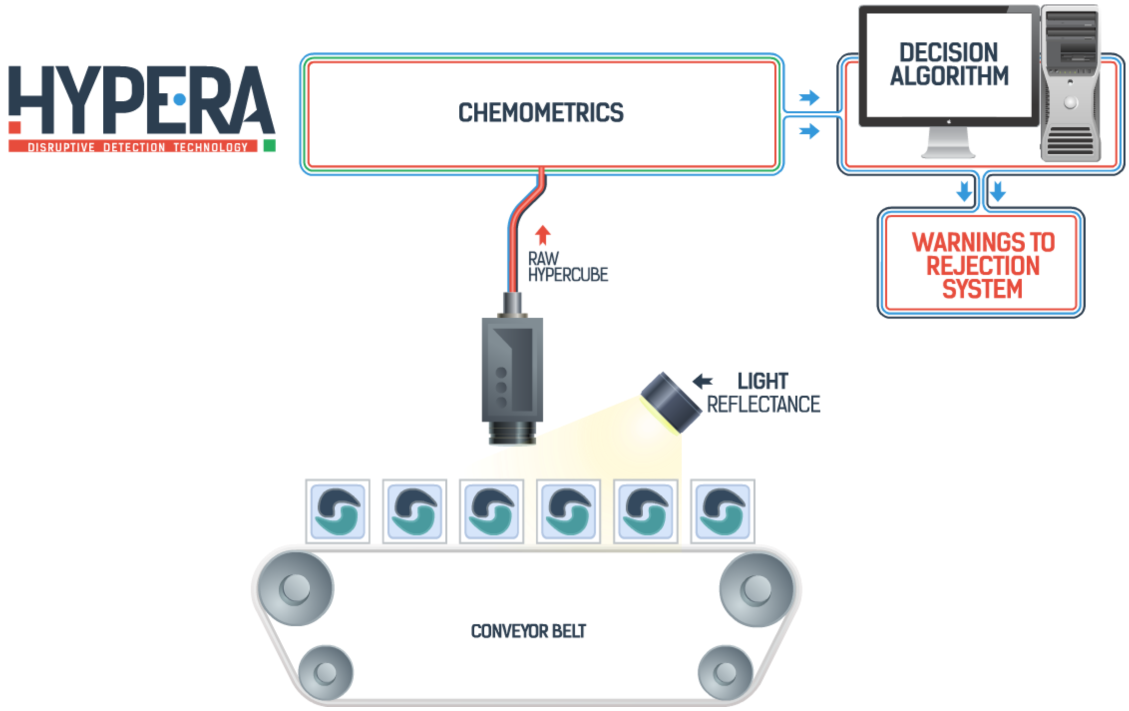

Figure 5: Conceptual representation of the HYPERA® set-up for inline monitoring applications in food industry (for instance, foreign bodies' detection).

The HSI system will be integrated in a process analytic platform for analysing and processing the data, using the 5G link as communication interface. Due to the large amount of multivariable data contained on a hyperspectral image, an adequate communication channel between the hyperspectral data cube source and the computer that hosts the machine learning prediction engine is required. Such a powerful computer is usually placed near the imager, which is not a cost-effective solution for massively using this emerging technology. The cost-effective alternative is using remote cloud-computing solutions; indeed, novel and affordable communication means are required. The performance of state-of-the-art wireless communication channels are, in most of the applications, not sufficient to satisfy the data rate requirement of a hyperspectral data cube offloading, that in some cases can overcome 2 Gbps. Low latency could become a desirable feature if, as happens in many cases, the product analysis works as a trigger for a rejection system to take actions (removing the product from the production line) in case the product results faulty or with characteristics that are not compliant with the target quality level.

A key feature of the communication channel is reliability. An unexpected lack of input from the source can generate malfunctioning at the chemo metric model that won't be able to detect the composition and evaluate the characteristics of the product. The proposed implementation of the system with the 5G node is depicted in Figure 6.

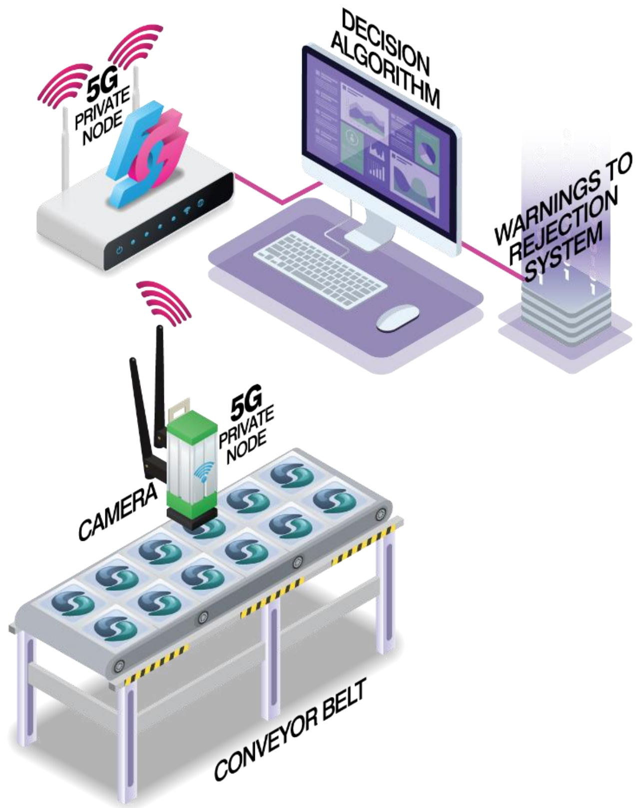

Figure 6: Proposed implementation of the HSI system in the production plant using the 5G node.

The data captured by the camera are wirelessly offloaded to the Processing Unit, equipped with a powerful Graphic Processing Unit (GPU), through the 5G connection offered by the 5G node. The raw data are then processed by the Processing Unit to perform the detection of defects or non-conformity in the analyzed product. The 5G node will instantiate the necessary network components, perform the initialization and report on malfunctioning of the HIS camera or GPU connection. Data about the connection parameters will be sent to the core network for statistical purpose.

The final aim of this UC is to implement and integrate an advanced monitoring system with 5G technology for improving the actual quality control system implemented in the industrial production chain. The implementation of novel monitoring technology and the 5G communication will improve the accuracy of the chemo metric models allowing detecting defects invisible to traditional quality control systems. Micro defects, changes or discontinuities in the product components distribution, non-conformity in the chemical composition, etc. will become detectable, leading to a substantial improvement of the quality of the final product, reducing waste and scrap optimizing the power consumption. The hyperspectral analysis of the product and the possibility of processing and storing the data, opens the possibility to perform statistical analysis and applying reverse engineering methods for the prediction and detection of defects in early stages of the production process.

5.1.1.2 Stakeholders and Roles

The time-critical process optimization represents a challenge for all the modern production plants both in terms of process control and management, and in terms of scrap and power-consumption reduction, to provide the end-user with a high-quality product, manufactured in the most efficient way for the most competitive price for value. A higher efficiency of a production process and a better-quality assurance methodology, have impact on the final consumer, the production plant, as well as on the environment. In relation to this specific UC, the main stakeholders are internal to the production plant.

Table 6: UC1.1 Stakeholders and Roles.

Stakeholders	Roles
P&G production plant	Main beneficiary
IRIS Technology Solutions	Technology provider
P&G Quality Assurance department	Business related to scrap reduction

5.1.1.3 Requirement analysis and KPIs

The industrial environment and the application described for this UC are demanding under different aspects. The high data rate required and the stringent requirements in terms of latency and reliability make this UC suitable for covering the three service classes defined by the 5G-PPP.

In UC1.1 the products to be inspected are moving on a conveyor belt. At the conveyor working speed the gap between the product under inspection and the subsequent product to be inspected is around 40 ms. In this time-slot the monitoring system has to generate the data and offloading it over the 5G radio network to the processing unit for the data elaboration.

Table 7: UC1.1 Technical KPIs.

Technical KPIs		
KPI	**Target**	**Measurement Method/Formula**
Uplink Throughput	> 2Gbps	Data-flow monitoring
Inspection and elaboration latency	40 ms	Timestamping difference
Number of devices simultaneously connected	< 10	Counting/detecting number of devices
Indoor Communication Range	Between 10 and 20 meters	RSSI at the receiver
Reliability	99.999%	% of data delivered without data corruption

Table 8: UC1.1 Business KPIs.

Business KPIs		
KPI	**Target**	**Measurement method/formula**
False negative	0.001%	% of good product rejected
Detection success rate	99%	% of non-compliant goods detected
Scrap reduction	0.1	# of compliant product rejected for each non-compliant product

5.1.2 UC1.2: Non-time-critical Communication inside the Factory

This Use Case will focus on the 5G technology as an enabler for multi IIoT sensors data gathering to perform smart monitoring inside the factory facility. The new platform will be integrated with existing data collection platforms to enhance the problem-solving capability in the production plant.

The 5G deployment will be hosted in a Glanbia production plant. Glanbia Ireland has 9 manufacturing facilities on the island of Ireland manufacturing a range of products from consumer-packaged liquid milk products to cheese, butter and dairy powder products for the international ingredients market. In consultation with the business and having assessed use cases across the Engineering, Maintenance, Quality, Health & Safety, and environmental management functions, the business has decided to focus on using this 5G-SOLUTIONS UC as an enabler for ***flexible mobile condition monitoring*** focusing initially on the Drier processes in one of 3 powder production facilities.

The Physical Asset of interest is constructed of stainless steel, is large in size, several floors high, and the environment in which this type of equipment is housed has historically presented challenges to the provision of reliable network services. Questions about the operating conditions of the asset or environmental context around the asset could only be answered by commissioning specific standalone studies. This is a time consuming and costly process.

5.1.2.1 UC objectives and Scenarios

The Vision for 5G is to provide a mobile environment that can provide reliable coverage in an area where mobile technologies have traditionally struggled. This 5G network will be the primary platform for a "***Mobile Maintenance Toolbox***" where IIoT enable instruments can be provisioned quickly, and can integrate with existing data collection platforms to provide powerful plant insight and enhance problem solving capability.

Figure 7: Drier Unit Installation at a Glanbia Facility under Construction.

Glanbia currently performs data collection and aggregation from around 20,000 sensors using PLC data. Augmenting the existing wired data collection system with 5G wireless technology will allow Glanbia to expand its data collection footprint and integrate intelligent instruments to complement wired technologies and drive the digital factory agenda in line with Industry 4.0 paradigm.

Specifically, Glanbia in conjunction with Orbis plan to setup a parallel Living Lab aligned with the existing MES infrastructure to progress and test the following Industry 4.0 initiatives:

- **IIOT:** Enhances 5G Process Connectivity, Additional Sensors and bypass Plant automation are delivered directly to the MES or Cloud IIoT platform.
- Edge Dashboards (Operator, Supervisor, Manager) with mobile access: Enhances data dissemination using 5G mobile client connectivity.

The 5G Living Lab network will need to cover approx. 12,000 m^2 over 5 Floors Approx. 30m high with a ground level footprint of 20m x 20m. The network will need to accommodate native 5G enabled sensors as well as IIoT

Edge Gateway(s) with 5G capability. The network will need to provide reliable coverage in a challenging environment. Glanbia imagines supplementing the existing MES platform with time series data collected via a 5G IIoT enabled network. IIoT Sensors (vibration, Temperature, pressure, etc.) will be deployed in an industrial 5G coverage space connected either directly to the 5G network, if suitable sensors are available, or to a 5G enabled IIoT gateway. This 5G enabled data source would complement the existing process data connected via the wired OPC connections to the Control Layer PLC equipment.

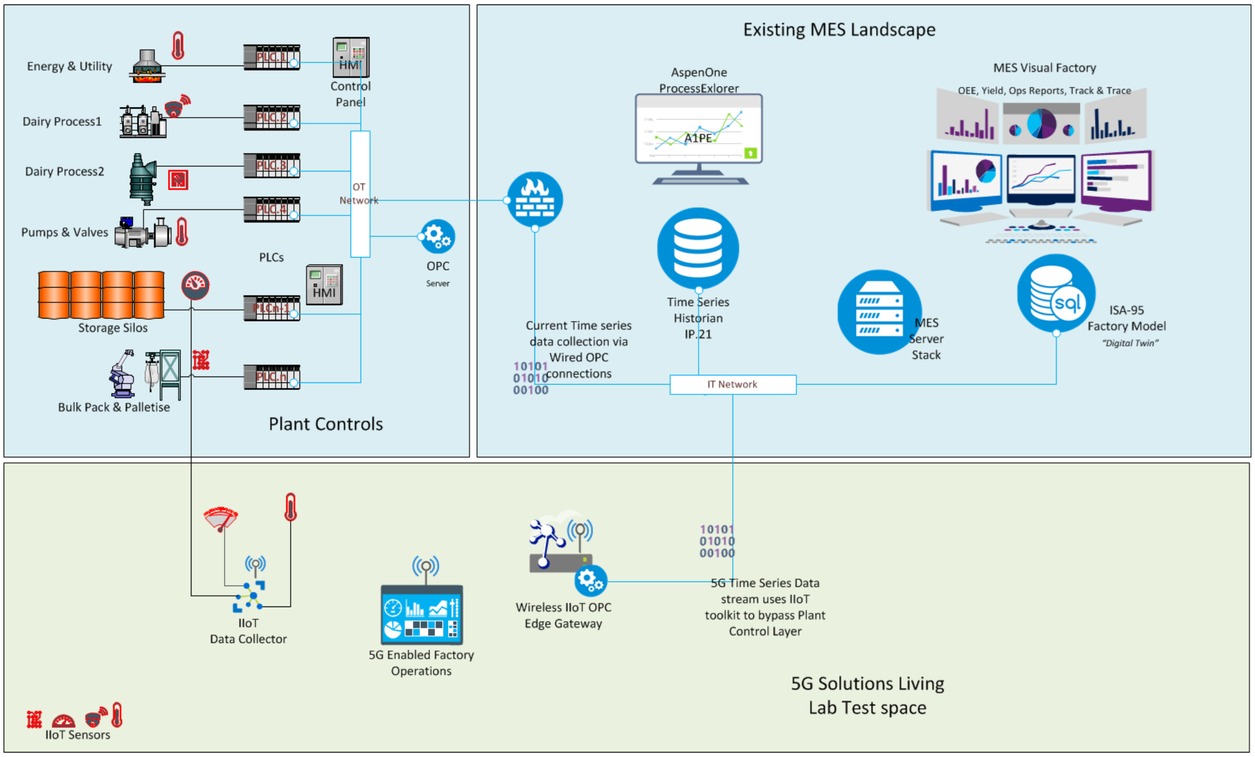

Figure 8: Reference architecture of the OPC and 5G-enables sensors integrating in the existing MES system.

Glanbia expects the 5G network to present a number of advantages:

- Reduced cost of deployment of sensors.
  - For engineering & Maintenance plant investigations.
- Flexibility of movement of sensors or network reach.
  - The Network can be extended more easily as there expensive cabling and associated containment will not be required.
  - The Sensors can be moved or re-deployed.
- Ease and speed of sensor commissioning: installation of additional sensors will not need to be supported by:
  - Additional Plant cable containment.
  - Additional network Cabling.
  - Additional PLC I/O slots.
  - PLC programming effort.
- The installation of new sensors will not need the same level of network containment in harsh or Hi-Care2 areas.

[2] Hi-Care areas are areas of a food manufacturing plant have restrictions on movement and special requirements in terms of equipment installation and use.

- Potential improved data Granularity:
  - Current conventions recommend polling the PLCs for data updates every 15 seconds. There is the potential to achieve a higher data granularity via a connection which bypasses the automation layer as the risk of adversely affecting the plant control will be eliminated. Using smart sensors transient impulse events in the plant would have gone undetected on the MES platform.

The 5G network foundation would form the basis of a data platform for manufacturing facilities worldwide that would enable Glanbia to begin the journey from data collection and presentation to realizing the more advanced capabilities that will be needed in the factory of the future; such as assisted and augmented reality applications for training and expert assistance to leveraging the diagnostic and prescriptive data driven applications that are already commercially available.

Table 9: UC 1.2 Objectives, Requirements and Participants.

Test Objectives	Requirements	Participants
Test the coverage of 5G technology in a context where wireless technologies struggled	Vast indoor area to be covered gradually/step by step, reach of scatter points	GLAN and OMES providing the sensors and MES, UOP providing the network infrastructure
Increase the speed of sensor commissioning	Installation of additional sensors will not need additional cables, PLC and I/O slots	GLAN and OMES providing the infrastructure, UOP providing the radio transceiver
Evaluate the data integration and interleaving	Data from cabled and 5G-enabled sensors have to be integrated and interpreted by the MES	GLAN providing the IIoT infrastructure in the plant, OMES adapting the MES interface
Evaluate reliability of 5G wireless network	High reliability under the area of coverage.	GLAN and OMES providing the sensors and MES, UOP providing the network infrastructure

5.1.2.2 Stakeholders and Roles

The non-time-critical communication inside the factory represents a challenge under several aspects. The reliable coverage of a wide area reaches of scatter points proved to be challenging. Several areas of the plant don't allow free movement and provisioning cabled sensors in those areas is problematic.

Table 10: UC 1.2 Stakeholders and Roles.

Stakeholders	Roles
GLAN engineering department	Main beneficiary
GLAN Maintenance department	Beneficiary and tester
GLAN Quality department	Business related to the increase of monitoring points
GLAN Health and Safety department	Interested for the mobile maintenance toolbox
OMES MES development and maintenance	Responsible for the MES integration
UOP	Technology provider. Providing the private 5G node in the factory premises

5.1.2.3 *Requirement Analysis and KPIs*

The possibility of integrating new sensors with the existing monitoring platform opens the possibility to access data that are undetectable today, in order to improve the maintenance processes and optimize the efficiency of the production plant. Considering the above objectives and scenarios the following initial KPIs have been identified.

Table 11: UC 1.2 Technical KPIs.

Technical KPIs		
KPI	**Target**	**Measurement method/formula**
Measure impulses/shocks undetectable today	< 1 s	Store in historian - Observation in IP21 historian
Mobile access performance within the coverage range	TBD	Check mobile access and user experience across the coverage range
Network latency	TBD	Measure IP latency from collector to sensor
Device density	TBD	TBD
Reliability	99.999%	Constant data stream 1 day at poll rate monitoring interference
Data contextualization	100% integration with MES to create additional context	Integrating 5G data in the existing ISA-95 batch model
Data visualization	100% compatibility with existing Visual Factory Tool to trend and find patterns in the data	Integrating 5G acquired data in teh existing Visual Factory toolkit (A1PE)

Table 12: UC 1.2 Business KPIs.

Business KPIs		
KPI	**Target**	**Measurement method/formula**
Maintenance time and efficiency	Measurable improvement	As-is vs To-be
Operator workload	Enhancement of monitoring and plant maintenance toolkit	Additional data collection and 5G enabled mobile maintenance toolkit
Operator Health and safety	Positioning and localization	TBD
Data collection footprint	Integration of new sensors	TBD
Time to solve the problem	TBD	TBD

5.1.3 UC1.3: Remotely Controlling Digital Factories

While in both UC1.1 and UC1.2, local on-site communication is assumed within the plant, in the case of UC1.3, the public wireless access network also plays a role in the E2E communication between remote workers and the factory. The simplest setup of this use case involves remote control applications running on tablets or smart phones for example. However, in view of the trend of new AR devices, it is likely that new remote services may arise to facilitate the creation of virtual back office teams.

5.1.3.1 UC objectives and Scenarios

Such remote teams may use the data coming from smart devices for preventive analytics and easy access to work instructions, whereby, e.g. they would be able to view the camera or iPad/Google Glass of a local worker. Additionally, the application of AR in the plant will facilitate:

- **Augmented-reality support in production and assembly**: Precisely positioned picture-in picture fade-ins, showing the operator the next step and helping to avoid misplacement and unnecessary scrap.
- **Augmented-reality support in maintenance and repair**: Repair machines without training due to augmented information and operational guidance.

Cross-functional communication, effective knowledge sharing and collaborative design platforms will be facilitated by solutions for communities of practice. In this use case family, there is a less stringent need for low-latency. Interaction times up to seconds are acceptable for remote servicing machines. However, high availability is key for allowing (emergency) maintenance actions to occur immediately. Bandwidth is important for video-controlled maintenance, with real-time augmented content mixed into the video signal. Moreover, latency is particularly important for real-time, remote motion control of local robots. Edge computing within the network is required for fulfilling the low latency requirements. Security threats are introduced due to the opening up of the machines to allow remote reconfiguration. As such, the cyber-representation of a factory or supply chain needs to be protected, with mission-critical actions being shielded from non-authorised parties.

Other overall issues that will be researched in use-case 1.3 in cooperation with work in UC1.1 and UC1.2:

- To test the availability/ coverage of the network for immediate use.
- To test the security of the network to protect against non-authorized access and malicious takeover of a machine or a plant.
- To measure the quantifiable quality of service parameters under several scenarios of use.

The experiments will be performed at MTP NTNU where there are several industrial scales physically and logically interconnected robotics laboratories being built as of the summer 2019. These are part of the NFR (Norwegian Research Council) supported initiative Manulab. (See e.g. https://www.ntnu.edu/ivb/manulab) These laboratories at MTP at Gløshaugen in Trondheim consist of several interconnected parts, a general robotics laboratory for welding, one for use with robotized direct construction of casting-forms, stations for automated shaping of metallic pipes and a section with several smaller robots and operator stations to study Industry 4.0 concepts, this especially in conjunction with the AGV lab. The following figures provide an overview.

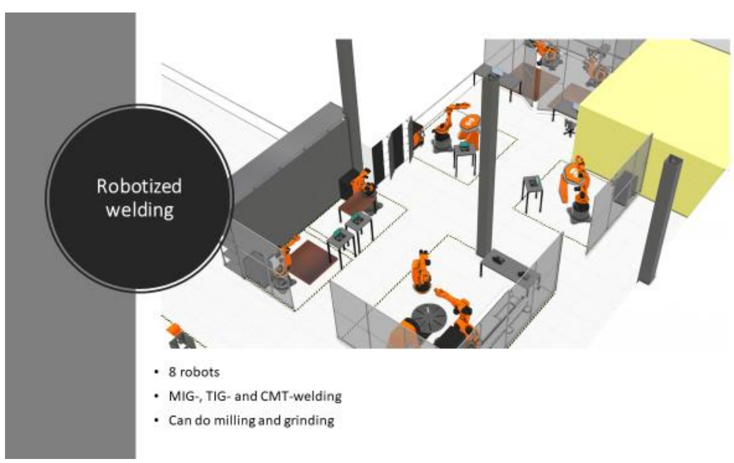

Figure 9: Robots for Welding, Milling and Grinding.

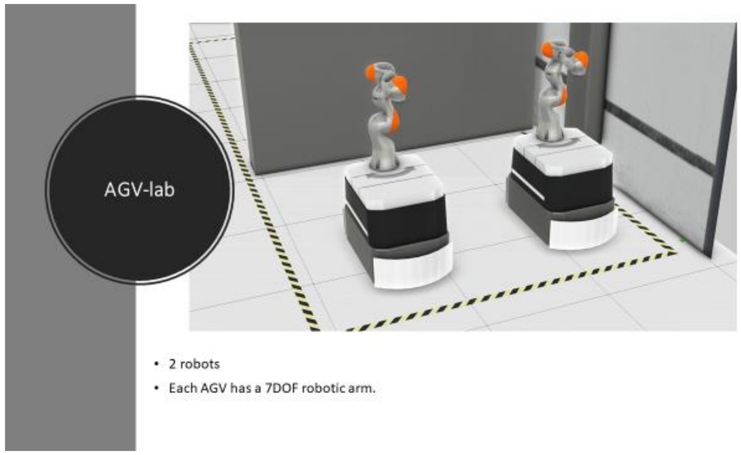

Figure 10: AGV-lab.

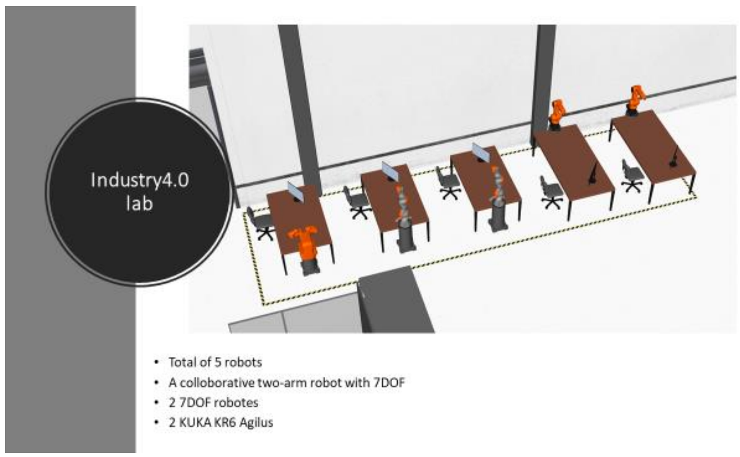

Figure 11: Industry 4.0 Lab.

MTP NTNU will instrument both the stationary robots and the AGVs with high-resolution cameras / 3D-cameras and auxiliary sensors to be connected to the 5G network. In addition, the robots and AGVs will be connected using 5G through their traditional interfaces found on external computers, and built in through gateways. Here we expect to construct several translations/gateways for proprietary interfaces, OPC UA - as well as ROS 2.0 - based interfaces, as well as additions to AAS components for Industry 4.0.

MTP NTNU will conduct experiments with use of different 5G connections where measures on KPIs are done while different kind of welding and other industrial-type operations are done in the labs.

It should be noted that a respective application will be made to the Norwegian research council for a Ph.D grant. The candidate will have as his/her main topic the study of UC 1.3.

The FoF CSP will collaborate with the factory to ensure the desired coverage and service level specification. This process must be designed, exercised, tested and validated. The critical goal and tasks are the (method) to test and validate the agreed coverage and service levels, including the desired QoS profile, considering the various UE and the different applications they perform. We anticipate that different types of connectivity and their QoS property are available and each type of connectivity should match well with the requirements of the applications.

5.1.3.1.1 Architecture/Component/Applications

As seen in Figure 12, there is communication both directly from sensory-systems such as 3D-cameras and from processed sensor data e.g. from the local on-board computer for robots and AGVs. Due to the processing needs there are latency requirements based on this, the same system will also be used for localization of AGVs. Thus, this lab will also contribute to some degree to both UC 1.1 and UC 1.2 in addition to UC1.3. The video-streams are expected to have throughput requirements in the order of 1 Gbps or less.

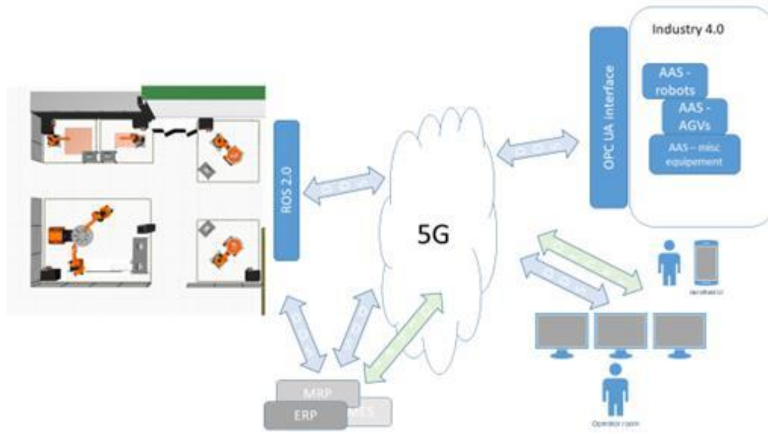

Figure 12: UC 1.3 Architecture.

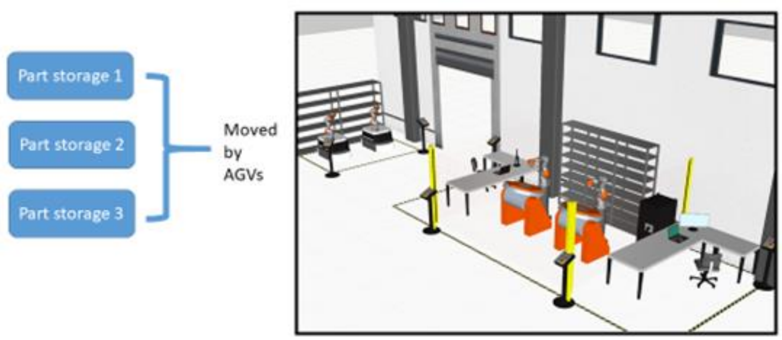

Figure 13: UC1.3 Physical Layout.

For UC1.3 (as well as UC1.1 and UC1.2) the principal set-up in Figure 12 and Figure 13 will be used for measurements of latencies, throughput, reliability and availability. In addition, and specific for UC1.3, measurements of the precision of positioning accuracy are needed.

Critical tasks that will be studied, in the set-up indicated in Figure 14 include:
(These tasks will be further developed.)

- Remote control of AGV (Direct control and indirect, planned operation).
  - Operators in local control-room
  - Operators at remote location i.e. at least 500km (Distance Trondheim - Oslo)
- Remote control of stationary robots (Direct control and indirect, planned operation).
  - Operators in local control-room
  - Operators at remote location i.e. at least 500km (Distance Trondheim - Oslo)
- Semi-local operation / control with use of AR-information added to operators UI.
  - AR-information processed and added at local site, edge computing
  - AR-information processed and added at remote location i.e. at least 500km (Distance Trondheim - Oslo)

- Positioning accuracy of movable equipment (on AGVs).

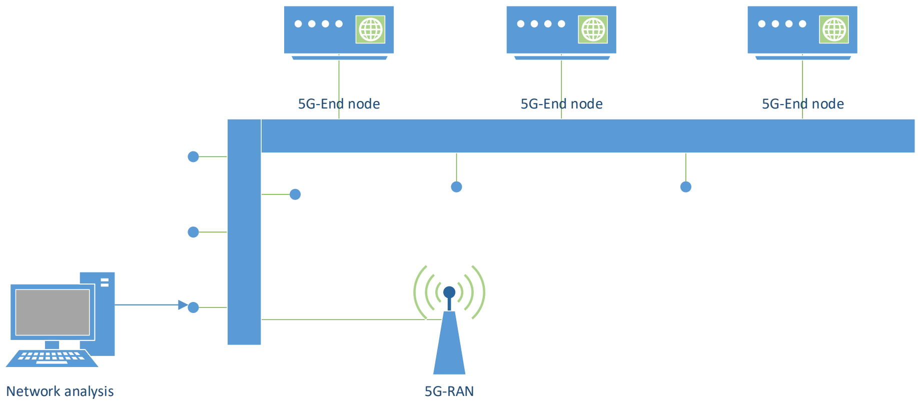

Figure 14: Principal Measurement Set-up.

5.1.3.1.2 UC Objectives

The main objectives of this use case are given in the Table 13.

Table 13: UC 1.3 Objectives.

Test Objectives	Requirements	Participants
To test the availability/ coverage of the network for immediate use To test the security of the network to protect against non-authorised access and malicious takeover of a machine or a plant	• Installation of private 5G RAN nodes within the factories to support the measurement of availability, latency, throughput and positioning accuracy. • Complementary communication channels for accessing remote services based on high speed wideband. • Real data and respective data sources (fixed or mobile)	▪IRIS ▪GLAN ▪OMES ▪NTNU ▪PGBS

5.1.3.2 Stakeholders and Roles

While a successful study with a positive outcome of the use of 5G in an environment that might be very difficult for the RAN, as done in UC1.1, UC1.2 is the foundation for in practice to be able to utilize a successful outcome of UC1.3, the specific results of UC1.3 will be of interest anyway, since measures might be taken at later stages to overcome any show-stoppers found in the other (related) use-cases.

Table 14: UC 1.3 Stakeholders and Roles.

Stakeholders	Roles
SMEs (represented by NTNU in the first iteration)	Main beneficiary
NTNU	Technology provider

5.1.3.3 *Requirements analysis and KPIs*

The technical and business requirements of UC1.3 are given in Table 15 and Table 16 respectively. Please note that some have also been reported in UC1.1 and 1.2.

Table 15: UC1.3 technical KPIs

Technical KPIs		
KPI	**Target**	**Measurement method/formula**
Throughput UL Video-streams UI	> 1Gbps	Data-flow monitoring
Throughput DL Video-streams UI	Order of Mbps	
Throughput UL Sensor data	Order of Kbps	
Throughput DL Sensor data	Order of Kbps	
latency	< 10 ms	Timestamping difference
Number of devices simultaneously connected	>10	TBD
Positioning accuracy	< 0,2m	Comparison to manual measures / comparison other indoor location systems
Indoor Communication Range	Between 10 and 30 meters	RSSI at the receiver
Reliability	99.99%	% of data delivered without data corruption

Table 16: UC 1.3 Business KPIs.

Business KPIs		
KPI	**Target**	**Measurement method/formula**
Availability of the system in compliance to all specified requirements	99,9%	Statistical sampling
Latencies perceived by operators in non-direct mode	Not significant, i.e. less than 1s	Measuring time differences of sync. clocks
Indoor positioning of 5G can possibly replace other existing systems of principally the same kind	Accuracy at least as good as other comparable existing indoor location systems such as WIFI-based ToF, Deccawave etc.	Comparison of own results with other published results / results in our own lab with competing equipment

The requirement-analysis for the KPIs takes into account that the use cases will need that we demonstrate use both on a low “instrumentation” level, as well as when used for covering several of the traditional industrial levels for networks. The most relevant issues and parameters, i.e. KPIs to measure/study for each UC 1.3, are directly measurable quantities such as positional accuracy, latency, reliability, availability of bandwidth etc. in the presence of extensive and unpredictable radio noise caused by electric welding, other electric equipment, reflections and blocking walls and equipment.

While the indicated performance will be needed for UC1.3, latency, reliability and bandwidth-availability will be focused on in UC1.1 and UC1.2 both on a low “instrumentation” level, as well as when used for covering several of the traditional industrial levels for networks. The latter is done with organization of virtual networks. Positional accuracy will be reported on in UC1.3. For UC1.3 also the reliability and timeliness of the achieved accuracy in this assumed-to-be-difficult environment will be reported.

5.1.4 UC1.4: Connected Goods

This Use Case will assess the potential for 5G to enable full-duplex communication of appliances such as washing machine in tomorrow's home. This ideally builds on an open source interoperable IoT building block standard to enable connection from different stakeholders in IoT generated data while developing the necessary security and privacy considerations. This technology will enable consumers to use and leverage IoT solutions in their home to interact with supply of product and services. The vision of P&G is to build a level of interactivity similar to the on-demand solutions in TV content via content providers such as Netflix, but leveraging appliance data. This can cover NILM (non-intrusive load monitoring) or smart meter data from home appliance. It can also cover camera-based information (e.g. fridge, trash can etc.). Based on the broad NILM of other full home data, product supply can be optimized via external provider. The multi-stakeholder IoT platform will enable smarter and combined delivery of the different product needs in the home. This will collaborate, in the future, with the needs for other uses cases such as car and networked energy. The focus of this specific Use Case is on providing a proof of concept for a washing machine.

Table 17: UC1.4 Objectives.

Test Objectives	Requirements	Participants
Validate the viability of a new business model	Data monitoring and behavioural analysis	PGBS providing the facility and equipment, UOP providing the 5G node
Explore the benefits of remote controlling house equipment	Definition of metrics to describe stakeholder benefits	PGBS providing baseline stakeholder studies
Evaluate the possibility of modular technology for house appliances	Prototyping and testing	PGBS providing consumer lounge

Specifically, the Use Case will progress the functionality of a full duplex communication of an appliance. A modular washing machine with removed built-in obsolescence will be built in the P&G innovation facilities. It will be used to assess the potential to enable real time connectivity of new features of the wash process from wash programming to product and water use. The machine will be available for testing at the regional university or at the P&G consumer lounge located in Brussels (Belgium). The proof of concept will enable the following elements:

- Collection of non-processed data key features in the washing machine on sensors coming from the motors, moisture sensors, a camera in the machine and turbidity sensors. These will be collected to automatically (without consumer involvement) determine key features to decide the wash program.
- The data are translated and collected in the cloud for determination of load size, amount of soil, type of garments and colours. Based on the composition the algorithm, running remotely in the cloud, will define the composition of the wash load.
- A subsequent algorithm will determine the most sustainable wash cycle for this load without consumer involvement.
- The cloud-based algorithm will activate the machine accordingly.
- Upon execution it checks progress and results accordingly.

For the consumer this process needs to be completely seamless and work almost instantly. To have an acceptable quality of experience the washing machine, once loaded, should provide an almost immediate feedback to the user. Once the washing program has been selected, the different sensors continuously monitor the washing execution, adapting the washing parameters accordingly.

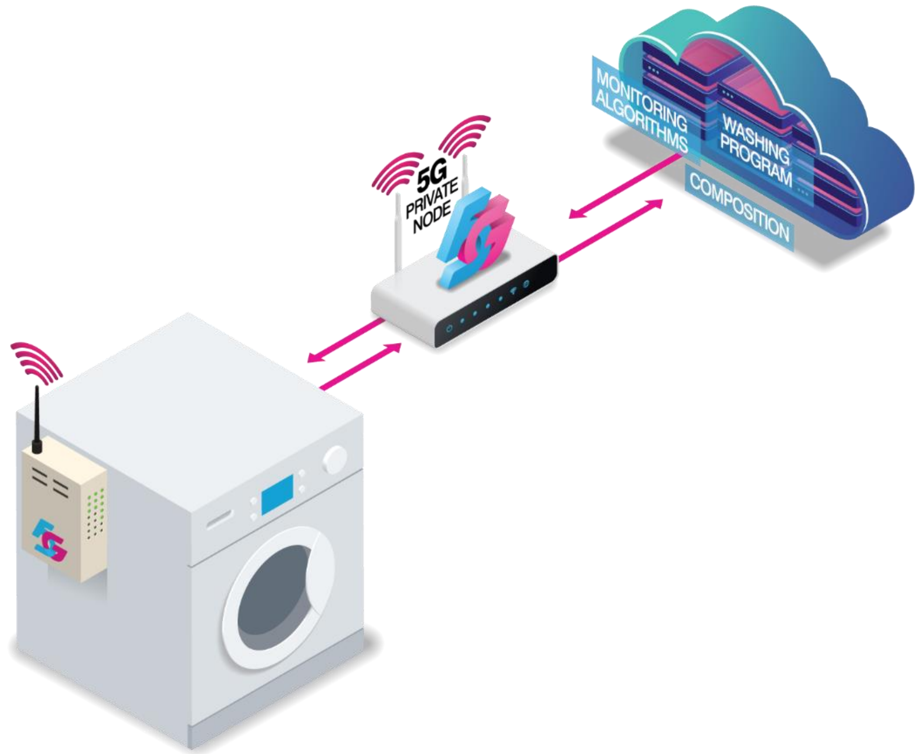

Figure 15: Simplified schematic of the proof of concept.

Figure 15 shows a schematic of the proof of concept leveraging on 5G connectivity between the washing machine and the remote algorithms. A machine with accessible electronics will be available for testing this proof of concept. It is under construction and will be finalized by the end of 2019 or January 2020 (working with University Gent). The sensor technology will be incorporated and include a camera for load detection. Testing will include comparing 5G with traditional connectivity to demonstrate that the use of 5G will bring results in terms of latency that are not achievable with previous communication technologies, reflecting directly on the quality perceived by the end-user and its level of satisfaction, other than a continuous monitoring of the washing process to optimize the water and soap consumption. Based on the proof of concept, it will be possible to determine the potential on performance improvement, water saving and energy efficiency with a 5G enabled appliance.

5.1.4.1 Stakeholders and Roles

The vision of having in the near future intelligent house appliances able to ensure the best performance without the human intervention opens the possibility of new business models. The stakeholders of this new business model can be numerous: from the consumer that won't need to take care of programming the appliance reducing the consumption due to the increased efficiency, to the environment that can benefit from the consequent lower impact. Appliance builder can build modular systems, where each module is independently controlled and so replaceable, reducing the cost of maintenance and disposal. The changes brought by this new vision affect several stakeholders across many sectors. Limited to the proof of concept that will be developed in the PGBS facility, it is possible to identify the stakeholders reported in Table 18.

Table 18: UC1.4 Stakeholders and Roles

Stakeholders	Roles

P&G Innovation Canter	Main beneficiary

5.1.4.2 *Requirement analysis and KPIs*

This UC represents a simplified and still under definition proof of concept for a way bigger vision that can potentially bring to new business models. At this stage it is difficult to provide exact figures and detailed descriptions of the methodologies or formulas used to characterize specific requirements.

Table 19: UC1.4: Technical KPIs.

Technical KPIs		
KPI	**Target**	**Measurement method/formula**
Unique sensors simultaneously connected	> 5	Number of sensors simultaneously connected
Operative latency in normal working conditions	50 ms	Network + elaboration latency in normal operation mode
Operative latency in fast-stoppage mode	10 ms	Network + elaboration latency in fast-stoppage mode
Indoor Communication Range	Between 10 and 20 meters	RSSI at the receiver
Reliability	99.999%	% of data delivered without data corruption
Data prioritization	50%	Data from some sensors need to be prioritized with respect to the other depending on the operation phase

Table 20: UC1.4 Business KPIs.

Business KPIs		
KPI	**Target**	**Measurement method/formula**
Easiness for the user	TBD	Specific consumer behaviour analysis metrics
Cost-Effectiveness improvement	TBD	Improvement with respect to state-of-the-art washing machines
Water consumption reduction	TBD	Water consumption reduction in comparison with current washing machines

5.1.5 UC1.5: Rapid deployment, Auto/re-configuration, Testing of New Robots

Evaluated in various settings and with different requirements, UC1.5 focuses on the possibilities of utilising the core functionalities of 5G in order to achieve one major feature of the Industry 4.0 in the FoF, such as significantly lower expenses and reduced time in order to either commission or reconfigure robotised manufacturing.

In UC1.5 the goal is to demonstrate how to achieve deployment of new robots into existing plants through automatic on-boarding of industry requirements. This encompasses auto-configuration of (mobile) robots and the corresponding 5G service configuration needed for interconnection / interworking across solutions from different vendors.

Other overall issues that will be researched in UC1.5 in cooperation with work in UC1.1, UC1.2 and UC1.3:

- To decide upon whether 5G can be utilised to improve the competitiveness of industry, here exemplified with small and medium-sized enterprises e.g. as they typically are in the western part of Norway.
- To get experiences of whether 5G technically and practically can be a replacement at all or some levels, and to which degrees, of the plethora of contemporary proprietary WSNs, proprietary real-time extensions for Ethernet and protocols with their resulting complexity.
- To get experience on how or whether 5G can complement and be used as part of or in conjunction with the other major industrial driving forces of today, mainly the Industry 4.0 initiatives. The experiments will be performed similarly as in UC 1.3.

5.1.5.1 UC Objectives and Scenarios

The main objectives of this use case are given in Table 21.

Table 21: UC 1.5 Objectives.

Test objectives	Requirements	Participants
To test possible systems integration through automatic on boarding of requirements.	Installation of a private G RAN node within NTNU Manulab/Industry 4.0 facilities	• NTNU • TNOR • YARA
To verify performance of the 5G RAN with the communication configured automatically.		

5.1.5.1.1 Architecture/Components/Applications

As seen in Figure 16, there is communication both directly from sensory-systems such as 3D-cameras and from processed sensor data e.g. from the local on-board computer for robots and AGVs. Due to the processing needs there are latency requirements based on this, the same system will also be used for localization of AGVs. Thus this lab will possibly also contribute to some degree to both UC 1.1 and UC 1.2 in addition to UC1.5. The video-streams are expected to have throughput requirements in the order of 1 Gbps or less.

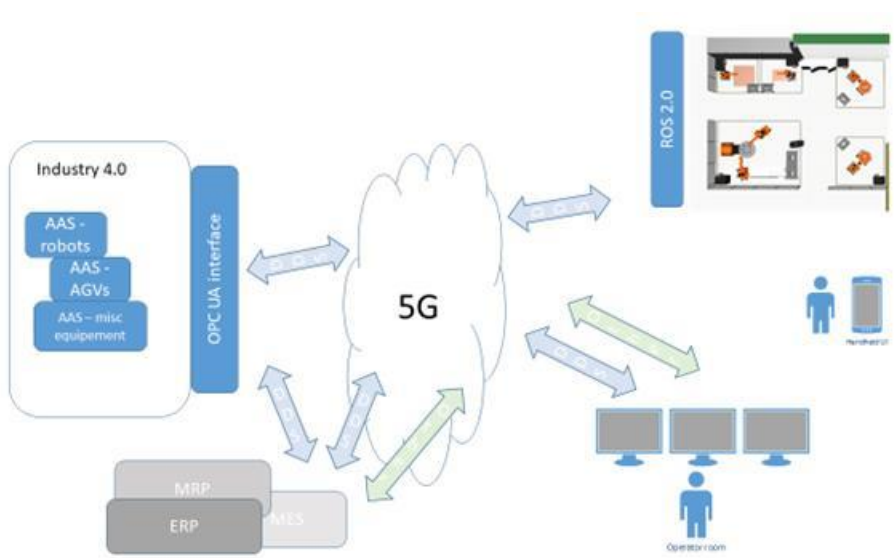

Figure 16: UC1.5 Architecture.

Critical tasks that will be studied include:

- possibility of increased level of automation and usage of robots being achieved by eased set-up and configuration, reduced time, effort and cost for this through leveraging of 5G-technologies;
- improved flexibility in the use of the aforementioned equipment due to the previous point;
- whether 5G can substitute traditional network-technologies, especially in a scenario where resources are shared, even with unrelated parties, therefore reduce the need for in-house competence in various networking technologies;
- to find out whether and if, how, information in so-called AAS (Asset Administrative Shell) can be utilised optimally, or even practically, to set up the necessary resources in a (possibly shared) 5G infrastructure;
- study the compatibility/co-operation and co-existence issues of 5G with several of the lower level technologies that can be expected to be part of Industry 4.0:
    - OPC UA (With DDS)
    - Industrial Internet Reference Architecture (IIRA)
    - ROS 2.0 (based on DDS as middleware)

UC1.5 specific tasks:

1. Initial configuration of total system
2. Setup and execution of Manufacturing procedure 1
3. Partial reconfiguration of total system
4. Setup and execution of Manufacturing procedure 2

5.1.5.2 Stakeholders and Roles

While a successful study with a positive outcome of the use of 5G in an environment that might be very difficult for the RAN, as done in UC1.1, UC1.2 and UC1.3 is the foundation for in practice to be able to utilize a successful outcome of UC1.5, the specific results of UC1.5 will be of interest anyway, since measures might be taken at later stages to overcome any show-stoppers found in the other (related) use-cases.

Table 22: UC 1.5 Stakeholders and Roles

Stakeholders	Roles
SMEs (represented by NTNU in the first iteration)	Main beneficiary
NTNU	Technology provider

5.1.5.3 Requirement Analysis and KPIs

General requirements of UC1.5 (some also reported in UC1.1, 1.2 and 1.3).

Table 23: UC1.5 Requirement Table

Type	Service Class	Description	Value
Technical	Throughput	UL Video-streams UI	1 Gbps
		DL Video-streams UI	Order Mbps
		UL Sensor data	Order of Kbps
		DL Control data	Order of Kbps
Technical	Latency	Sensor and control data	< 10 ms
Technical	mMTC	Number of devices connected	< 5

Technical	Mobility	Speed of the connected devices	2 m/s
Technical	Communication range	Distance between the 5G node and the connected devices	Between 10 and 30 meters (indoor)
Technical	Reliability	% of data delivered without corruption	99.99%
Technical / administrative	parameterization-availability	Access to the needed data for automatic programmability of the network	99% (only exceptional cases might be omitted)
Technical / administrative	Compatibility of interfaces	Degree achievable of interaction between I4.0 AAS and 5G-core functionality provided	99% (only exceptional cases might be omitted)

5.1.5.3.1 KPIs

The requirement-analysis for the KPIs take into account that the use cases will need that we demonstrate use both on a low "instrumentation" level, as well as when used for covering several of the traditional industrial levels for networks.

For the most relevant issues and parameters, i.e. KPIs to measure/study for each UC (1.1, 1.2, 1.3 and 1.5), some are purely qualitative such as "feasibility of using an infrastructure delivered by an external vendor such as Telenor for industrial purposes". Others are more directly measurable quantities such as the aforementioned positional accuracy, latency, reliability, availability of bandwidth etc. in the presence of extensive and unpredictable radio noise caused by electric welding, other electric equipment, reflections and blocking walls and equipment. While the indicated performance will be needed for UC1.5, latency, reliability and bandwidth-availability will be focused on in UC1.1 and UC1.2.

This is also the case for the measures of positional accuracy which will be reported on in UC1.5. Here this is to be used with AGVs for production purposes. For UC1.5 also the reliability and timeliness of the achieved accuracy in this assumed-to-be-difficult environment will be reported. The technical and business requirements of UC1.5 are given in Table 24 and Table 25 respectively. Please note that some have been also reported in UC1.1 and 1.2.

Table 24: UC 1.5 Technical KPIs.

KPI	Target	Measurement method/formula
Throughput UL Video-streams UI	> 1Gbps	Data-flow monitoring
Throughput DL Video-streams UI	Order of Mbps	
Throughput UL Sensor data	Order of Kbps	
Throughput DL Sensor data	Order of Kbps	
latency	< 10 ms	Timestamping difference
Number of devices simultaneously connected	< 10	
Indoor Communication Range	Between 10 and 30 meters	RSSI at the receiver
Reliability	99.99%	% of data delivered without data corruption
Availability of parameters for networking	99%	Manual inspection while developing

Compatibility of interfaces	99%	Manual inspection while developing

Table 25: UC 1.5 Business KPIs.

Business KPIs		
KPI	**Target**	**Measurement method/formula**
Availability of the system in compliance to all specified requirements	99,9%	Statistical sampling
Degree of automatic configuration of network	90%	% parameters automatically configured
Degree of automatic configuration of machine-set-up (for production)	70%	% of functionality needed to be manually configured

5.2 Smart Energy Living Lab Description and Detailed Analysis

The vertical energy represents one of the main industries addressed by 5G-related activities and architectures. In general, this is especially true for IoT based energy monitoring and management as well as energy network control scenarios. In this project, three main use cases arising in that wide area called Demand Side Management (DSM) have been considered of particular interest from the operator's point of view. Accordingly, the Living Lab Smart Energy has been conceived as a complete, closed-loop test and validation environment that dynamically supports the main players (and related requirements) by providing useful feedbacks and fundamental (not only operational) indicators to assess current and forthcoming technologies before the go-to-market phase.

The Living Lab Smart Energy is primary mMTC and URLLC oriented, since all use cases require a suitable level of reliability, low latency and wide coverage. Tests will involve residential and commercial users (UC 2.1) and Fully Electric Vehicle (FEV) owners/drivers or FEV fleet owners/managers (UC 2.2 and 2.3). To enable the testing and validation of UC 2.1, a number of distributed indoor sensors, post fiscal meters, Energy Management Systems and one Aggregator Management platform will be used requiring mMTC and URLLC.

To enable the testing and validation of UC 2.2, a set of public "smart" charging points equipped with 5G communication devices will be used, under the control of a charging platform, enabling innovative services based on dynamic charging and possibly also V2G, interconnecting the e-mobility stakeholders and requiring mMTC. To enable the testing and validation of UC 2.3, a set of 5-10 public charging stations equipped with 5G modems will be used. One of the charging stations will be enabled to take real time measurements of network frequency and forward them to the other charging stations involved in the provisioning of the balancing service. The charging stations will be equipped with local controllers driven by the frequency measurements received by the master requiring mMTC and URLLC.

This LL aims at providing effective evidence about the potential benefits from large-scale adoption of 5G technology in the smart grid sector. As mentioned above, preliminary estimation of expected 5G KPIs reveals that the added value brought by the new generation of communication technology lies in the potential level of reliability, low latency and wide coverage. The Smart Energy LL presents three use cases arising in Demand Side Management (DSM). DSM refers to the changes in electricity use by consumers from their normal consumption patterns in response to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized. The three use cases are described in the following.

5.2.1 UC 2.1: Industrial Demand Side Management

This use case deals with DSM at the level of business consumers (large, medium or small enterprises). The focus is on the optimal scheduling of industrial loads during normal plant operation, the computation and actuation of flexibilities offered on the Dispatching Market and the control actions needed to keep the peak power consumption limited. The first aspect covered by this use case is the planning and aggregation of loads. A distributed monitoring and load shifting control system (based on sensors, meters and in-cloud data analytics and control tools), will be setup to perform a real-time schedule of loads and assess the actual energy behaviour of each activity/production, with the aim of evaluating possible actions of power reduction to be offered on the Dispatching Markets, where the operator of the electricity transmission network buys the balancing power needed to operate the network; this action may be performed by the customer as a single actor of the market, if the power reduction constraints set by the Regulator are met, or in aggregated form with other prosumers (by means of an Aggregator). 5G technologies is expected to play an important role, as both data communication from the field to the cloud and communications among the Aggregator and involved customers must be reliable, fast and with minimal delay (latency). The second aspect concerns the peak power consumption, which represents one of the critical parameters for this class of customer segment. The simultaneous use of electrical devices may involve peak loads that can result in the tripping of commercial meters due to overload detection.

With the introduction of new tariff schemes accounting for the peak power consumption in addition to the energy component (e.g., maximum demand) and the presence of fluctuating unpredictable Renewable Energy Sources (RES), the problem of keeping the peak power limited is quite important: it appears crucial to rely on a technological solution to promptly switch off the loads responsible for the peak/overload and, therefore, to reschedule the load in a more efficient way. In this sense, 5G technology plays a crucial role: a post-commercial meter will be used to detect the power peak/overload and to generate an alert, which will be transferred to a pre-selected set of control devices that will reduce the power consumption and trigger the computation of a new load schedule as a recovery action. Hence, the objective of this use case is to demonstrate in the field that 5G technology can be effectively used for offering new grid services and drastically reduce the tolerance implemented on the meters before disconnection, without having an impact on the customer perception and quality of service.

5.2.1.1 Stakeholders and Roles

The UC 2.1 Stakeholders and their roles are given in Table 26

Table 26: UC 2.1 Stakeholders and Roles.

Stakeholders	Roles
IREN	ESCo, Energy Utility and system integrator of energy efficiency services for different users and clients (private, public, corporate, business)
A2T	Technology provider for development and deployment of software modules and interfaces implementing data processing and control strategies; CRAT will partially support A2T as linked third party

5.2.1.2 UC Objectives

The main objectives of this use case are given in Table 27.

Table 27: UC 2.1 Objectives

Test objectives	Requirements	Participants
To receive, access, process and respond to real-time information about energy consumptions via 5G for energy efficiency purposes	Availability of 5G-EVE Turin facility to support measurement s of key KPIs of latency and data rate. Smart in-house energy consumption device	• A2T • IREN
Monitor, aggregate and control electrical devices through 5G		

5.2.1.3 *Requirements Analysis-KPIs*

The technical KPIs are given in Table 28, while the business KPIs in Table 29.

Table 28: UC 2.1 Technical KPIs

Technical KPIs		
KPI	**Target**	**Measurement method/formula**
Data Rate (Kbps)	Not critical	Downlink throughput
Latency (ms)	<10	Network + elaboration latency in normal operation mode
Reliability	>99.999%	% of data delivered without data corruption
Coverage	>99.9% Indoor	Data reception success rate when device in different locations (statistical sampling from >1000 measurements in different locations)

Table 29: UC 2.1 Business KPIs.

Business KPIs		
KPI	**Target**	**Measurement method/formula**
Availability of the system in compliance to all specified requirements	99,9%	Statistical sampling
Energy efficiency	Better than conventional system	% energy reduction compared t conventional solution

5.2.2 UC 2.2: Electrical Vehicle Smart Charging

Smart charging is a form of DSM where the selection of the charging station used for recharging a PEV and the power absorbed during the recharging process are under the control of a charging point operator, according to a set of grid boundary conditions and drivers' charging preferences. Moreover, the driver's experience may involve a variety of interactions between the driver and the charging infrastructure through apps and the charging station dashboard, depending on the charging point operational policies and business models. New paradigm in mobility as well as all smart mobility solutions implies a strong interaction of EVs and electricity distribution grids, posing new challenges and opportunities in the way the next generation networks will be operated. In this regard, the 5G network can be used for allowing a reliable real time scheduling of charging sessions and provide a fast reschedule in case of overload, in case a contractual threshold is overcome due to an excessive number of simultaneous charging sessions, or in case the electric power generated from renewables suddenly falls short of the predictions.

5.2.2.1 Stakeholders and Roles

The UC 2.2 Stakeholders and their roles are given in Table 30.

Table 30: UC 2.2 Stakeholders and Roles.

Stakeholders	Roles
A2T	Development and deployment of software modules and interfaces implementing data processing and control strategies; CRAT will partially support A2T as linked third party
ENEL	Technology provider providing charging stations up to 22kW AC equipped with 5G communication modems for testing purposes
IREN	EMPS/CPO managing and offering charging solutions to its clients; Aggregator playing on national dispatching market

5.2.2.2 UC Objectives

The main objectives of this use case are given in Table 31.

Table 31: UC 2.2 Objectives.

Test objectives	Requirements	Participants
• To exchange control metering data/state of charge and asset status via 5G among the charging stations and the charging infrastructure back-end and eventually the aggregator.	5G-EVE Turin facility availability to support testing and measurements of key KPIs related to reliability and latency.	• A2T • ENEL X • IREN
• To demonstrate remote and continuous communication between charging point operators to monitor and report on EV charging via 5G; • To demonstrate the efficiency in managing interaction of the charging infrastructure with the Aggregator for receiving and implement real time charging profiles coming from energy network/market needs		

5.2.2.3 Requirements Analysis-KPIs

The technical KPIs are given in Table 28, while the business KPIs in Table 29.

Table 32: UC 2.2 Technical KPIs

Technical KPIs		
KPI	**Target**	**Measurement method/formula**
Data Rate (Kbps)	Not critical	Downlink throughput
Latency (ms)	<10	Network + elaboration latency in normal operation mode
Reliability	>99.999%	% of data delivered without data corruption
Coverage	>99.9% Indoor	Data reception success rate when device in different locations

		(statistical sampling from >1000 measurements in different locations)

Table 33: UC 2.2 Business KPIs.

Business KPIs		
KPI	**Target**	**Measurement method/formula**
Availability of the system in compliance to all specified requirements	99,9%	Statistical sampling
Reliability	>99.999%	% of data delivered without data corruption

5.2.3 UC 2.3: Electricity Network Frequency Stability

This UC deals with the involvement of active demand in the provisioning of the electricity services needed to maintain the electricity network frequency at its rated value (e.g., 50 Hz in Europe). Basically, the network frequency depends on the difference between the demand and supply. It remains constant so long as this difference is zero. Any imbalance between the demand and supply sides results in a deviation from the nominal network frequency, which is typically resolved by the Transmission System Operator (TSO) by asking the generators to provide or release the power needed to clear the imbalance (balancing service). The Dispatching Market, namely the market where the TSO buys this service from legacy generators, has been recently opened to active demand, and Plugin Electric Vehicles (PEVs) aggregates appears the most promising form of active demand to this purpose.

Since network frequency instability can occur within seconds or less, a fundamental requirement to enable PEVs smart charging to frequency regulation functions is the availability of highly reliable and low latency communications allowing a fast and coordinated action of distributed PEVs aggregates. Keeping in mind that the current smart meters installed in the charging stations take measurements every minute, and that the measurements do not include network frequency, in the absence of a highly performing communication infrastructure, each charging station should react alone and be equipped with a new, potentially expensive, frequency meter. Hence, the deployment of 5G communications in charging stations could dramatically decrease the number of frequency meters needed to provide the balancing service, and consequently the related total cost of ownership. The smart charging system involved in UC 2.2 can be extended to create the superposition of two control signals working on different time scales: a slow control signal, computed according to the requirements of UC 2.2 under the assumption of nominal network frequency, and a fast control signal, computed by a new controller installed in the charging stations, driven via 5G by the real time measurements of network frequency so as to enable primary frequency regulation.

5.2.3.1 Stakeholders and Roles

The UC 2.3 Stakeholders and their roles are given in Table 34.

Table 34: UC 2.3 Stakeholders and Roles.

Stakeholders	Roles
ENEL	Charging station technology provider incorporating 5G modems and a frequency meter. Besides, provider of backend and aggregator software
A2T	Development and deployment of software modules and interfaces implementing data processing and control strategies; CRAT will partially support A2T as linked third party

5.2.3.2 UC Objectives

The main objectives of this use case are given in Table 35.

Table 35: UC 2.3 Objectives.

Test objectives	Requirements	Participants
• Power network frequency via 5G to the charging stations • Remote and continuous communication among TSO and aggregators to monitor and report on EV charging via 5G	▪ RAN node in 5G facility availability to support testing and measurements of key KPIs related to latency ▪ Remote voltage/current sensors and smart relays	• A2T • ENEL

5.2.3.3 Requirements Analysis-KPIs

The technical KPIs are given in Table 28, while the business KPIs in Table 37 sotto.

Table 36: UC 2.3 Technical KPIs

Technical KPIs		
KPI	**Target**	**Measurement method/formula**
Data Rate (Kbps)	Not critical	Downlink throughput
Latency (ms)	<10	Network + elaboration latency in normal operation mode
Reliability	>99.999%	% of data delivered without data corruption
Coverage	>99.9% Indoor	Data reception success rate when device in different locations (statistical sampling from >1000 measurements in different locations)

Table 37: UC 2.3 Business KPIs.

Business KPIs		
KPI	**Target**	**Measurement method/formula**
Availability of the system in compliance to all specified requirements	99,9%	Statistical sampling
Frequency stability	Better than conventional system	% frequency stability compared to conventional solution. Statistical sampling

5.3 Smart Cities and Ports Living lab Description and Detailed Analysis

In this living lab, we will mainly focus on the use cases arising from various aspects in the context of smart cities and ports. In particular, we shall evaluate six use cases covering the areas of smart lighting, smart parking, smart cities, smart buildings/campus, and the smart port. These use cases are designed with 5G requirements, including eMTC, eMBB, URLLC, and thus can be used for analysis of the results relative to the baseline 5G target KPI values in different scenarios.

5.3.1 UC 3.1: Intelligent Street Lighting

IoT is changing how people interact with their environments. There are nearly going to be 50 billion connected devices in the world by 2020. Street lighting is one of the most energy consuming equipment in cities.

In 5G-SOLTUIONs, we plan to virtualise intelligent street lighting where the sensors can detect the activities and only uses the energy when there is a requirement. The proposed system provides a solution for energy saving. This is achieved by sensing and approaching a vehicle using a transmitter and receiver couple. Similarly, as soon as the vehicle or an obstacle goes away the Light gets switched OFF as the sensor sense any object at the same time the status of the street light can be accessed from anywhere and anytime through internet. Upon sensing the movement, the sensor transmits the data to furthermore the Light to switch ON. The sensors will generate data that will help us in gathering information about the need for the lightings.

Size: We plan to use 40-50 virtualised street lighting to simulate an actual smart city.

Requirements:

- NURO will provide the VNFs for virtualised street lights.
- NURO will provide the VNF to run and calculate the needs for street lights.
- High data usage from the VNFs.
- A controller VNF to control and work as an IoT platform.

5.3.1.1 Stakeholders and Roles

The UC 3.1 Stakeholders and their roles are given in Table 34

Table 38: UC 3.1 Stakeholders and Roles.

Stakeholders	Roles
NURO	Application and Technology provider
TNOR	5G Facility provider
City	City Infrastructure provider

5.3.1.2 UC Objectives

The main objectives of this use case are given in Table 39

Table 39: UC 3.1 Objectives.

Test objectives	Requirements	Participants
• Energy use reduction • Map-based visualisations for quick and easy access enhancing user's experience • Remote (secure) management of public street lighting	• IoT probes to emulate smart devices in street lighting (to be provided by NURO) • Automatic data notifications in order to respond to outages and other systems issues • Availability of 5G-VINNI Norway facility supporting MEC functionality for real time data provisioning through 5G	• NURO • TNOR

5.3.1.3 Requirements Analysis-KPIs

The technical KPIs are given in Table 40, while the business KPIs in Table 41 below.

Table 40: UC 3.1 Technical KPIs

Technical KPIs		
KPI	Target	Measurement method/formula

Data Rate (Kbps)	-	-
Mobility (km/h)	-	-
Latency (ms)	<100	Network + elaboration latency in normal operation mode
Density (devices/m^2)	>1	-
Reliability	>99%	% of data delivered without data corruption
Coverage	>99% Indoor	Data reception success rate when device in different locations (statistical sampling from >1000 measurements in different locations)
Service Provisioning time (minutes)	-	-

Table 41: UC 3.1 Business KPIs.

Business KPIs		
KPI	**Target**	**Measurement method/formula**
Availability of the system in compliance to all specified requirements	99,9%	Statistical sampling
Energy reduction	Better than conventional system	% energy reduction compared to conventional solution. Statistical sampling

5.3.2 UC 3.2: Smart Parking

The mobile phone has evolved rapidly over the past decade from a monochrome device with a minuscule screen and little processing power to one with high resolution, palm sized screen and processing power rivalling a laptop. In smart cities, the number of cars has increased significantly with the parking becoming an issue in the cities. Optimisation has been a key to solving this issue. In the Smart parking use case, we plan to use mobile app to book a parking spot for a car arriving in the city and a sensor on the parking location to indicate the availability of the parking spot to other users.

The users will be able to book a parking spot for 30 mins before arriving to it and once the car is parked, the timer will start calculating the costs. This will help in faster and more efficient parking, as well as save time in the ticketing for the parking as all the payments can be handled by the mobile app.

The mobile app will show the location of available parking spots that can be reached in 30 mins nearest to the destination of the user. Once the user books the parking space, it shown as booked to other users for 30 mins, in this time three booking user has to park his car, the sensor at the parking spot can detect if anything is parked or not.

Requirements:

- NURO will provide the smartphone application
- NURO will provide VNF for the sensor on the parking spot
- NURO will provide the management VNF
- High computational need by the VNFs

5.3.2.1 Stakeholders and Roles

The UC 3.2 Stakeholders and their roles are given in Table 42

Table 42: UC 3.2 Stakeholders and Roles.

Stakeholders	Roles
NURO	Technology provider
TNOR	Technology provider
Parking Space providers	Parking infrastructure

UC Objectives

The main objectives of this use case are given in Table 43.

Table 43: UC 3.2 Objectives.

Test objectives	Requirements	Participants
Fast and easy identification of empty parking spaces	• Smartphone application for guiding the drivers to the closest available free parking place (to be provided by NURO) • Interface to parking systems for retrieving real-time data on parking slots. • Availability of 5G-VINNI Norway facility for real-time parking information	▪ NURO ▪ TNOR

5.3.2.2 *Requirements Analysis-KPIs*

The technical KPIs are given in Table 44, while the business KPIs in Table 45 below.

Table 44: UC 3.2 Technical KPIs

Technical KPIs		
KPI	**Target**	**Measurement method/formula**
Data Rate (Kbps)	-	-
Mobility (km/h)	<100	Vehicles will move at different speeds, while testing the service (statistical sampling)
Latency (ms)	<100	Network + elaboration latency in normal operation mode
Density (devices/m^2)	>0.1	-
Reliability	>95%	% of data delivered without data corruption
Positioning accuracy (m)	<10	Compare calculated position with actual parking location and parking available length
Coverage	>95%	Data reception success rate when device in different locations (statistical sampling from >1000 measurements in different locations)
Service Provisioning time (minutes)	-	-

Table 45: UC 3.2 Business KPIs.

Business KPIs		
KPI	**Target**	**Measurement method/formula**
Availability of the system in compliance to all specified requirements	99,9%	Statistical sampling
Traffic congestion reduction	Better than conventional system	% congestion in specific area compared to the case with no smart parking available. Statistical sampling

5.3.3 UC 3.3: Smart City Co-Creation

Smart City enabled by IoT is seen as a key area of development and growth, for the benefit of cities and societies. IoT will contribute with increased values by solving problems in a more innovative and productive manner or producing products and services in a more cost-effective manner. An explosive increase in the number of IoT devices is expected - some estimates say that there will be nearly 30 billion IoT units world-wide by 2020.

The target and ambition of this use case is to enable an explorative and wider approach to Smart City/IoT by facilitating for co-creation and exploring by external collaborators into 5G and advanced networking and experimental platform capabilities. We have initiated collaboration with a H2020 Smart City Lighthouse project (+CityxChange) managed by NTNU Smart Sustainable Cities (SSC), and may as well involve other relevant projects. The Urban Living Lab innovation and co-creation way of work and methodologies will be used and assessed along with the "Experiment as a Service" (EaaS) concepts and principles coming from 5G-VINNI.

In this use case we are exploring and testing the capabilities of 5G-SOLUTIONS and its feasibility as a platform capable of supporting an agile way of working and co-creation from the point of view of Smart Sustainable Cities. This will involve capabilities for effective on-boarding of experiments and experimenting by running test-cases, enabling effective testing, measurements, monitoring and data collection. Furthermore, the ambition is to explore and test the feasibility of adapting to customer's use case specific KPIs, including the platform's capability to be reconfigured and adapted to changing use case requirements by the different customers and their specific use cases to be tested. While setting an ambitious goal it is also recognized that it is important to start with the simpler use case scenarios and KPIs while evolving step-by-step into the more advanced.

5.3.3.1 Stakeholders and Roles

Table 46: UC 3.3 Stakeholders.

Stakeholders	Role
Vertical Enterprise Customer (represented by "customer project")	TBD
Vertical System Integrator	TBD
Vertical Communication Service Provider	TBD
Public Network Communication Provider	TBD
Infrastructure Service Provider	TBD

5.3.3.2 UC Objectives

Initial high-level test objectives, requirements and participants.

Table 47: UC 3.3 Objectives.

Test Objectives	Requirements	Participants
• Agility for use case definition and on-boarding (MEC or non-MEC), considering both using pre-established function and self-on-boarded function • Exploring customer-facing KPIs and their relevance • Explore & assess methodologies like "Co-operative Inquiry Methodology" and Urban LL innovation and co-creation.	• Open accessibility of 5G-VINNI Norway facility for their testing framework and 3rd party function on-boarding, e.g. onto the MEC platform. • Open accessibility of the 5G-SOLUTIONS data collection and visualisation	• TNOR • NTNU SSC[3]

5.3.3.2.1 Elaborated UC Objectives

Agility for use case definition and on-boarding (MEC or non-MEC), considering both using pre-established function and self-on-boarded function. This can involve feasibility assessment and validation both technically and business wise, considering various business and service management layer capabilities, such as:

  - Explore catalogue / catalogue availability
  - Negotiate and create order
  - Place order
  - Activate order
  - Run, monitor and manage service / application (instance / session, see also below)
  - Update service / application (instance / session)
  - Terminate service / application
- Exploring customer-facing KPIs and their relevance:
  - Set up and schedule test case
  - Test the test and experimentation set-up
  - Collect data; Monitor data collection
  - Result data handling
  - Result analysis and assessment
- Explore & assess methodologies like "Co-operative Inquiry Methodology" and Urban LL innovation and co-creation.
  - TBD / FFS.
    (This can be tested via specifically designed workshops and/or hackathons conducted with a number of platform users with similar needs or characteristics and solution actors that can fit to and be suitable for such an event.)

At an overall level, the above will consider and where relevant measure in quantitative fashion ease of use and result of management policies.

5.3.3.2.2 Initial factors that will drive Requirements

The above high-level use case description, objectives and ambitions will drive the requirements, priorities and roadmap while taking into consideration what is realistic evolution of the 5G-SOLUTIONS platform. These requirements and platform capabilities will be considered when the specific use cases are agreed and designed. Some examples and initial use cases and their use case scenarios are provided below. It is important to start with the simpler use case scenarios and KPIs while evolving step-by-step into the more advanced, while taking into consideration what is realistic evolution of the 5G-SOLUTIONS platform.

[3] *NTNU Sustainable Smart City (SSC) is another department within NTNU that does not participate in the 5G-SOLUTIONS consortium. UC 3.3 will be executed in cooperation with NTNU SSC.*

Throughout the co-creation collaboration process the use case scenarios will be defined and established. This will allow for exploring and testing of aspects/factors/tasks identified above as seen from and demanded by the customers and stakeholders. Stakeholder roles will be further identified and analysed, along with their personas, their pain-points and the value propositions / assumptions for specific scenarios. This will result in specific test objectives and KPIs being identified for the specific use cases to be on-boarded, explored and tested.

In parallel, 5G-SOLUTIONS will investigate and analyse the “meta-level” KPIs in regard to Experimentation as a Service (EaaS) as well as aggregating results across the deployed and tested use cases and their use case scenarios.

The exact KPIs for these are for further study and TBD. In the below we provide three examples and initial use cases, their use case scenarios and initial and preliminary set of KPIs.

The following three smart city co-creation use-case scenarios are identified:

1. Road infrastructure and maintenance monitoring
2. Remote operations VR/AR- (Virtual Reality/Augmented Reality
3. Backup for institutions (health and nursing homes)

Business validation is focused around initial understanding of the following items in the UC scenarios:

- Which direct actors and other stakeholders are involved (incl. user, customer, vendor etc.)?
- Which problems (paint points) are currently experienced during the UC working process?
- How these problems are solved today (analogue vs. digital, persons, processes, HW, SW etc.)?
- What is the expected benefit/value proposition) from applying 5G solutions to the problem?
- What are the requirements for HW and SW in the expected 5G solution?

Below, three Smart City co-creation use-cases are initially described using a detailed UC scenario template. Inputs from main actors are required filling in the remaining description details:

Table 48: Monitor road infrastructure and maintenance.

Items	Description
UC ID & Name:	• Smart City Co-creation
UC-Scenario ID & Name:	• Monitor road infrastructure and maintenance (UC3.3_1)
Brief Description:	• Video of road surface in city/urban area for registration of maintenance needs
Actors:	• Trondheim municipality https://www.facebook.com/groups/InnovasjoniTk/ • Trøndelag County
Stakeholders:	• Telenor • NTNU, CityxChange research program http://cityxchange.eu, • Norwegian Public Roads Administration (NPRA)
Software/hardware requirements:	• 5G router inside municipality inspection vehicle • Camera on top of vehicle
What is the problem (pain points) in use case (for actors/ stakeholder during activity process)?	• Poor camera quality • Low capacity for video streaming – poor data rates
How is the problem in use case solved today (As-Is)	• Using 4G enabled video cameras on municipality vehicles
What is expected benefit/Value proposition	• Reduced personal/overhead cost for road maintenance (Trondheim

to use case from expected 5G solution (To-Be)	Municipality) • Low latency and increased response time (NTNU and Trondheim municipality) • Stationary cameras can also increase traffic management signalling system and other municipality real time services (Trondheim municipality/Trøndelag county/NPRA)
Additional information	• Camera data for predictive maintenance via machine learning https://ai.ku.dk/news/ai-for-earth/ • NTNU/SINTEF/Telenor research project on communication infrastructure(roads) https://www.sintef.no/prosjekter/road/ using Lidar laser technology and 3D modelling software

Table 49: Remote assistance for operations and health.

Items	Description
UC ID & Name:	• Smart City Co-creation
UC-Scenario ID & Name:	• Remote assistance for operations and health (UC 3.3_2)
Brief Description:	• Remotely assistance of service maintenance and health personnel using VR/AR
Critical\Crucial Tasks to be performed:	• https://www.hamar-dagblad.no/helsevesen/medisin-og-helse/hamar/vr-skal-gi-bedre-behandling/s/5-80-45010
Actors:	• Trondheim municipality - city maintenance and nursing homeshttps://www.facebook.com/groups/InnovasjoniTk/ • Trøndelag County/Norwegian State (hospitals)
Stakeholders:	• Telenor • Redzinc and other vendors • NTNU: CityxChange research program http://cityxchange.eu,
Software/hardware requirements:	• 5G phone terminal and video camera on person in field remotely assisted. • 5G router in nursing home/ambulance
What is the problem in use case (for actors/ stakeholder during activity process)?	• City maintenance workers and ambulance workers demands skill and access to analogue instructions and templates
How is the problem in use case solved today (As-Is)	• Analogue flow of activities of skilled workers in field
What is expected benefit/Value proposition to use case from expected 5G solution (To-Be)	• Less personnel/overhead cost (Trondheim municipality/Trøndelag County/Norwegian State) • Improved and more efficient maintenance and health/emergency operations, improved accessibility (Maintenance and nursing home workers)
Additional information	• https://www.hamar-dagblad.no/helsevesen/medisin-og-helse/hamar/vr-skal-gi-bedre-behandling/s/5-80-45010 • Redzinc, provider of VR/AR support for ambulance in 5G Heart • French-Norwegian collaboration on VR/AR for ambulance personnel using AR/VR based on Microsoft Hololens (http://nomadeec.com)

Table 50: 5G backup for health and nursing homes.

Items	Description
UC ID & Name:	• Smart City Co-creation

UC-Scenario ID & Name:	• 5G backup for health and nursing homes (UC 3.3_3)
Brief Description:	• 5G backup for fiber solution
Critical\Crucial Tasks to be performed:	• Critical for nursing/health services
Actors:	• Trondheim municipality https://www.facebook.com/groups/InnovasjoniTk/
Stakeholders:	• Telenor, NTNU • CityxChange research program http://cityxchange.eu,
Software/hardware requirements:	• 5G routers and handsets/terminals • Mobile Data Access with VPN between router and server/user
What is the problem (pain points) in use case (for actors/ stakeholder during activity process)?	• Downtime of fiber - low reliability.
How is the problem in use case solved today (As-Is)	• No backup today – when downtime access to EPJ (Electronic Patient Journal) and other IT systems is lost.
What is expected benefit/Value proposition to use case from expected 5G solution (To-Be)	• More efficient service, less personal/overhead cost (Trondheim municipality) • Improved reliability (Nursing homes)
Additional information	• Trondheim municipality have 8+ health and nursing homes

5.3.3.3 Requirements analysis-KPIs

In order to fulfil the above-mentioned requirement, the following initial and preliminary analysis is provided in terms of UC architecture and KPIs. The following relevant technological KPIs to be validated for the co-creation UCs are the following:

Table 51: Technological KPIs for the co-creation UCs.

Technological KPI's (UC 3.3)	**A 4G baseline (As-Is)**	**B 5G Baseline (To- Be 1)**	**C 5G Roaming (To-Be 2)**	**D 5G Egde (To- Be 3)**
Data Speed/Throughput Downstream (max, average, etc.)	120 Mbps	> 120 Mbps	=B	> B
Data speed /Throughput Upstream (max, average, etc.)	40 Mbps	> 40 Mbps	=B	> B
Latency	70 ms	< 50 ms	=B	< 10 ms
Realiability (stying connected when mobile)	99%	>99,99%	=B	>B
Coverage indoor/Outdoor	99%	>99,9	=B	= B
QoE (Quality of Experience)	< 4	> 4.3	=B	>B
Positioning accuracy (1) (geographical position for device, longitude, latitude, altitude)	< 100 m	< 1m	< 1m	0,1m
Positioning accuracy (2) (geographical position for object detected from video/lidar/radar)	< 100 m	< 1m	< 1m	< 1m

A. Telenor Norway 4G/LTE baseline
   - Refers to current 4G performance - commercially offered by telecom operator

B. Telenor Norway 5G non stand-alone core baseline
   - Refers to Telenor Norway's initial 5G set up in Trondheim (5G Baseline)

C. 5G-SOLUTIONS / 5G-VINNI roaming into Telenor Norway 5G network
   - Refers to 5G-VINNI Home net in Trondheim, ref. B

D. 5G Edge enabled local breakout of data traffic
   - Refers to solution using edge cloud platform by 5G-SOLUTIONS / 5G-VINNI in Trondheim

5.3.4 UC 3.4: Smart Buildings – Smart Campus

5.3.4.1 UC Objectives and Scenario

Cooperative Positioning for Smart Industrial IoT System

Accurate indoor positioning is very important for the maintenance of a large-scale industrial IoTs in the context of such as smart buildings/smart campus. However, the fundamental challenging behind is that different sensors or devices in buildings/campus may have different level of intelligence, e.g. advanced fire detection senor versus low cost temperature sensor, and different types of connectivity, e.g. wired, Wi-Fi or Bluetooth, which makes the central device management system very complex and less robust against errors or system failures. In addition, location information of sensors/devices can also be easily lost during regular maintenance when a technical staff forgot to update the new position of the sensor to the system. It can also be largely deviated in a poor connectivity area where a limited number of hotspots were used. As a result, when an event occurs, it usually takes longer time to track down the issue and locate the malfunctional sensors or devices according to the limited information collected from the device management system. Clearly, this significantly reduces operation efficiency.

5G has the ability to easily handle massive IoT devices connected to a system, and it can also provide accurate indoor positioning information for each connected IoT device, which makes it ideal for this use case. We are particularly interested in:

- how 5G can be leveraged to accurately locate any capable 5G smart IoT device in an indoor environment, including development of 5G smart cooperative localization algorithms.
- how many 5G portable nodes are needed to cover a specific building area with a pre-defined positioning accuracy and error range.
- What architectures needs to be applied for localization, e.g. centralized or distributed.
- What is the time delay for 5G cooperative localization, e.g. how fast to locate the object from the launch of the device, and how fast can 5G track the change of location when object is moving from one place to another.

We shall conduct such experiments in our designated IBM ThinkSpace area within our IBM Dublin Technology Campus as shown in Figure 17.

Figure 17: IBM Think Space

Predictive Maintenance for Smart Industrial IoT System

The basic set-up of this use case is similar to the previous one (cooperative positioning). However, our main focus in this use case is on how 5G can be used to increase the life span of the sensor/device of the industrial IoT system, and further how 5G can be used to support real-time prediction of device status for maintenance before a device physically breaks down, while in the cooperative positioning use case, the focus would be on how quickly and accurately 5G can help identify the position of an IoT device when a breakdown really happens.

The knowledge of current device status together with prediction of future device operation status is practically very important in the operation of smart industrial IoT system. Currently, most IoT device management systems are designed with a focus on monitoring real-time on/off status of the device and the key functional value of the device, without considering other aspects of the device which may eventually affect the operational life cycles of the device. For instance, an operator will be interested in knowing the on/off status of a smoke detection sensor as well as the density of the smoke in a given area, but with less interest in such as the temperature, humidity around the sensor, the battery usage of the sensor, among others, which may affect the life span of the smoke sensor. With a proper design of the algorithms using machine learning, e.g. support vector machine (SVM), it is possible to predict if a device needs to conduct a specific maintenance well in advance of its regular maintenance or before an issue arises, this clearly increases the reliability of the system and reduces further costs for system maintenance. To do this, this use case requires the communication infrastructure to provide:

1. A reliable connectivity for various information gathering.
2. A wide coverage of devices located in different areas, both indoor and outdoor.
3. A flexible machine to machine communication capability to capture environmental context in real time (mMTC).

This use case focuses on:

1. How IoT devices can set up a communication channel to retrieve required information with its nearby devices in an efficient and effective manner. For instance, a smoke detection sensor needs an external temperature value to make a prediction. Assuming that this information can be provided by a temperature sensor located in 5 meters, the question is how the smoke detection sensor can quickly identify the temperature sensor in its vicinity and then set up a communication channel to retrieve the

temperature value for its own prediction. In a similar way, if the temperature sensor needs the information from the smoke detection sensor to make the prediction, the smoke sensor also needs to cognitively forward its information to the other side in a secure and timely manner.

2. How 5G will practically affect the energy consumption of different types of sensors in reality compared to other communication technologies, such as Wi-Fi.
3. How reliable is it to deploy 5G communication network in a cloud-based framework, in particular with IBM Cloud ecosystem, e.g. IBM Watson IoT platform. For instance, how to ingest 5G data flows with the IoT platform, and what the performance metrics would look like, including such as percentage of data packet losses, and information lost in the database etc.

Enhanced Safety Monitoring of Vehicles in Parking Lots

This use case is aimed at using 5G to consistently monitor the parking areas in the campus in order to enhance the safety of parked vehicles for IBM employees. We are interested in facilitating 4k cameras in the parking area to identify any anomaly behaviours near/in the vehicles, which can hardly be done using 4G network technologies. By using 4k cameras, very detailed information of each vehicle can be clearly captured, and this information flow can be timely transmitted to the IBM Watson platform for further analysis. For instance, by developing proper algorithms, it is possible to identify:

1. If a car is properly parked or not – for instance, if the vehicle occupies an EV parking space or a wheelchair access parking space, which it should not be allowed.
2. If someone is sneaking around and wants to intrude the vehicle – capture the face information of the person and sends back to the security department.

From the communication perspective, this use case needs fast and reliable connection speed from 5G for information gathering, transmission to the cloud for analysis, and timely response to relevant people and security departments if an emergent event happens. A picture of the parking area within our campus is shown below.

Figure 18: IBM Employee Parking Areas near Building 6 within the Campus.

This use case is subject to the feasibility and practical conditions of facilitating 5G base stations and devices in the IBM parking lots within the IBM Dublin Technology Campus. All use cases listed above need to consider any privacy issues that may occur during data collection, analysis and processing.

5.3.4.2 Stakeholders and Roles

The UC 3.4 Stakeholders and their roles are given below.

Table 52: UC 3.4 Stakeholders and Roles.

Stakeholders	Roles
IBM	Technology provider
IBM campus community	Main beneficiaries

5.3.4.3 Requirements Analysis-KPIs

The technical and business KPIs are given in the tables below.

<u>Cooperative Positioning for Smart Industrial IoT System</u>

Table 53: UC 3.4 Technical KPIs.

Technical KPIs		
KPI	**Target**	**Measurement method/formula**
Positioning accuracy	< 1m	Compare calculated position with actual location
Coverage	> 99.9%	Data reception success rate when device in different locations (statistical sampling from >1000 measurements in different locations)
Reliability	> 99.99%	% of data delivered without data corruption
Connection density	> 1	Evaluate service while increasing device density
Data Rate	> 100Mbps	Throughput measurement at device

<u>Predictive maintenance for Smart Industrial IoT System</u>

Technical KPIs		
KPI	**Target**	**Measurement method/formula**
Positioning accuracy	< 1m	Compare calculated position with actual location
Coverage	> 99.9%	Data reception success rate when device in different locations (statistical sampling from >1000 measurements in different locations)
Reliability	> 99.99%	% of data delivered without data corruption
Connection density	> 1	Evaluate service while increasing device density
Data Rate	> 100Mbps	Throughput measurement at device

<u>Enhanced Safety Monitoring of Vehicles in Parking Lots</u>

Technical KPIs		
KPI	**Target**	**Measurement method/formula**
Coverage	> 99.9%	Data reception success rate when device in different locations (statistical sampling from >1000 measurements in different locations)
Reliability	> 99.99%	% of data delivered without data corruption

Data Rate	> 100Mbps	Throughput measurement at device
Latency	< 10ms	Network + elaboration latency in normal operation mode

Table 54: UC 3.4 Business KPIs.

Business KPIs		
KPI	**Target**	**Measurement method/formula**
Time to response to detect any potential device issues	**Note:** Target values and measurements methods are under investigation	
Cost for repair & maintenance		
Health and safety of a repairman		
Confidence in the prediction model		

5.3.5 UC 3.5: Autonomous Assets and Logistics for Smart Port

The smart port is located in the Yara Porsgrunn production site at Herøya, Norway. The smart port is part of the Yara Birkeland project. The Yara Birkeland project is a design to establish a zero-emission delivery of containers with product from the Yara Birkeland Terminal (YBT) at Herøya in Porsgrunn to the feeder ports in Brevik and Larvik. The containers with product are then discharged at the feeder port for transfer to oceanic vessels, which deliver the containers to the distributions port. Parallel to delivering the containers with products to the feeder port, the ship will also load empty containers or, in time, containers with material to Herøya – thus collecting containers for future orders to the YBT.

The key drivers for the project are to:

1. Reduce diesel-powered truck haulage locally in the Porsgrunn/Larvik area by 40.000 trips per year, thus reducing emissions and increasing road safety by reducing the number of heavy vehicle trips.
2. Digitize and automate the cargo information flow to simplify the logistic process and generating the required information for the cargo.
3. Establish autonomous container movement of inbounds and outbounds at Herøya between the loading stations and the YBT.
4. Establish autonomous transportation of outbounds from the YBT to the feeder ports and inbounds from the feeder ports to the YBT.

To achieve this, the project will build a port with an automatic crane system, a battery powered container feeder and battery powered straddle carriers that handle the transport at the site. The route of the container feeder is indicated in Figure 19.

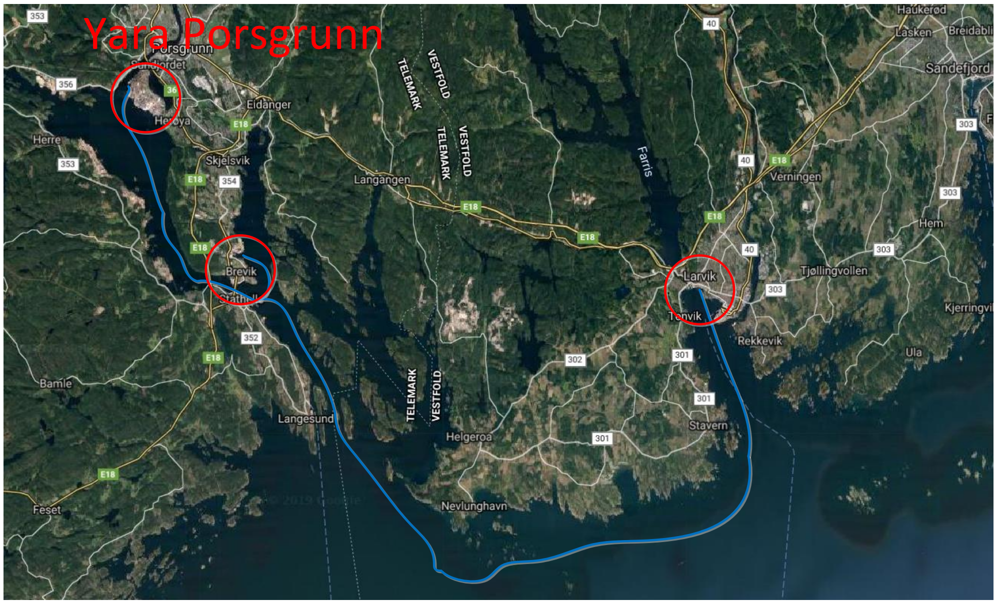

Figure 19: The route of the container feeder.

The port area of the Yara Birkeland project is the smart port described in this use case. The smart port contains several sub systems and the need for wireless communication is be planned to be a 5G network as a replacement of a traditional Wi-Fi system.

The smart port has straddle carriers picking up and delivering containers at dedicated loading areas. It has an automatic crane that is used in the stacking area / harbor. This automatic crane is used for loading and discharging the container feeder, interchange of containers to the straddle carriers and arrangement of the containers in the smart port stacking area.

The feeder will transport the containers to other local feeder ports located in Brevik and Larvik as shown in the picture. From these ports the containers will be transported with container ships that are part of the global transportation system. The feeder (Birkeland) is a fully battery powered container ship. The feeder is shown in Figure 20.

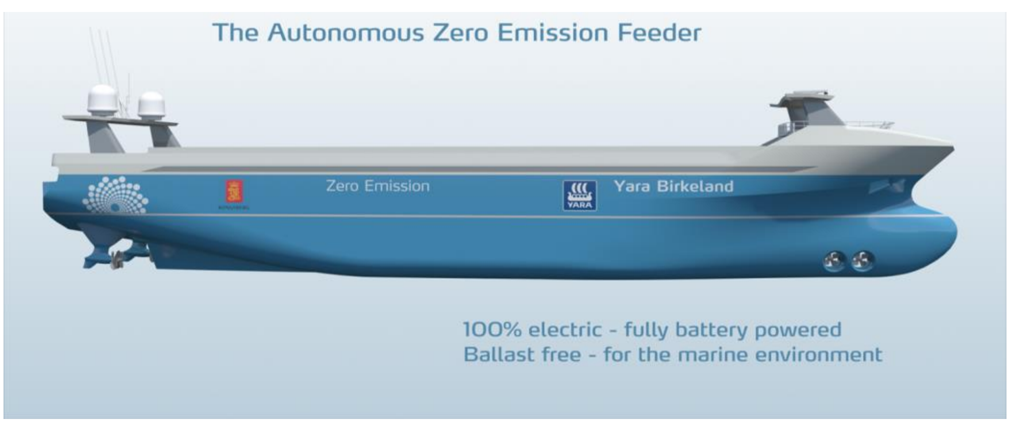

Figure 20: The Feeder.

The smart port is about the work process of handling containers / products. The work process will be digitized in the Birkeland project. This means that data input will be done through tablets in an integrated system, updating the logistic system databases. The tablets should be connected to the 5G network. Parts of the logistics solution will be cloud based. Figure 21Figure 21 shows which parts of the digitized system that is part of the smart port.

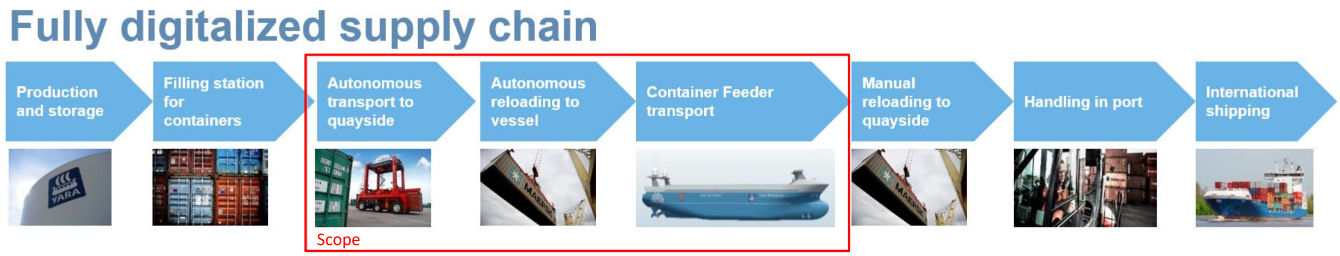

Figure 21: Parts of the Digitized System That is Part of the Smart Port.

Straddle carriers will pick up containers at a dedicated area. The area is about 1 km from end to end. It contains two dedicated pick-up areas as well as the smart port. Quite a lot of tall concrete buildings surround the test area and challenges the coverage of the 5G solution. The straddle carriers will at first be manually operated by a driver. The control of the straddle carriers will move towards autonomous operation through the project. The operation area will become a mixed traffic area, giving challenges to the autonomous operation.

Each of the three straddle carriers will be equipped with 5G modems. They will get their commands through the logistic systems. They will need to pick up containers in physical identified locations. The 5G systems capability to track the position of the straddle carrier will be checked against a DGNSS implemented with the solution. The autonomous operation will need coverage in the complete area to avoid stops of the straddle carriers. A video feed from the carriers will be available for the central control room operator.

Figure 22: A Straddle Carrier.

The automatic crane is connected to the system via a fiber-optic connection. It will need information from the straddle carriers through the logistics system about the position of the container. It will also need to communicate with the feeder during loading and unloading of containers. The vessel, crane and the straddle carriers have real time applications. Figure 23 shows the automatic crane.

Figure 23: The automatic crane.

The 5G solution will be quite integrated in our infrastructure. This will give new vulnerabilities in our IT infrastructure. Keeping the risk at an acceptable level is a critical subject. At the same time any downtime of the 5G solution will hinder the loading operation. Over time this will give a negative impact of the production at our site. This means that Cyber security is critical for the success of the use case.

5.3.5.1 Stakeholders and Roles

The UC 3.5 Stakeholders and their roles are given in Table 42 54.

Table 55: UC 3.5 Stakeholders and Roles.

Stakeholders	Roles
NURO	Technology provider
TNOR	Technology provider

5.3.5.2 UC Objectives

The main objectives of this use case are given in the table below.

Table 56: UC 3.5 Objectives.

Test objectives	Requirements	Participants
• Demonstrate the 5G technology's potential to increase service offering in the smart port. • Demonstrate the multi-access cloud to provide connectivity and logistics support to vessels and port vehicles that are not pre-defined • Demonstrate and explore the accuracy in positioning • Demonstrate signal coverage both in reach and inside concrete buildings • Test IT security • Testing of smart and rapid re	• Installation of a private 5G node at the Birkeland port / quayside at Herøya. • Development of applications and communication • protocols to govern the logistics interface between port infrastructure and new, undefined assets. • Use of 3 straddle carriers, 1 crane and 1 vessel equipped with 5G client UEs (by YARA) • Multi-access cloud functionality • Seamless transmission between base stations (hand-over / roaming) • IT security penetration testing – 3rd party vulnerability test • Readiness and exposure of 5G-VINNI capabilities	• TNOR • YARA

deployment of use case	for rapid re-deployment of use case	

5.3.5.3 Requirements Analysis

The following test cases are listed below:

- Demonstrate the 5G technology's potential to increase service offering in the smart port.
- Demonstrate the multi-access cloud to provide connectivity and logistics support to the vessel and the port vehicles.
- Demonstrate and explore the accuracy in positioning.
- Demonstrate signal coverage both in reach and inside concrete buildings.
- Test IT security.

The requirements for the use case are listed like this:

- Installation of a private 5G node at the Birkeland port / quayside at Herøya.
- Implement communication links between port infrastructure and the 5G solution.
- Use of 3 straddle carriers, 1 crane and 1 vessel equipped with 5G client UEs (by YARA).
- Multi-access cloud functionality.
- Seamless transmission between base stations (hand-over / roaming).
- IT security penetration testing – 3rd party vulnerability test.
- 5G enabled tablets for user input.

5.3.5.3.1 KPIs

Several of the tests need to be done in steps. The first step of positioning and coverage could be to equip a car and existing loading systems with a 5G modem. Other relevant steps will be planned at a later stage of the use case.

The technical KPIs are given in the table below.

Table 57: UC 3.5 Technical KPIs.

Technical KPIs		
KPI	**Target**	**Measurement method/formula**
Data Rate (Kbps)	>100	Throughput measurement at device
Mobility (km/h)	<50	Vehicles will move at different speeds, while testing the service (statistical sampling)
Latency (ms)	<10	Network + elaboration latency in normal operation mode
Density (devices/m^2)	>1	-
Reliability	>99.99%	% of data delivered without data corruption
Positioning accuracy (m)	<0.5	Compare calculated position with actual parking location and parking available length
Coverage	>99.9%	Data reception success rate when device in different locations (statistical sampling from >1000 measurements in different locations)
Service Provisioning time (minutes)	<90	-

5.3.5.3.2 Business level performance KPIs

The reason for using a 5G network is based on several arguments. The key element however is to reduce the need and cost for infrastructure. It is expected that the need of antennas will be less than for antennas needed in a private Wi-Fi solution. This means however that the cost is moved from an investment to operational cost (e.g., the phone bill). There will be an economic break even where the cost of implementing and maintain a Wi-Fi is beneficial. The cost structure from the telecommunication companies is therefore quite critical for the success of the 5G solution.

Further, we expect that a 5G network will provide accurate positioning of the actual assets. If this meets our expectation the need for global positioning systems will be less in future straddle carriers. This will then help the business case further.

If the 5G solution shows its capability to handle critical communication it will be an even stronger alternative as the network for autonomous assets. Both safety and regularity requirements need to be met.

If the 5G shows it capability to give acceptable speed and coverage inside our concrete buildings 5G could be established as the preferred solution for our plant of the future. It will then need to be capable to assist the maintenance with instruction videos, AR solutions and even have the possibility to connect sensors that use low energy to maintain long battery life.

All of these objectives need a well-built security of the 5G solutions. As customer we need to be convinced that the 5G solution can provide this level of security. If we cannot trust it, we cannot use it.

The availability of the system needs to be in the category always working. The capability to support real time applications can be a showstopper.

A possible advantage is that the private 5G network can be extended to other non-Yara controlled areas like Brevik and Larvik providing better cyber security for the complete solution.

5.3.6 UC 3.6: Port Safety - Monitor & Detect Irregular Sounds

Irregular noise or sound detection technology, such as for explosions or gunshot detection, is considered a major safety and security part of a smart port design. The deployment of such detection systems (e.g. sensitive microphones and UHD+ 360o CCTV (closed-circuit television) cameras) through the use of a reliable 5G network, transmitting real-time audio-visual information on events to the ports operations centre, is of utmost importance to port authorities by allowing them to act immediately and find out the exact location of the incident.

We plan to use machine learning to detect the irregular sounds coming from any of the microphones. We plan to first gather marked data to detect how the port sounds are usually on a normal day. This will help train the machine learning algorithm to understand the normal state, this will help us detect abnormal states in the sounds coming from the microphones. The machine learning algorithm, using TensorFlow, will run on a VNF and gather the outputs from the microphones at the port.

5.3.6.1 Stakeholders and Roles

The UC 3.6 Stakeholders and their roles are given in Table 58.

Table 58: UC 3.5 Stakeholders and Roles.

Stakeholders	Roles
NURO	Technology provider
TNOR	Technology provider
YARA	Port Owner

5.3.6.2 UC Objectives

The main objectives of this use case are given in the table below.

Table 59: UC 3.6 Objectives.

Test objectives	Requirements	Participants
Precise information identification on the specifics of the event, e.g. shooter's location	• Real-time monitoring through 5G wireless connectivity • Reliable secure network ensuring accurate and timely information (relevant KPI latency) • Sensors attached to the street lighting controls in order to generate detailed, location-based information • UHD+ video surveillance systems • Availability of 5G-VINNI Norway facility	• TNOR • NURO

5.3.6.3 Requirements Analysis-KPIs

The technical and business KPIs are given in the table below.

Table 60: UC 3.6 Technical KPIs.

Technical KPIs		
KPI	**Target**	**Measurement method/formula**
Data Rate (Kbps)	>100	Throughput measurement at device
Mobility (km/h)	<50	Vehicles will move at different speeds, while testing the service (statistical sampling)
Latency (ms)	<10	Network + elaboration latency in normal operation mode
Density (devices/m^2)	>0.1	-
Reliability	>99.99%	% of data delivered without data corruption
Positioning accuracy (m)	<10	Compare calculated position with actual parking location and parking available length
Coverage	>99.9%	Data reception success rate when device in different locations (statistical sampling from >1000 measurements in different locations)
Service Provisioning time (minutes)	-	-

Table 61: UC 3.2 Business KPIs.

Business KPIs		
KPI	**Target**	**Measurement method/formula**
Availability of the system in compliance to all specified requirements	99,9%	Statistical sampling
System reliability	<1% of false alarm <1% of event detection omission	% create events. Test detection ability. Statistical sampling

5.4 Media/Entertainment Living lab Description and Detailed Analysis

5.4.1 UC 4.1: Ultra-High-Fidelity media

Rapid progress in display and capture technologies is enabling a new, highly immersive production and viewing experience with ultra-crisp, wide-view pictures with deep contrast and multi-channel sound. Both linear and non-linear content will be used for testing the Ultra High-Fidelity Media (UHFM) experience. In order to guarantee a high quality of experience for UHFM, 5G network should be able to support efficient network management, fair resource allocation, high speed transport capabilities and strategies, e.g. by means of local and network caching of content. UC involves media streaming to devices using a variety of applications supported by the partners under different network configurations.

The last few years have been witnessing a quantum shift in the production and commercialization of digital media. High Definition (HD) digital media is now pervasive in every domain. UHD and higher resolution content is a definite trend. Applications range from Digital Cinema Projection through Broadcast TV, corporate messaging and training, science, medical and military. The distribution of UHFM digital media, for these and every other application, has been made possible by the development of highly efficient compression standards that reduce the size of files and bit-streams significantly while maintaining picture quality to allow storage, cashing and distribution of media on a mass scale, be it to the cinema, digital live broadcast channels, or streaming on demand to home and mobile consumers.

Indeed, film distribution has started moving towards Ultra-High Definition (UHD) - four times the HD size. Well established companies, such as the BBC, are putting substantial effort in the creation of UHD content considering increases in resolution towards UHD and frame rate towards 100 Hz. Domestic television sets and mobile devices e.g. smartphones, tablets, laptops, etc. have been introduced with UHD resolution screens, and are capable of displaying and capturing even higher resolutions. Undoubtedly, the production and exploitation of UHFM content will dominate the market for years to come.

In the meantime, there have been dramatic changes in the generation, production and use of digital media. Indeed, User Generated Content (UGC) has been inundating the storage cells of smart mobile devices, personal computers and social networks alike. A new wide range of sources of UGC has emerged; originated by the pervasive and increasing impact of connected devices, such as smartphones, tablets and wearable devices, able to capture the news and the event as it unfolds anytime anywhere. Moreover, the latest smart device models are equipped with high-specification cameras, enabling users to capture videos with professional quality, even in UHD out-of-the-box. Exploiting the mobile social media concept, both the TV broadcasting industry and academia have been continuously building integrated TV and web platforms to engage the users in the broadcasting process. Of course, the pervasiveness of social networks also means that such platforms should not only be used to generate new forms of media and interaction, but should be accessible to all, irrespective of geographical location e.g. mobile consumers or access device.

The realisation of this vision is underpinned by decades of research and advances in video and multi-view media processing, as well as, other related research fields, meaning that the time is now ripe for integrating research outputs with technologies that support real-time creation and distribution of more advanced content forms while enabling interaction and crowd-sourcing among users and professional content creators. Indeed, the community of knowledge creators, developers and commercialisation enterprises in the fields of mobile applications, UHFM broadcasting, or both, is fully aware of the unprecedented growth of related technology and is wholly convinced of the great potential of a UHFM broadcasting to all consumers no matter their status e.g. being at home or mobile.

The challenge broadcasters currently face is the understanding of pros e.g. additional capabilities such as slicing, or limitations that emerging NGA networks (with focus on 5G) offer in order to take advantage and adapt technological infrastructures and business models. Respective efforts over 4G networks demonstrated great capacity, latency and density limitations. To this end, no matter if content mobile distribution services exist over current mobile networks, they cannot guarantee higher quality and eventually support most of the times lower content formats.

In order to test the potential of producing and distributing UHFM over emerging 5G networks FNET will provide current and upcoming applications, content and services to the 5G-SOLUTIONS UOP 5G-VINNI testbed. In addition, FNET will define a set of comprehensive scenarios able to provide meaningful outcomes to analyze technological, application and business aspects. Specifically, streaming content services provided by FNET (e.g. NovaGO, NovaFlix, etc.) in various formats to a wide number of available 5G devices using UOP 5G-VINNI testbed. The main aim is to measure latency in a wide range of experiments using cashing services that the testbed offers. Additionally, quality guarantee services, density and mobility issues will be tested as well.

One aspect to be proved is the possibility to scale delivery for large audiences. 3GPP has prioritized the work around unicast use cases since the first release of 5G, Rel'15, and hence 5G point-to-multipoint would only be addressed starting from Rel'17. The lack of PTM characteristics may lead to an inefficient service provisioning and utilization of the network and spectrum resources when distributing the same data to multiple users and devices (e.g., live and linear content with very large audiences or mass software updates). However, whether 5G unicast is already able to withstand massive media consumption needs to be investigated.

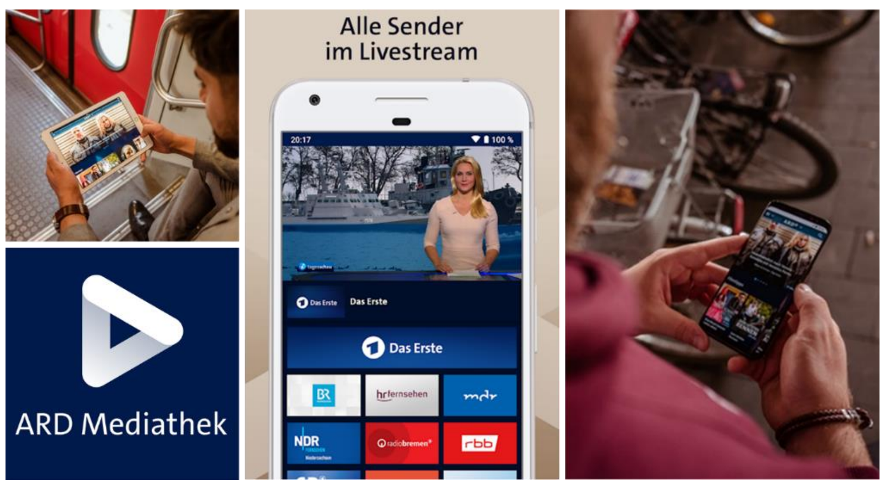

Figure 24: Example of the ARD Mediathek App Providing Access to Linear TV Content.

The scenarios will include content services provided by FNET (e.g. NovaGO ([5]), NovaFlix ([6]), etc.) that will provide streaming services in various definitions to a wide number of available 5G devices using UoP 5G test network. IRT will provide live streaming test sequences with different qualities and data rates from HD to UHD.

The aim is to measure latency in a wide range of experiments using cashing services that the testbed offers. An additional objective is to test unicast distribution of linear content to concurrent users stressing 5G radio and network capabilities. This could be supported by the setup of specific QoS/SLA requirements under a network slicing approach.

5.4.1.1 Stakeholders and Roles

Table 62: UC 4.1 Stakeholders and Roles.

Stakeholders	Roles
FNET content production & transmission engineers	Technical/Content
IRT stakeholders (public service broadcasters in Germany, Austria and Switzerland)	Technical/Business

FNET OTT marketing experts	Business
Network engineers	Technical/Network Transmission-Network Management
End users	User experience

5.4.1.2 UC Objectives

In the following we describe high-level test objectives, requirements and participants:

Table 63: UC 4.1 Objectives.

Test Objectives	Requirements	Participants
• Verify that caching of content significantly improves downlink speed and latency. • Evaluate network management strategies. • Evaluated unicast distribution of TV services under SLA	• Local and/or network caching infrastructure and services provided by the testbeds. • Real or simulated traffic and relative applications. • 5G-VINNI Patra ICT-17 facility availability.	• FNET and IRT will provide real and/or simulated traffic and the relative applications. • UOP will provide the 5G infrastructure. • CTTC will design novel caching techniques exploiting the knowledge of local and global content popularities, while advanced machine learning-based algorithms will enable the short and long-term prediction of the network status.

5.4.1.2.1 Elaborated UC Objectives

- Verify caching of content improves downlink speed and latency while reducing network overload and increasing number of viewers.

  Our aim is to measure the impact that caching mechanisms have in on-demand services while the content is consumed in various analyses by a significant number of 5G users.

- Evaluate network management strategies;
- Measure ease of use and result of management policies i.e. slicing.
- Evaluate unicast distribution of TV services under SLA.

Measure the ability of 5G networks to scale according to user demand and network load for unicast-only distribution of audio-visual services with different content quality and SLAs.

5.4.1.2.2 Initial factors that will drive Requirements

The main driver for this use case is the ability for the broadcasters, to offer live and on demand streaming services, with various content analyses, QOS and SLAs to 5G mobile subscribers. The use case will not only evaluate the technical part of the broadcasting (e.g. transmission, latency, mobility, etc.) but the business aspects as well e.g. reduction of costs vs current practices, ease of use from both the operator subscriber sides, flexibility, wide accessibility, privacy, enhanced use experience, etc.

Table 64: Minimum technical requirements.

Data Rate (Mbps)	Mobility (km/h)	Latency (ms)	Connection Density (devices/m2)	Reliability (%)	Positioning Accuracy (m)	Coverage (%)	Device Autonomy	QoE (MOS)
<1000	<100	<100	>1	>99.99	<10	>99.9	-	>4.3

Table 65: Minimum business requirements.

Requirement	What needs to be evaluated
B1: Personnel cost	People are the biggest cost in most enterprises; therefore, with these services can we do more with same resources? can we do more with less resources? are more expensive resources required? Which are more specialized and harder to find?
B2: Overhead cost	How can the new service reduce non-people costs? Energy costs? Green: reduce CO2? less infrastructure, less buildings, less transport?
B3: Time to market	How does 5G accelerate the provision of new innovative services to customers / citizens and which of them are critical for business (competitive differentiation) and for public services (deliver return-on-taxes to citizens)?
B5: Data privacy	How does 5G improve confidence in protection of the individual in the digital age of their data and identification?
B6: Accessibility	How does 5G help a wider community to share in the benefits of an enhanced digital age: More accessible in cost? Types of location? Device types? Disabilities?

5.4.1.2.3 Use Case Scenarios, Test Objectives and KPIs

The main scenarios that this use case will investigate are:

- Use case scenarios to verify that caching of content improves downlink speed and latency.
- Use case scenarios to verify and evaluate network management strategies.
- Use case scenario to evaluate unicast distribution of TV services under SLA.

This scenario will test the concurrent reception of a given TV service by an increasing number of users in a cell for certain video qualities ranging from HD to UHD. A key component will be the fulfilment of a SLA between the content provider and the network operator that will specify the QoS requirements for such services. In order to fulfil the above-mentioned requirement, the following analysis is provided in terms of UC architecture and KPIs.

5.4.1.3 Requirements Analysis

5.4.1.3.1 Architecture/Component/Applications

1) FNET will provide the client applications
2) From the Core Network:
    a) SIM cards.
    b) 5G Modems, smartphones, laptops.
    c) Cashing infrastructure.
    d) Network management infrastructure.
    e) Slices:
        i) The “standard” ones as envisioned for daily usage on any city
        ii) URLCC.
        iii) Custom SLA/QoS for UL video transmission. Parameters TBD later in the project. This slice should not be “always available” but set up and tear down on-demand so to not use spectrum and similar

resources continuously in vain but to be used on demand only when an event happens (pre-planned like a festival or in real time like breaking news).

f) The ability to associate a 5G SIM with a specific slice, move a SIM (or session?) from one slice to another on a pre-configured pattern, e.g. if the "special custom slice" exist then move the associated SIM to that slice, otherwise allow it to work on the standard slice).

g) Measurements of the End-to-End traffic, density, load, latency, error rates, per modem at all times; End-to-End means at least from the cellular modem at the UE to the Core Network "exit" into the public internet, as the video transmission application is about End-to-End service, not about segments like "air segment" only. If partners want to measure these segments then this is an additional info gathered and analysed by them.

h) Support full mobility – moving from one cell to another smoothly like in the real world.

5.4.1.3.2 KPIs

Relevant service classes: eMBB, eMTC:

- Enhanced Mobile Broadband (eMBB): data-driven use cases requiring high data rates across a wide coverage area.
- Massive Machine Type Communications (mMTC): need to support a very large number of devices in a small area, which may only send data sporadically, such as Internet of Things (IoT) use cases.

Table 66: UC 4.1 Service technical KPIs

KPI	Target	Measurement method/formula
Peak Data Rate	20 Gbps downlink	Measure peak data rate under full load.
Latency	<5 s (Content delivery network) < 5 ms (Live-TV distribution) <1 ms (6DoF VR) 30 ms (Crowdsourced Video)	Measure latency using packet tracer.
area traffic capacity	DL: 3.75 Tbps/Km^2	Measure total throughput when X devices within an area download content.
Throughput per 4K video stream	~15 Mbps	Measure throughput per device for 4K video stream.
Mobility	Content Delivery network: 0-5 Km/h for pedestrians. 60-100 Km/h for users in vehicles. Live-TV distribution: 3 Km/h for pedestrians. 50 Km/h for vehicles. 6DoF VR: 10 Km/s	Check whether eMBB.8 is achieved under different mobility scenarios.
connection density	10K devices per cell	Increase cell load by simultaneous request of the same TV service.
Media request response time	<1 sec	Measure the time between the user input request and the actual content delivery to the user.

Table 67: UC 4.1 Service performance KPIs.

KPI	Target	Measurement method/formula
UHF service reliability	>99.9%	Based on MOS (Mean opinion Score)
UHF service availability	>99.9%	Statistical measurements

No effect to other services	No impact on other legacy services	Test other legacy services KPIs while users use the UHF service
Policy Enforcement	Policy control based on service operators' requirements (e.g., bundle services, charging related policies)	Confirm whether policy control is available

Table 68: UC 4.1 Energy Efficiency KPIs.

KPI	Target	Measurement method/formula
System energy consumption	TBD	Energy consumption per architectural category (RAN, MEC, central cloud, core mobile)
Energy consumption at device	Measure battery consumption at the user equipment for the visualization of TV services	Battery consumption at the user device will be measured for unicast distribution

Table 69: UC 4.1 Infrastructure KPIs.

KPI	Target	Measurement method/formula
Caching capacity	Values to be defined after live tests are executed?	TBD
Caching read speed via 5G NW	Values to be defined after live tests are executed?	Repeat previous measurement when caching is employed (compare results)
Resources allocation	Values to be defined after live tests are executed.	Employ the NW management techniques and repeat previous measurements (compare results)

Table 70: UC 4.1 Business level performance KPIs

KPI	Target	Measurement method/formula
Explore catalogue / catalogue availability	**Note:** Target values and measurement methods are still under investigation	
Run, monitor and manage service / application (instance / session)		
Update service / application (instance / session)		
Terminate service / application		
Service SLA assurance		

5.4.2 UC 4.2: Multi-CDN

Content Delivery Networks (CDN) are currently playing an important role in guaranteeing an adequate traffic load and latency reduction when multiple users get access to a particular content. High quality live TV consumption is set to be one of the most challenging scenarios to be tested. For such purpose, an initial set of trials will be focused on evaluating the possibilities of 5G to enhance unicast delivery by means of higher data rates, lower latency and sustainable QoS.

The possibilities of future 5G networks including caching and edge computing capabilities open an opportunity to work around the concept of Multi-CDN in which a particular CDN cache or CDN provider can be selected according to the experienced QoS or decisions at the network side for e.g. traffic load balancing.

QoS monitoring plays a prominent role in delivering content over a CDN in order to detect failures and playback problems along the delivery chain. By knowing the failures and problems, the overall streaming quality, QoS and user experience can be increased constantly. Argos, a tool developed by IRT, is capable to measure the streaming quality, QoS and playback failures of each media stream. The current solution measures

QoS at the user's device by collecting, processing and storing data in real time. On this basis, the possibility to monitor KPIs of the 5G network may also help to improve decisions on CDN selection based on real-time performance.

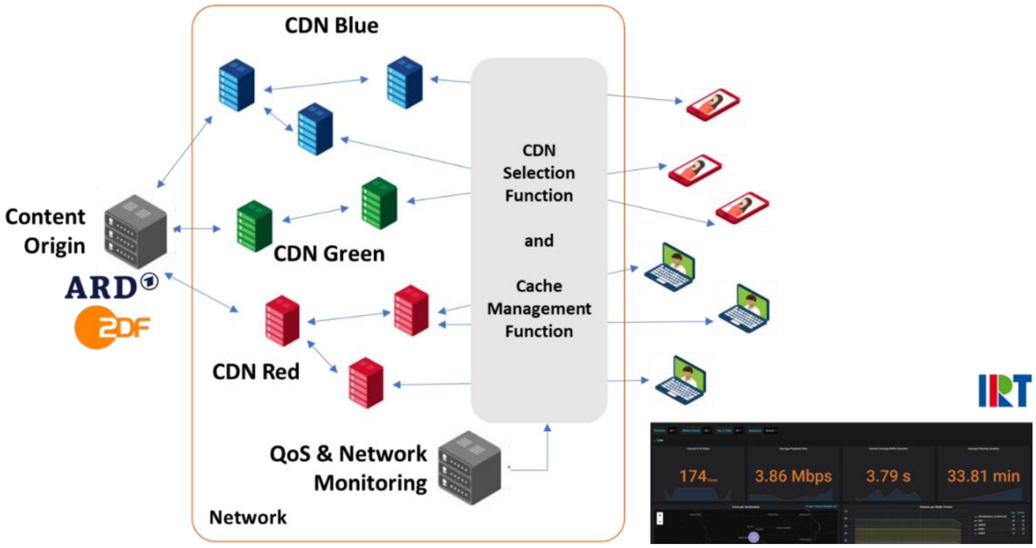

Figure 25: Multi-CDN approach for 5G networks.

IRT Argos is able to measure the QoS of a wide variety of common streaming technologies like Progressive Download, HLS, MPEG DASH or CMAF, and different device groups, like HTML5 and HbbTV Browsers, Android or iOS devices [7]. Furthermore, on demand and live media content is supported.

But besides the collection of QoS data on the device, also performance data of different CDNs can be collected with Argos. This enables the provider of the media content to use different CDNs and evaluate the performance of each CDN in real-time. Based on this data, a multi-CDN scenario can be established that enables the dynamic switching between different CDNs caches in real time.

The trials for this use case will explore the possibilities of providing the optimum QoS for users by means of a dynamic selection of the CDN cache where the user is receiving content or even the prediction of congestion and the use of edge computing resources in order to instantiate new caches on demand. The possibilities of network slicing to guarantee a sustainable QoS at scale will also be investigated.

5.4.2.1 Stakeholders and Roles

Table 71: UC 4.2 Stakeholders and Roles.

Stakeholders	Roles
IRT content delivery experts	Technical/Content
IRT stakeholders (public service broadcasters in Germany, Austria and Switzerland)	Technical/Business
End users	User experience

5.4.2.2 UC Objectives

Table 72: UC 4.2 Initial High-level Test Objectives, Requirements and Participants.

Test Objectives	Requirements	Participants
• Evaluate CDN switching strategies to identify and	• Implement multi-CDN and caching strategies and	• IRT will provide the necessary servers, clients, analytics tools, access to

prevent QoE effects under various CDN loading conditions. • Evaluate local caching strategies to optimize efficiency on costs and traffic volume and boost the QoE for trending content situations.	embed on a proxy connected to a Software Defined Radio (SDR) entity along with and enhanced client-side analytics tool. • Deploy smart proxy/cache with parsing capacities for MPEG-DASH & HLS encrypted contents • 5G-VINNI Patra ICT-17 facility availability.	multi-CDN for CDN-switching decision and smart edge cache. • Up will provide the 5G facility (in particular SDR-based gNodeBs), hosting and onboarding capabilities for smart proxies/caches as VNFs • CTTC will devise dynamic slicing algorithms, where the different types of resources (i.e., communications, storage, computation) will be allocated on-the-fly to boost the network performance.

5.4.2.2.1 Elaborated UC Objectives

- Evaluate CDN switching strategies to identify and prevent QoE effects under various CDN loading conditions.
- A multi-CDN approach will be built into the 5G networks by means of an initial deployment of content caches and Multi-CDN network service on the cloud which will trigger decisions on the selection of the best cache/CDN to guarantee the best QoE at the user end.
- Evaluate local caching strategies to optimize efficiency on costs and traffic volume and boost the QoE for trending content situations.

The optimized locations for caches within the 5G network will be determined according to performance KPIs, cost and QoE. Different locations will be tested, from the cloud to the edge.

5.4.2.2.2 Initial Factors that will Drive Requirements

Key requirement is the ability for the broadcasters, to offer live and on demand streaming services with various content analyses, QOS and SLAs to 5G mobile subscribers. The use case will not only evaluate the technical part of the broadcasting (e.g. transmission, latency, mobility, etc.) but the business aspects as well e.g. reduction of costs vs current practices, ease of use from both the operator subscriber sides, flexibility, wide accessibility, privacy, enhanced use experience, etc.

Table 73: UC 4.2 Minimum Technical Requirements.

Data Rate (Mbps)	Mobility (km/h)	Latency (ms)	Connection Density (devices/m2)	Reliability (%)	Positioning Accuracy (m)	Coverage (%)	Device Autonomy	QoE (MOS)
>100	<1	<50	>0.01	>99	<10	>99	-	>4.3

Table 74: UV 4.2 Minimum Business Requirements.

Requirement	What needs to be evaluated
B1: Personnel cost	People are the biggest cost in most enterprises; therefore, with these services can we do more with same resources? Can we do more with less resources? are more expensive resources required? Which are more specialized and harder to find?
B2: Overhead cost	How can the new service reduce non-people costs? Energy costs? Green: reduce CO2? Fewer infrastructures, less buildings, less transport?
B3: Time to market	How does 5G accelerate the provision of new innovative services to customers / citizens and which of them are critical for business (competitive differentiation) and for public services (deliver return-on-taxes to citizens)?

B5: Data privacy	How does 5G improve confidence in protection of the individual in the digital age of their data and identification?
B6: Accessibility	How does 5G help a wider community to share in the benefits of an enhanced digital age: More accessible in cost? Types of location? Device types? Disabilities?

5.4.2.2.3 Use Case Scenarios, Test Objectives and KPIs

Use case scenario to evaluate CDN switching strategies to identify and prevent QoE effects under various CDN loading conditions.

Testing will be performed under different conditions in order to test the possibility for CDN provider switching either at the user end (with manifest manipulation) or with functions integrated within the network that could route traffic, especially when CDN caches are integrated within the network.

This use case scenario will also evaluate local caching strategies to optimize efficiency on costs and traffic volume and boost the QoE for trending content situations.
The optimization for the allocation of caches within the 5G network will be tested according to cost, traffic volume and QoE at the user device. The KPIs will be analysed under different conditions. As an example, the possibility to allocate a cache per cell or a cache serving multiple cells will be evaluated. The provision of caches within the 5G network could off-load the amount of concurrent connections from the 5G network to the CDN provider.

In order to fulfil the above-mentioned requirement, the following analysis is provided in terms of UC architecture and KPIs.

5.4.2.3 Requirements Analysis

5.4.2.3.1 Architecture/Component/Applications

a) From the network, the implementation of the use case requests edge computing infrastructure in order to provision NFs for content caching and the ability for installing proxies and routing functions within the network either at cell level or for multiple cells.
b) From the user perspective, phones enabled with 5G are required. The content playout will be performed by means of a browser player which could run under Android OS.
c) Connectivity to the CDN provider over the internet and to cloud services for multi-CDN switching management will be required.

5.4.2.3.2 KPIs

Table 73: Service creation and on-boarding

KPI	Target	Measurement method/formula
Peak Data Rate	20 Gbps downlink	Measure peak data rate under full load
Latency	<5 s (Content delivery network)	Measure latency using packet tracer
Stream latency	<45 sec	Measure Stream latency using packet tracer
Throughput per 4K video stream	~15 Mbps	Measure throughput per device for 4K video stream
Mobility	Content Delivery network: 0-5 Km/h for pedestrians. 60-100 Km/h for users in vehicles.	Check whether eMBB.8 is achieved under different mobility scenarios
Connection density	10K devices per cell	Increase cell load by simultaneous request of the same

		TV service
Media request response time	<1 sec	Measure the time between the user input request and the actual content delivery to the user
Cache activation response time	<10 sec	Measure the time a new cache is activated when concurrent connections are detected in a cell.
Cache redirection response time	<10 sec (or the size of a segment so that there is no interruption)	Measure the time the network is redirecting the player to a new cache.

Table 74: Service level and QoE KPIs

KPI	Target	Measurement method/formula
UHF service reliability	TBD	Based on MOS (Mean opinion Score)
UHF service availability	TBD	Statistical measurements
No effect to other services	No impact on other legacy services	Test other legacy services KPIs while users use the UHF service
Policy Enforcement	Policy control based on service operators' requirements (e.g., bundle services, charging related policies)	Confirm whether policy control is available

Table 75: Service Reliability (Robustness, Dependability) KPIs

KPI	Target	Measurement method/formula
System energy consumption	TBD	Energy consumption per architectural category (terminals, RAN, MEC, central cloud, core mobile)
Energy consumption at device	Measure battery consumption at the user equipment for the visualization of TV services	Battery consumption at the user device will be measured for unicast distribution

Table 76: Service Coverage, Capacity and density KPIs

KPI	Target	Measurement method/formula
Caching capacity	Values to be defined after live tests are executed	TBD
Caching read speed via 5G NW	Values to be defined after live tests are executed	Repeat previous measurement when caching is employed (compare results)
Spectral efficiency (resources allocation)	Values to be defined after live tests are executed	Employ the NW management techniques and repeat previous measurements (compare results)

5.4.3 UC 4.3: On-site Live Event Experience

In highly-populated live events, such as sports venues, music concerts, or carnivals, lots of users try to upload images, live videos and recorded clips as well as watch other participants' content or background content related to the event. At the same time, special groups of users require continuous Service Level Agreements (SLAs) higher than those of the mass. The challenge for media service providers is to offer a good QoE to their clients in a dense client environment. Currently, the providers sharing the radio access, backhaul and core network try to optimise their quality independently causing a dramatic degradation of the QoE. There are also special users such as emergency services and first responders, which require a steady QoS. 5G network must be able to provide extra resources for specific users, groups or services. UC 4.3 involves the generation and simulation of various subscriber profiles in terms of bitrate and quality requirements and the evaluation of the corresponding QoE. In addition, this use case will be validated with tens of real end-users in large live showcasing events of Patra's carnival (Q1 2021 & Q1 2022). End-users, participants in the carnival, will be provided with 5G enabled smartphones and/or applications (e.g. for uplink streaming) so that they can test the experience and provide us with feedback together with QoE evaluation, also helping us in validating the business potential of this particular use case. In addition, we will also demonstrate cross network connectivity on demand through the 5G-VINNI facilities in Patra and in Norway. Uplink network performance and the quality of the uplinked/streamed content will also be measured and evaluated by end-user viewers.

LiveU will provide an App, LU-Smart, currently available for 4G, that uses its own adaptive h.264 video encoding coupled to the smartphone cellular link performance, to transmit live from that location. The uniqueness is also in that it can also bond a 2nd IP connection, that of the smartphone WiFi, so that a higher resiliency and bandwidth may be achieved where WiFi is available.

Event type: Such events include, for example small and large Sports events, music concerts and other performance events, political gatherings, religious gathering, festivals, happenings etc.

Location: The use case may be limited to specific geographical locations such as a concert hall, a stadium, a worship house, a nature location, a public square, an urban park etc; they may also be spread on several streets (imagine new year's even in central Manhattan), several squares; they may be stationary or mobile, such as a public parade or an ongoing marathon.

Massive live video generation & consumption: The main story is of many of the people present in such an event stream live from the location(s). Their main destinations are the social networks.

At the same time, many of these people also consume live content from the same event as it is upstreamed by other people attending the event. This consumption is mainly from social networks, but also from professional content producers such as the digital rights holders covering the event.

Side and less demanding content generation may take place concurrently of uploading images (including large size and large quantities) and recorded video.

Guaranteed QoS: In parallel, guaranteed SLA/QoE in audio and video upstreaming and consuming is needed for privileged users such as the emergency services or first responders. Since the regulatory framework, guidelines and business model for allowing these users to use commercially available cellular networks is not yet in place, we will address this part of the use case as a "nice to have add on", but not the mandatory part. On the other hand, a special private 5G network may be deployed for their usage, taking part of the spectrum and co-existing with the commercial networks, yet this is not under the scope of WP6.

Sizing: Scalable, from tens of people upstreaming and consuming live from/to smartphones to tens of thousands.

5.4.3.1 Stakeholders and Roles

Table 75 provides the UC 4.3 stakeholders and their roles.

Table 75: UC 4.3 Stakeholders and roles

Stakeholders	Roles
LIVEU content delivery experts	Technology provider
UOP	Technology provider
CTTC	Technology provider
TNOR	Technology provider

5.4.3.2 UC Objectives

The main objectives of this use case are given in the table below.

Table 76: UC 4.3 Objectives

Test objectives	Requirements	Participants
• Evaluate co-existing network slicing strategies and their impact on user experience and network performance, under various traffic conditions. • Evaluate SLAs and especially guaranteed SLA for uplink real time video transmission at high density events, also while having high bandwidth downlink transmission at the same time (viewers in the event). • Measure the downlink and uplink speeds under different profiles. • Evaluate network performance and user experience while offloading traffic between different networks and between slices.	• Implement multiple different subscribers SLAs, deployed to different real and simulated users. • Implement guaranteed SLA/QoS for high-quality real-time video upstream. • Implement and test slicing strategies • Headless media players that generate QoE logs and can switch amongst a set of available Bitrates/Qualities. • Availability of videos of various qualities. • Distribution of videos through different RANs. • 5G-VINNI Patra & Norway ICT-17 facilities availability, including assured service quality (ASQ) interconnection.	• LIVEU will provide uplink live streaming and recorded streaming application for Android or iOS, device with enhanced RF (compared to smartphones) for single link, multilink and multi slice uplink content generation, the receiving software servers (or cloud). • The testbed will provide the subscribers' profiles, deployments, guaranteed SLA per subscriber type. • UOP will provide the 5G-VINNI Patra facility for 5G cellular coverage where the carnival is taking place. UOP will provide 5G smartphones. UOP will provide lifecycle management of the services to be deployed followed by operational support and testing, as well as administrative support for the real users' engagement (in coordination with the city authorities and with CTTC). For mobility tests, UOP shall provide the vehicle and drivers. UOP (or others) may simulate DL traffic loads in order to test simultaneous upstreaming and down streaming viewing of crowds. • TNOR will contribute to the provisioning and on demand handling of value-added connectivity (VAC) across borders via 5G-VINNI interconnection capabilities.

5.4.3.3 KPIs

The technical and business KPIs are given in the table below.

Table 77: UC 4.3 Technical KPIs

Technical KPIs		
KPI	Target	Measurement method/formula

Data Rate UL (Kbps)	>2000	Uplink throughput measurement at device
Data Rate DL	> 1500	Downlink throughput measurements at each viewing device, for at least 95% of the streaming period
Mobility (km/h)	<100	Vehicles will move at different speeds, while testing the service (statistical sampling)
Latency (ms)	<100	Network + elaboration latency in normal operation mode; excluding CDNs, etc. distributions latencies
Density (devices/m^2)	>1	-
Reliability	>99.99%	% of data delivered without data corruption
Coverage	>99.9%	Data reception success rate when device in different locations (statistical sampling from >1000 measurements in different locations)
QoE (MOS)	>4.3	User feedback

Table 78: UC 4.3 Business KPIs

Business KPIs		
KPI	**Target**	**Measurement method/formula**
QoE-based user profiles	To provide reliable service based on the user profile.	Throughput measurement at device per user profile. Compare with the expected user profile throughput (e.g., VIP).
SLA cost	Understand the cost of an SLAed profile with guaranteed SLA.	Cost, depending on SLA levels and quantities (number of devices, areas etc.).

5.4.4 UC 4.4: User & Machine Generated Content

This use case is about media-related experience in mainly generating professional and semi-professional content for various purposes including live news coverage, live sports and other entertainment coverage, telemedicine related live transmission such as video from rural medical centers to medical experts or live from moving ambulances, real time security cameras, automotive-generated content such as multiple cameras enabling teleoperation or uploading huge amounts of sensory-generated data. User Generated Content for both professional and non-professional journalism is also included and tested.

For the broadcast and news coverage transmissions, this continues the application of replacing the traditional satellite trucks (disruptive) while allowing many more use cases (e.g. news coverage from indoors, from underground, at no-time notice, on the move, from drones, etc.).

When either very reliable transmission is needed or high video quality (in the past full HD, nowadays 4K and in the coming years even 8K), and/or during mobility, then multi-link bonding may be used. In this use case the professional or semi-professional content generator minimizes the risk for transmission failure from anywhere and regardless of potential degradations in any single network, aggregates bandwidth from one or more networks and in our project – also trialling aggregating bandwidth from two 5G slices of the same MNO, to provide the professional grade transmission.

The various bonding combinations that will be tested are listed separately below. They include bonding multiple 5G connections of the same slice type, of different slice types, of 4G with 5G, of 5G with WiFi, and more. Bonding different types of slices shall include a standard eMBB slice with a dedicated slice for upstream video (such as defined in the NEM-5G “Media Slice”). This special slice may be set up dynamically on demand (real time or in advance reservation). We shall measure the dynamics of such operations.

- **Event type:** Basically, any event or “non-event” can be the source generating this content in both live video and non-live uploading. News happens anywhere, anytime. Sports and entertainment event also happen everywhere, including in the most remote and wild areas.
- **Location:** Anywhere, including areas of very poor 5G or even 4G coverage, by any single MNO.
- **Live video generation:** In this UC live/real time content is generated at various qualities. For the professional TV and Sports rights holders, at least 4K and many times 8K is required. For professional news coverage, 4K is needed. Video is compressed though, with HEVC H.265 real time encoders and then transmitted to the TV studio or a cloud virtual receiver where it is decoded and handled.
- **Sizing**: Scalable. In many cases there would be more than one broadcasting teams at the same location covering the same event. So, the number ranges from a single camera to tens of professional and semi-professional TV cameras.

Some examples are presented below:

- 2019 Epic mountain bike, live from remote areas, helicopter, motorcycles, bicycles[4]
- 2015, Sky news, Guinness book of records for most live, 150 live transmissions into the Sky News TV studio[5]

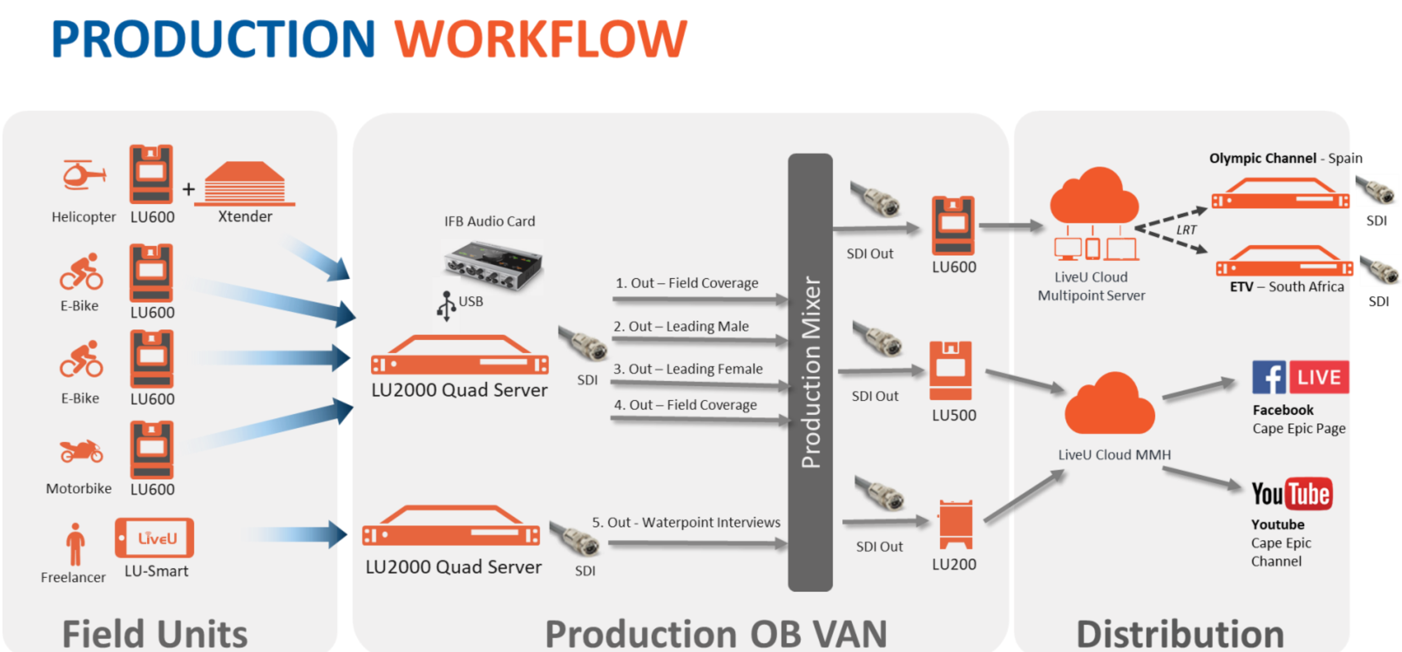

Figure 26: Real World Production: Epic Mountain Bike, multi-source, remote areas.

(IRT) IRT will evaluate new forms of news gathering and storytelling where the reporters use conventional electronic devices with public network connectivity to record, gather, edit and distribute news for their broadcaster. Depending on the characteristics of the network and the connectivity in place, the use case may become challenging. In particular, when covering events with huge audiences or in emergency situations, the use of the conventional public MNO network becomes instable and current single modem 4G networks cannot ensure a high-quality performance link as required by broadcasters.

[4] https://www.youtube.com/watch?v=JUxPIa_Y_zY
[5] https://www.youtube.com/watch?v=gHdE3Jz8Vgk

Future 5G technology and networks become relevant for this use case in order to test new features and functionalities that may enhance user experience and leverage key benefits of this type of journalism characterized by immediacy, portability, and ease of access.

IRT will test different aspects of single link mobile journalism in relation to 5G technologies and networks in the field. In this sense, the facilities available in Oslo and Patras will be used for testing together with small-scale integration at the IRT labs.

In close connection with its stakeholders, the purpose of the trials and tests will be linked to two mobile journalism apps currently used by the teams of the two main broadcasters in Germany:

- The muPro App is used to establish live audio connections to end-units inside the ARD[6] and additionally, upload audio files and content to the ARD public broadcast network in Germany.
- The Reporter App, developed by ZDF Digital, is a journalism tool that permits the capture of video and its on-line editing to produce, among others, ready-to-broadcast reports for TV.

Figure 27: ARD muPro App (left) and ZDF-Digital Reporter App (right) for mobile journalism.

The use of these Apps involves compact solutions with no huge work stations or external monitors necessary. In connection to 5G, several components of this use case will be tested with the aim of stressing the 5G network to reach their limits in terms of KPIs which will be compared to the current performance of the use case under 4G. Even more, the added value components such as network slicing or edge computing will be part of the use case.

The trials under this use case will assess the following aspects:

- Capabilities of 5G technology in isolation. 5G NR and Core will be stressed in terms of data rate, latency, reliability in order to understand the limits of 5G to transmit content with different encoding formats (e.g. HD or UHD) or nature (content for live transmission or upload).
- Capabilities of 5G technology with concurrent professional users. It is very likely that in case of an event several broadcasters and production companies arrive to the event with similar equipment aiming to realize a connection to cover the event. In this case, it is necessary to understand the performance of the network "as it is" and try to find the limits in terms of data rate, latency, connection density, etc.
- Explore the paradigm of "slice-booking". The journalist is able to book and release a network slice with customized SLA requirements that need to be set up for the purpose of an immediate transmission. This will be used to guarantee connectivity for journalism by reserving a certain amount of resources independent of other users concurrently connected to the network. This also needs to be tested in concurrency with other users, either public attending the event or other broadcasters.

[6] ARD is the joint organisation of Germany's state public-service broadcasters which operates 54 regional and local radio stations and 7 television networks.

- Additional testing for the support of mobility and hand-over between cells. In a moving event it is essential to ensure network connectivity under similar QoS conditions as for a static event. The potential disruptions and limits under this scenario will be assessed.
- Benefits of the multilink bonding approach with 5G.

A final test will involve the possibility to stablish an interview scenario between the reporter on the field and a journal in the TV studio with bi-directional communication. Here one of the most critical KPIs to be assessed is End-to-End latency in both directions and the possibilities for minimizing the relative delay to enable a fluent conversation.

5.4.4.1 Stakeholders and Roles

The stakeholders for this use case are:

- LiveU: bonding devices, multi-slice and multi-technologies strategical planning
- FNET: offering content production & transmission engineers
- FNET: OTT marketing experts
- IRT: production and transmission engineers and end users (public media journalists)
- Network engineers
- End users

5.4.4.2 UC Objectives

The objectives of this use case are given in Table 81.

Table 81: UC 4.4 objectives.

Test Objectives	Requirements	Participants
• Measure uplink speed and latency, End-to-End and End-to-Core point, under different subscription profiles. • Validate and evaluate: • QoE metrics, such as video start-up & latency, video freezing & buffering, continuity, etc. • UGC and professional media generation density support. • The value in multilinking 5G connections from the same operator for professional video coverage. • "multi-slice" – using multilink bonding done on two different slices of the same operator, multilink with WiFi, multilink of 5G with 4G, etc. combinations the uplink contribution at various network conditions such as cell-edge, reflections/multi-path, different spectrum bands, etc. • Other modes of professional	• High quality UGC • Mobile application for UGC acquisition and a UGC converging server. • 5G UEs • Professional video contribution solutions over 5G cellular single and multilink. • 5G-VINNI Patra ICT-17 facility availability. • Implementing dynamic set-up/tear down of a dedicated upstream slice for video delivery	• FNET and LIVEU will provide the required UGC. Multilink, multi-slice and single link professional contribution solutions and applications. • UOP will offer its 5G-VINNI facility and corresponding resources to host the various UGC applications and the related use cases. • CTTC will design uplink-oriented slicing schemes where resources will be allocated in an efficient manner to guarantee the QoS requirements of the UGC. • IRT will test and emulate applications for generated content from the field (newsgathering) to test performance and stress the 5G network. • The testbed will deliver the dynamic dedicated upstream

usage, such as fast upload of GByte files of pre-recorded material. • Upstream special slice set-up and tear-down flexibility		slice set u and tear down and measurements of relevant parameters

5.4.4.3 KPIs

The UC 4.4 KPIs are given in Table 82 and Table 83.

Table 82: UC 4.4 Technical KPIs

Technical KPIs		
KPI	**Target**	**Measurement details**
E2E latency	<5 s (Content delivery network) < 5 ms (Live-TV distribution) <1 ms (6DoF VR) 30 ms (Crowdsourced Video)	Measure E2E latency using packet tracer
Uplink stream latency	<0,5 sec	Including video capture, compression, transmission to cloud/studio and decoding.
Downstream latency	<0,5 sec	Including encoding/transcoding, transmission not via a CDN, decoding.
Connection density	10K devices per cell	
Mobility	Content Delivery network: 0-5 Km/h for pedestrians. 60-100 Km/h for users in vehicles. Live-TV distribution: 3 Km/h for pedestrians. 50 Km/h for vehicles. 6DoF VR: 10 Km/s	Check whether eMBB.8 is achieved under different mobility scenarios
Two-way throughput (DL+UL)	20 Gbps downlink and 10 Gbps uplink two-way throughput	Measure peak data rate under uplink and downlink full load
Multi-link reliability	Relevant bandwidth under the various bonding set-ups defined in sub-chapters below; at least 15 mbps for each uplink continuous transmission	Measure video bandwidth, continuity, breaks, latencies
Dedicated slice setup and tear down timings	<3 minutes	Dynamic, on demand and/or in advance, setup and tear down in specific locations;
Seamless transition of a SIM from eMBB slice to/from dedicated dynamic slice	Continuous, non-interrupted, seamless transfer; <30 sec from set-up. < 5 msec transition time	Ensure that a SIM registered to get service from a dedicated upstream slice can get in seamlessly and without service interruptions

Note: Business case KPIs shall be identified and defined at a later stage.

5.4.5 UC 4.5: Immersive and Integrated Media and Gaming

Immersive and Integrated gaming is becoming a new standard in game development. With the increase in the "immersivity" provided by new hardware solutions. Virtual reality (VR) has been the first step in developing a truly immersive gaming experience for players to enjoy. With the ability for players to become absorbed in their gaming environment, whether they're playing a few rounds of Fortnite or Overwatch, taking on the games for pleasure or profit in an online casino, or playing something personal offline. VR has a prominent future in the videogame industry.

For 5G-SOLUTIONS, we plan to develop a multiplayer game that will run on android with google daydream to provide immersive VR experience. The game will include multiple players going into the same environment, where they stand and defend themselves from various enemies. The game and the multiplayer servers will completely be virtualised.

5.4.5.1 Stakeholders and Roles

Table 79 provides the UC 4.5 stakeholders and their roles.

Table 79: UC 4.5 Stakeholders and roles.

Stakeholders	Roles
NURO	Technical/Content
UOP	Technology provider
CTTC	Technology provider
LiveU	Technology provider

5.4.5.2 UC Objectives

The objectives of this use case are given in Table 8085.

Table 80: UC 4.5 objectives.

Test Objectives	Requirements	Participants
• Measure latency in collaborative gaming, combining distributed gaming architectures and caching. • Measure data throughput and QoE that can be achieved by employing channel bonding techniques.	• Caching infrastructure and services. • Collaborative games implemented using a distributed architecture, various AR/VR applications. • 5G-VINNI Patra ICT-17 facility availability.	• NURO for games app and AR/VR. • UOP will provide the 5G-VINNI Patra facility and the FPV scenario. • CTTC will provide effective innovative E2E dynamic inter-slicing algorithms to enable a seamless collaborative gaming experience by bonding resources across different network domains.

5.4.5.3 Requirements Analysis

Sizing: Up to 10 players can play at once in one environment.

Requirements:

- NURO will provide the android application
- VNF/CNF for matchmaking for the multiplayer game
- CNF for running the game server
- VNF for KPI monitoring and leaderships
- Less than 5ms latency in the inter-VNF connections

- Less than 10ms latency in edge to VNF connection

5.4.5.3.1 KPIs

The UC 4.4 KPIs are given in Table 8585 and Table 86.

Table 81: UC 4.5 Technical KPIs

Technical KPIs		
KPI	**Target**	**Measurement method/formula**
Data Rate (Kbps)	>200	Throughput measurement at device
Mobility (km/h)	<1	Vehicles will move at different speeds, while testing the service (statistical sampling)
Latency (ms)	<10	Network + elaboration latency in normal operation mode
Density (devices/m^2)	>0.1	-
Reliability	>99%	% of data delivered without data corruption
Coverage	>99%	Data reception success rate when device in different locations (statistical sampling from >1000 measurements in different locations)
QoE (MOS)	>4.3	User feedback

Table 82: UC 4.5 Business KPIs.

Technical KPIs		
KPI	**Target**	**Measurement method/formula**
QoE	>4.3	User feedback

5.4.6 UC 4.6: Cooperative Media Production

Cooperative Media Production, or At-Home Production or Remote Integration (REMI) has become the new standard for production companies, broadcasters and sports organizations of all sizes.

Wireless At-Home/Cloud Production solutions allow broadcasters to reduce costs by producing live shows from a centralized studio control room instead of on-site production and satellite trucks. These on-site trucks involve huge costs both in terms of duplicated equipment and personnel, in very low efficiency due to the overhead involved such as travel time of the teams and the equipment, quality variance between events, production faults, lower efficiency in multi-site simultaneous events management etc. At-home production solves all of these inefficiencies and reduced support of live events by allowing sending only the camera and audio teams to the field, whereas the [production is done either in the professional studio facility or anywhere else as seen fit.

Sports and event producers can deliver multi-camera live events while eliminating the need to spend a fortune on production vehicles, satellite uplinks and travel expenses. In this use case several cameras are each connected in the field to cellular-based transmission devices, including bonding devices to provide the utmost reliability and bandwidth. These field devices then transmit the video stream over the cellular and the standard public internet (ISP) to a single receiving/decoder server with several physical SDI outputs. LiveU shall provide several (probably 4) bonding video encoders-transmitters which will use its Precision Timing feature to allow synchronization of the video streams at the receiving end – the remote production software.

The multiple video streams in the station or production facility are then used for the actual remote production. Video quality is up to 4K from each camera.

Sizing: Up to 4 cameras in the field connected to a single receiver/decoder over the cellular and public Ethernet (ISP). From there the video is outputted for further, standard, production workflow. Multiple cameras can be deployed in the same venue, or multiple venues going into the same single studio production. In case QoE/QoS can be guaranteed for the cameras, e.g. using special slices, this will also be tested. Bonding uses multiple cellular networks and/or slices from the same operator to provide the required reliability, bandwidth and synchronicity between the cameras.

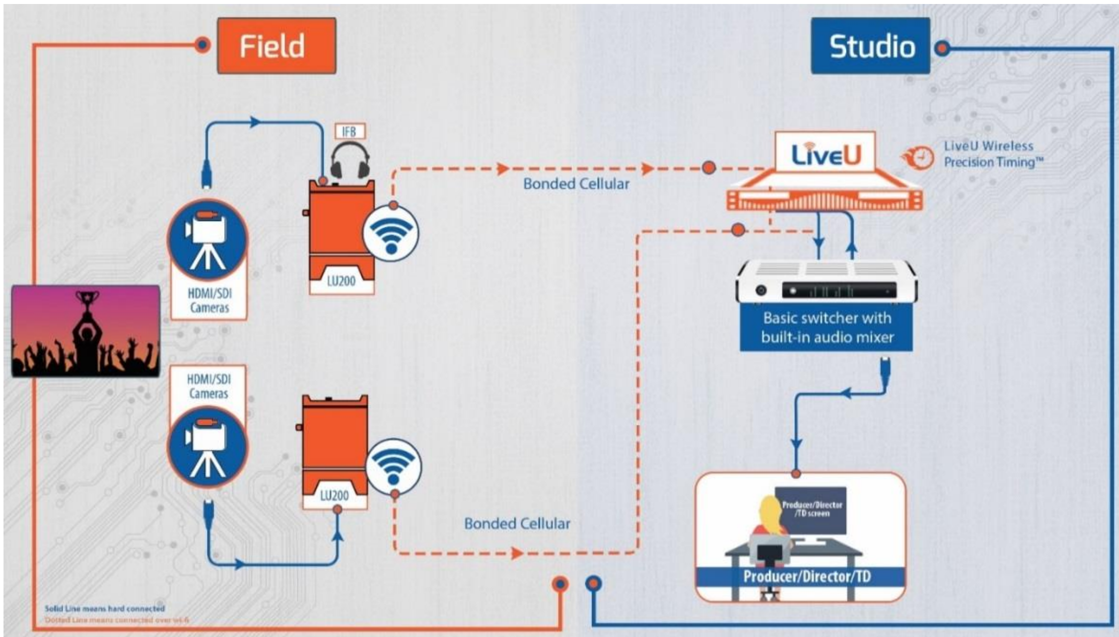

Figure 28: Basic at Home Remote Production with Cellular Bonding.

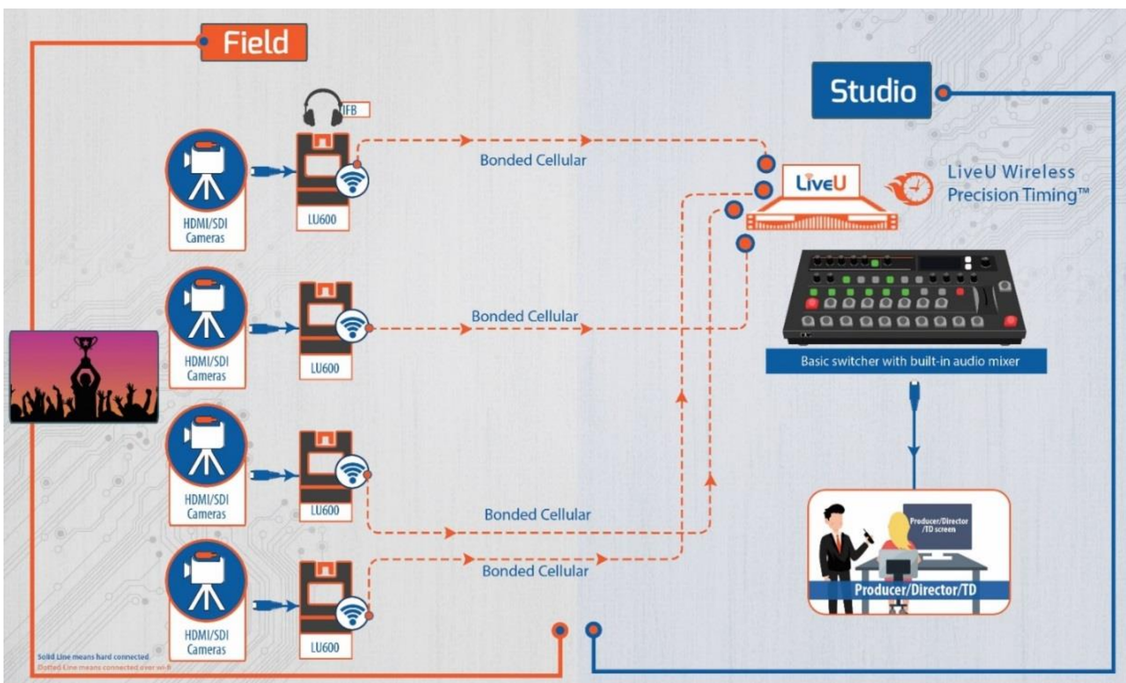

Figure 29: Capacity at Home Remote Production.

FNET can provide live and on demand content to the trials e.g. cameramen having LIVEU equipment can provide content from a stadium, etc. to the above editing studio. The initial bonded flows suggested for demo and testing in VINNI platform are:

1) Single 5G IP connection/modem/SIM (i.e. not bonded); stationary and on the move.
2) Single 5G connection (modem, SIM using the Patras private 5G network) bonded with a single and/or multiple 4G connections; This demonstrates the seamless moving between different coverage/MNOs areas, showing how 5G deployment can be "relaxed" and non-complete yet the professional video contribution (UC #4) is maintained.
   a) The 4G can be either the commercially available 4G(s) MNO(s), and/or the Patras private 4G (if it operates on standard EU LTE spectrum)
3) Single 5G using "standard slice" and single 5G using a "special M&E slice".
4) Bonding a 5G "standard slice" and a 5G "special media UL' slice; one or more modems on each slice. From one modem/SIM on each slice and up to 3 modems on each slice.
   a) This shows how, for example, a TV reporter that arrives at a breaking news or similar location starts transmitting using the standard slice that is normally available there, and when there are more reporters on-site and/or other users that make that standard slice QoS lower, the MNO may dynamically set up a new slice with guaranteed or improved SLA/QoS, and move one or two of this reporter's SIMs to that new slice transparently/seamlessly (the Orchestrator role?). The bonding uses the two connections seamlessly, the QoS of the transmission improves, the "standard slice" is somewhat off-loaded, etc.
5) Similarly, yet from two and up to 5 5G standard slices and the SDN/NFV dynamicity is achieved by the MNO dynamically increasing/decreasing the capacity of that standard slice.
6) Single 5G and WiFi; so, traffic is offloaded dynamically to the WiFi, showing seamless flow when going in and out of WiFi coverage areas.
   a) This scenario may be important in demoing UC 3#, user generated content, where the LiveU bonding transmission App is installed on the people in the field so that they can transmit uplink into the studio improved reliability and bandwidth when bonding their smartphone 5G cellular connection bonded with their smartphone WiFi.

It is expected that on top of these basic transmission scenarios additional ones will be added.

5.4.6.1 Stakeholders and Roles

The table below provides the UC 4.6 stakeholders and their roles.

Table 83: UC 4.6 Stakeholders and roles.

Stakeholders	Roles
FNET	• Content production & transmission engineers • OTT marketing experts
LIVEU	Will provide knowledge and uplink video transmission in single link and bonding devices in support of the real time professional content
Network engineers	Technology provider
End users	Main beneficiaries

5.4.6.2 UC Objectives

Table 84: UC 4.6 Objectives.

Test Objectives	Requirements	Participants
• Measure latency, throughput and QoE that can be achieved when cooperative media production applications are installed and used. • Estimate the impact of the cloud and various RANs.	• Reliable multi-camera transmission content from the field to a remote production facility or cloud. • Synchronise live and OD streams over bonded multiple links. • RTSP, RTMP servers to provide ultra-low latency live contents. • Timestamped players compatible with RTSP flows/ WebRTC players. • 5G-VINNI Patra ICT-17 facility availability.	• FNET and LIVEU and will provide all the required server and client applications, live video contribution systems, content and support. • UOP will provide the 5G-VINNI Patra facility • CTTC will design novel intra-slicing network schemes, capable of handling different content types (e.g., eMBB for streaming and URLLC for synchronised subtitles) in order to optimize the production of cooperative media.

5.4.6.3 KPIs

The KPIs of UC 4.6 are given in Table 85, while the business KPIs in Table 86.

Table 85: UC 4.6 Technical KPIs.

Technical KPIs		
KPI	**Target**	**Measurement details**
Latency	<5 s (Content delivery network) 30 ms (Crowdsourced Video)	Measure latency using packet tracer.
Synchronization	< 0.5 sec	Measured between multiple synchornized bonded transmissions, at the remote production SW.
Throughput per 4K video stream	~15 Mbps	Measure throughput per device for 4K video stream.

Table 86: UC 4.6. Business KPIs

Business KPIs		
KPI	**Target**	**Measurement details**
Policy Enforcement	Policy control based on service operators' requirements (e.g., bundle services, charging related policies).	Confirm whether policy control is available.
User content filtering in real time	The user generated content should be filtered in real time and converged with the operator's generated content for broadcast.	Confirm that user content filtering in real time is available.
Content synchronization	The user should be able to see the selected content in synched time.	Confirm that user content sync in real time is available.
Cost of service	Cost of high quality 4K upstream, guaranteed.	Define the parameters that impact the cost and identify the cost itself.

5.4.7 Requirements Analysis for UCs 4.3/4.4/4.6

For use cases (3, 4, 6) the basic requirements are:

1) Adding LiveU video bonding server to the Patras lab, assuming the "media studio" is there. It is connected via an ISP, has a public IP address (port forwarding behind a Firewall should be ok) and similar IT requirements, but not part of the 5G Core network itself, so less hassle.
   a) Should be supported by a wide enough incoming ISP service so to not limit the multitude of simultaneous cameras/Apps transmitting into this studio, for example during the festival. For LiveU, each of the smartphone App may transmit at probably up to 8mbps and its bonding devices may transmit at up to 25mbs or so.
   b) Alternatively, it could reside in the cloud (e.g. Amazon farm) and managed by LiveU, but this adds latency due to the distribution.
2) Two LiveU bonding transmission devices them (budgeted in the proposal)
3) Having at least 6 5G cellular modules/modems that work with the LiveU bonding transmitter device. While not yet available by modem vendors, LiveU is working on getting these for its commercial products and believes it will have them in time (2020) for the 3.5 GHz VINNI and EVE platforms.
4) SIM cards for a commercially locally available 4G networks (at least 2 different 4G networks) and for the testbed 5G, and/or private4G network.
5) At least two professional cameras, preferably 4K resolution (so to demonstrate the higher bandwidth and image quality and resulting needed QoS). Transmitting from the same location/venue using the two LiveU bonding devices thus simulating a simple 'remote at home production" (in the Patras media lab) ; should be provided locally by Patras or similar;
6) 5G Smartphones to be equipped with LiveU LU-Smart video transmission application for 5G (under development); LiveU needs to know what Smartphones will be available and get one sample ASAP to develop/port the App.
7) A Media Studio "production house" in Patras to act/simulate as a broadcaster's studio that receives the live feeds, add graphics or similar, and distribute it to social networks, TV affiliates etc. This is the "at home remote production".
8) LiveU SW/HW receiver installed in Telenor in order to receive the video being transmitted into Patras media studio also in Telenor, at same quality and minimal added latency, over the public internet ("video hopping").
9) From the Core Network:
   d) SIM cards
   e) Modems, smartphones
   f) WiFi
   g) Slices:
      i) The "standard" ones as envisioned for daily usage on any city
      ii) URLCC
      iii) Custom SLA/QoS for UL video transmission. Parameters TBD later in the project. This slice should not be "always available" but set up and tear down on-demand so to not use spectrum and similar resources continuously in vain but to use on demand only when an event happens (pre-planned like a festival or in real time like breaking news).
   h) The ability to associate a 5G SIM with a specific slice, move a SIM (or session?) from one slice to another on a pre-configured pattern, e.g. if the "special custom slice" exist then move the associated SIM to that slice, otherwise allow it to work on the standard slice).
   i) Measurements of the End-to-End traffic, density, load, latency, error rates, per modem at all times.; End-to-End means at least from the cellular modem at the UE to the Core Network "exit" into the public internet, as the video transmission application is about End-to-End service, not about segments

like “air segment” only. If partners want to measure these segments then this is an additional info gathered and analysed by them.

5.5 Multi Living lab

Multi Living Lab (MLL) aims to test and validate the business and technological performance of multiple vertical UCs concurrently. In LL1 – LL4, a series of vertical UCs are defined based on three network slice types, eMBB, mMTC and URLLC, according to the ITU specification. MLL will select and combine a subset of UCs from LL1 to LL4, run them simultaneously, and validate the KPIs specific to MLL with the concurrent UCs. The Cross-Domain Service Orchestration (CDSO), developed in WP2, will be responsible for managing and orchestration the services of concurrent UCs.

MLL reuses existing UCs developed in LL1 to LL4 and focuses on two aspects: i) strategically selecting and combining a subset of UCs; ii) evaluating and validating the performance aspects of concurrently operating the selected UCs. The first aspect guides how a MLL UC is defined and discussed in Section 5.5.1 whereas the second aspect relies on how the performance of a MLL UC is define and discussed in Section 5.5.3. The requirements of running and testing MLL UCs are described in Section 5.5.2.

5.5.1 UC Classification and Characteristics

Precisely speaking, MLL does not define new UC. The so-called MLL-UC is a mixture of existing UCs defined in LL1 – LL4, i.e., one MLL-UC contains more than one LLx UCs. The objective is to investigate the performance and behaviour of dynamic network slicing. In 5G network slicing, one big challenge lies in how to dynamically allocate and orchestrate the resources to meet the demands of multiple vertical customers simultaneously. To this end, MLL-UCs are designed to reflect the challenges in orchestration and testing.

The design of MLL-UCs relies on how LLx UCs are selected and combined, i.e., the mixing criteria. As a starting point, the following mixing criteria are considered:

- Mixing by slice types: one MLL-UC contains multiple UCs, which are provisioned by one or more network slice instances. These slice instances could belong to
  - One slice type, or,
  - Multiple slice types.

  Note that some individual UCs require multiple slice types themselves, e.g., eMBB+URLLC for UC4.6, eMBB+mMTC for UC4.1, eMBB+URLLC+mMTC for UC1.1. An MLL-UC including these UCs is automatically classified to the “multiple slice type”.

- Mixing by VNF types: in LL1 – LL4, one UC, regardless of how many network slices types it requires, is composed of network functions (NFs), including PNFs and VNFs. The VNF could be:
  - Non-3rd party default VNFs that are supplied, supported, and managed by the ICT-17 platforms (5G-EVE and 5G-VINNI). The orchestration of these VNFs is within the scope of ICT-17 platforms.
  - 3rd party VNFs specific to the UC. These VNFs, if deployed on the ICT-17 platforms, requires extra efforts on preparation and integration before being onboarded in the ICT-17 platforms. Furthermore, additional work is demanded to orchestrate these VNFs, either via their own VNFM or via a plug-in to integrate with the ICT-17 orchestrator.

  If a MLL-UC contains multiple 3rd party VNFs from multiple UCs, it imposes new requirements on orchestration and resource allocation, opposed to a MLL-UC with only default VNFs.
- Mixing by Orchestration requirements: in LL1 – LL4, each UC specifies its requirements on orchestration, i.e.,
  - UC is hosted by and orchestrated by ICT-17 (Type A): in this case, CDSO will outsource the orchestration to ICT-17.

  - UC is not hosted by ICT-17 and has its own orchestrator (Type B): in this case, CDSO will outsource the orchestration to UC's own orchestrator.
  - UC is not hosted by ICT-17 and does not have its own orchestrator (Type B): in this case, CDSO will provide MANO-type orchestration.

  In a MLL-UC, a mixture of UCs leads to a mixture of orchestration options, e.g., (assuming Type A is dominant and there is always at least one UC of Type A)

  - Only UCs of Type A: then ICT-17 orchestration is sufficient;
  - UCs of Type A and Type B but Type B is treated like Type A: then both ICT-17 and Non-ICT-17 orchestration (UC-specific) are demanded;
  - UCs of Type A and Type B but Type B is treated differently than Type A: then CDSO orchestration will act as a UC orchestrator in parallel to ICT-17 orchestration;
  - UCs of Type A + Type B, in which Type B has both "like Type A" and "Not like Type A" cases: then ICT-17 orchestration, Non-ICT-17 (UC-specific) orchestration, and CDSO orchestration will coexist to orchestrate the UCs of one MLL-UC.
- Mixing by the infrastructure facility sites: in LL1 – LL4, UCs can be hosted in different ICT-17 facility sites, 5G-EVE (Turin), 5G-VINNI (Norway) or 5G-VINNI (Patras). In MLL, UCs can be mixed in two options:
  - All UCs are hosted in one facility site: i.e., in 5G-EVE (Turin), 5G-VINNI (Norway) or 5G-VINNI (Patras).
  - UCs may span across multiple facility sites.

  In both options, the constituent UCs could belong to the same or different slice types. Note that LL4 UCs (spanning 5G-VINNI Patras and 5G-VINNI Norway) themselves need cross-facility-sites network slices. If one MLL-UC contains a LL4 UC, then it is automatically classified as "multiple facility sites".

- Mixing by Testing requirements: Testing and validating concurrently operating UCs is also challenging as it involves negotiating and scheduling multiple test cases for each individual UC, collecting data for each test case, etc. In LL1 – LL4, each UC may require testing capabilities like:
  - Test and collect network KPIs provided by ICT-17
  - Test and collect application KPIs that are UC-specific and need to be facilitated by extra testing tools and resource in each LL
  - Test and collect KPIs of network components, e.g., VNFs or network services like RAN or Core network
  - Correlate the network KPIs from ICT-17 and application KPIs from each LL

  In the MLL, each constituent UC can require the same/similar testing capabilities as in individual LLs. But the overall testing requirements are more than a simple addition of the individual testing requirements. Additional requirements are imposed to account for the influence of concurrent UCs, e.g.,

  - how the performance of each UC is affected or degraded while other UCs coexist.
  - What is the influence of testing requirements on the UC performance (note: some testing methods may interfere with network operations? e.g. active probing)

In summary, Table 87 exemplifies how MLL-UCs can be designed by combining different mixing criteria. The concrete MLL-UCs will be decided in the near future.

Table 87: Multi-LL UCs

MLL-UC	Slice Type	Facility scope	VNF	Orchestration
1	One slice type	One facility	NO 3rd party VNF	Only type A
2	One slice type		3rd party VNF	Only type A

3	One slice type		3rd party VNF	Type A + Type B
4	Multiple slice type	One facility	NO 3rd party VNF	Only type A
5	Multiple slice type		3rd party VNF	Only type A
6	Multiple slice type		3rd party VNF	Type A + Type B

5.5.2 Requirements analysis

Since MLL is focused on combining and integrating multiple UCs, its requirements are mainly addressed from the perspective of integration, combination and coordination. The requirements of each constituent UC have been addressed in the corresponding LLs and will not be repeated here.

1. Orchestration requirement (internal to CDSO): 5G-SOLUTION orchestration is realized by CDSO. In the MLL, CDSO is expected to provide extra orchestration and LCM responsibility such as:
    - Negotiate with ICT-17 and UC's own orchestrator to ensure that all constituent UCs in the MLL-UC can be admitted into the corresponding facility sites, e.g., check resource availability and facility readiness for the VNFs, etc.
    - Identify the type of UC orchestration (Type A, Type B) and assign the orchestration tasks to individual orchestrator (e.g., ICT-17, UC's own orchestrator, or CDSO itself)
    - Coordinate and schedule orchestration tasks among the participating orchestrators
    - Schedule and order multiple services from the corresponding orchestrator (ICT-17, UC's own orchestrator or CDSO itself)
    - Check the service status (successful or failed service activation, etc.).
    - Relay the run-time modification requests to the corresponding orchestrator, e.g., add UEs, change QoS profile, etc.
2. Orchestration requirements (external to ICT-17 orchestrators and UC's own orchestrators). These requirements should be communicated with ICT-17 iteratively.
    - Design and prepare the multiple slice services in the concurrent mode. Each UC has its own requirements on QoS, VNFs, isolation, resource sharing, security, etc. Combining these services smartly may achieve a good trade-off between cost efficiency and performance assurance, e.g., allow some VNFs to be shared.
    - On-board multiple slice services in the concurrent mode to ensure that all service packages can be successfully on-boarded and validated before being activated. Check if the sequence of activation is a matter or not. If so, design a proper activation sequence and send it to CDSO.
    - Activate multiple slice services in the concurrent mode and report service status.
    - Execute the received requests on the run-time modifications.
    - Terminate the multiple slice services in the concurrent mode: pay special attention to the shared resource.
    - (Extra): some UCs may require special robustness or backup solutions, e.g., UC4.4 – UC4.6 requires smooth transition between two slice instances when video performance is degraded. This brings up extra requirements on real-time testing and LCM between slice instances. In the MLL, if one slice is shared by multiple UCs, then the transition needs to be targeted at specific UEs of the specific UC, which involves OSS/BSS.
3. Resource requirement: all the facility sites have limited resource, which constraints the number of concurrently operating UCs. Resource dimensioning is a key step for MLL to succeed. Each LL and UC provides resource requirements on
    - Deploying the slice service in the facility site: e.g., VNFs, UEs, orchestrator if any.
    - Testing and validating the slice service in the facility site: e.g., data specification, data collection and storage, testing tools if application KPIs is required.
    - Sharing:

- Share one slice with coexisting UCs: some LLs/UCs do not demand a dedicated slice to themselves, e.g., LL4 UC4.4, UC4.6. In the MLL, these UCs can share one slice with other UCs.
- Share one resource with coexisting UCs: some LLs/UCs allow sharing certain VNFs with other UCs.

These requirements will be analysed to assist the corresponding facility site design the required network slices. First of all, the facility needs to ensure that it has sufficient resources to provision the required slices. Second, the facility can optimize its design by taking advantage of the sharing requirements, e.g., share one VNF or share one slice among multiple UCs.

4. Testing and KPI visualization requirements: ICT-17 can provide testing capabilities at two levels, network KPIs and component KPIs. For each level, different requirements arise.
   - Network-level testing:
     - Scheduling requirements: the testing platform is required to distinguish the network-level KPIs for each participating UC and record them separately.
     - Integration requirements: many UCs require application KPIs. It is of high interest to correlate the applications KPIs with network-level KPIs as a means to understand the relationship between network performance and application performance. Then, the network-level testing is expected to associate with application-level testing for each UC.
   - Component testing: The E2E network performance is determined by the performance of constituent components. Measuring the component performance enables in-depth troubleshooting.
     - If the tested components are isolated components, the test cases are straightforward and testing data can be forwarded to the related UC directly.
     - If the tested components are shared by multiple UCs, then proper mechanisms are needed to distinguish the measurement data between different UCs

Note that ICT-17 does not provide Application-level testing. Each LL has its own testing facility to validate UC-specific application KPIs. In the MLL, additional testing requirements arise with regard to orchestrating the application-level testing of multiple LLs:

- Data requirements: except for the KPIs specified by each individual UC, some additional data may be desired, such as the service information of all concurrent UCs and the traffic data, which helps to evaluate the influence of running slice services concurrently. Such data may be stored in the common database and accessible to all UCs while they run their own data analysis.
- Resource requirements: each E2E test consumes resources on storing and communicating the measurement data. When multiple UCs run concurrently, the workload on the testing platform will increase. It is important to make sure that all testing results are reliable and not impacted by the lack of resources during the run-time operation.
- Orchestration requirements: when multiple UCs run simultaneously, their corresponding test cases also run simultaneously. If application level testing is involved, an orchestration and scheduling scheme is needed to coordinate with each LL to schedule the test cases and collect the data for each LL testing facility and the ICT-17 testing platforms.

5.5.3 Target KPIs & SLAs Values

In the MLL, each participating UC can define and measure its own KPIs in the same/similar way as in the individual LL. On top of that, MLL defines additional KPIs to account for the impact of running UCs concurrently. The following KPIs are under consideration:

- The time (response delay) of activating all UCs in one MLL-UC. It is interesting to investigate how the overall response delay varies with the number of UCs and the mixing criteria.
- The success and failure rate of activating UCs in the concurrent mode. This KPI is complex and has to be analyzed in different contexts, e.g., the relevance to the mixing criteria.
- The percentage of UCs whose SLA/KPIs are met in the concurrent mode. Again, this KPI relies on the mixing criteria.
- The percentage of KPI violation for UCs whose SLA/KPIs are not met in the concurrent mode
- The traffic load that can be carried by each UC in the concurrent mode. This KPI acts as a reference for a fair comparison of UC KPIs in the "stand-alone" mode and the "concurrent" mode.
- The number of UEs that can be supported by each UC in the concurrent mode. Similar to the traffic load, this KPI is also used as a reference for a fair comparison of UC KPIs in the "stand-alone" mode and the "concurrent" mode.
- The KPI difference between the "stand-alone" mode and the "concurrent" mode for all constituent UCs. Note that a fair comparison will take into account the impact of traffic load and number of supported UEs.
- Flexibility

6 KPIs Visualization System

This section provides a brief description of the KPI visualization system and its core components that will be designed and implemented throughout the project. A detailed description will be provided within the scope of deliverable D.3.1.

The KPI visualisation system is a data collection and presentation medium that supports the visualization of the KPIs resulting from the experiments taking place within the scope for the project. It is responsible for the entire flow of calculating and visualizing the KPIs. The basic requirement here is for the necessary data to be available for use by the 5G facilities and the various applications.

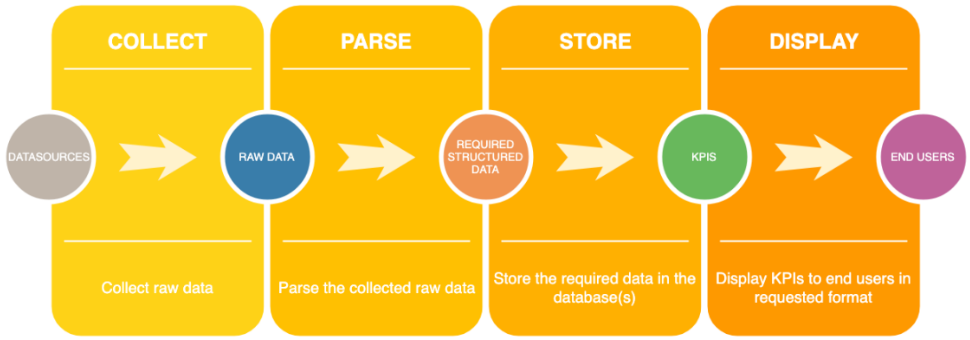

Figure 30: KPIs Visualization System Flow Diagram.

Below, we present a brief description of the basic modules comprising the 5G visualisation system.

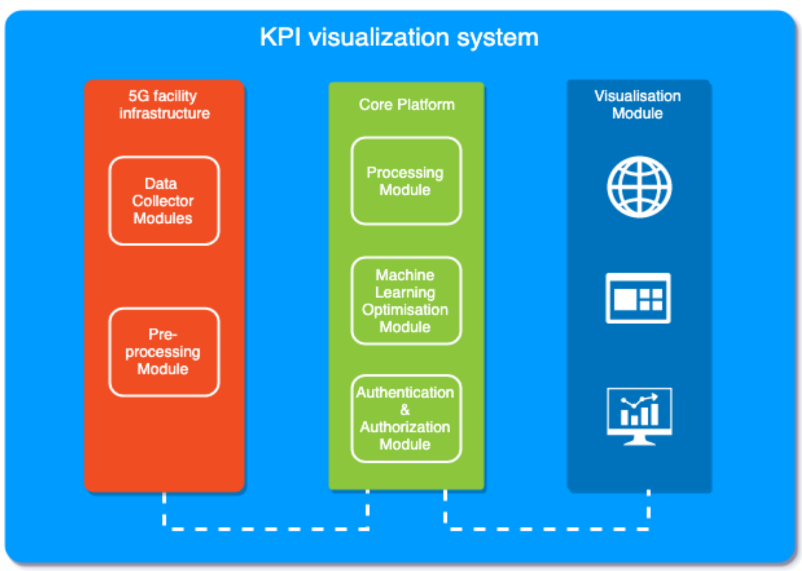

Figure 31: Modular Architecture.

- **Data collector:** Module for collecting data from all the available data sources (5G facilities, use case applications etc.). This has not been yet defined however it can be file based, a REST API, a remote DB query etc. The decision for each integration will be based on the amount of data transferred and the API available from the other side.

- **Data parser:** Responsible for parsing of the data collected from the various data sources. Depending on the amount of data transferred in each case and therefore the large amount of bandwidth required, there may be some pre-processing taking place in the facility infrastructure before the data is transferred to the KPI visualization system. Though outside the core infrastructure of the KPI visualization system, this pre-processing module is part of the overall visualization system.

- **Machine Learning algorithms:** Depending on the KPIs required, some machine learning models may be designed and trained to forecast desired values of specified KPIs. The KPI visualisation system will integrate with the platform hosting these algorithms.

- **Authentication & Authorization module:** All users within the KPI visualization system will be authenticated and authorized. Authentication will occur through a login process where the user will have to enter his credentials acquired through a registration process. Once the user is authenticated, he can perform specific actions based on his role and access rights. This is the responsibility of the authorization module to ensure that every action can be performed by a specific subset of users.

- **Visualisation module:** This is the front-end module the end user will interact with. Once authenticated, the user will be able to navigate to the use cases that are of interest to him. There he will need to provide the necessary filters for the experiment he wants to visualize the KPIs for. Once all the necessary information is provided, the KPIs are calculated and displayed to the user in the desired format (tabular and plot(s)) that provide valuable technical and business insights such as geographic maps, heat maps, fever charts, pie charts etc. Plots can have interactive capabilities to allow users to drill into details for their analysis. Predefined alerts can also be displayed when certain values are reached.

7 Conclusions and Next Actions

In this deliverable the project consortium analysed all those UCs, within the 5G-SOLUTIONS project scope, that are expected to shape the future of 5G networks and applications. This analysis resulted in identifying the stakeholders and the roles of those in each UC, the objective of each UC, the requirements from the stakeholders, the technical and business KPIs and the required targets of those KPIs and the measurements that have to be taken. The use case analysis has taken into account the most recent recommendations on the 5G use cases and KPIs from the 5G-PPP perspective. The classification of the use cases based on the 5G-PPP recommendations has also shaped the recommended methodology for identifying the use case requirements and relative KPIs.

The identification of the use case requirements as well as the technical and business KPIs is a stepping stone for the project, since it feeds other critical tasks, and points out the technological enablers for facilitating the execution of the field trials. To this end, the use cases will be validated towards their conformance to target 5G KPIs, as well as their business potential, ethical and social acceptance. This deliverable defined in a clear and solid way the KPIs, their target values and the measurements that have to be provided, in order to prove and validate that the 5G technology can provide prominent industry verticals with ubiquitous access to a wide range of forward-looking services with orders of magnitude of improvement over 4G.

Requirements' capture process in this deliverable, aimed at documenting the end-users (stakeholder) needs about the new innovative vertical use cases that require 5G performance capabilities in the domains of Factories of the Future, Smart Energy, Smart Cities, IoT, Media & Entertainment. Those use cases and the relative scenarios have been mapped to specific target KPI and SLA values (e.g. throughput, mobility, latency, density, reliability, positioning accuracy, coverage, service provisioning time, QoS, QoE, etc.), which set the baseline for conducting the actual measurements during the field trials.

This deliverable will be updated (D1.1B), so that more specific formulas and measurements are given, which will feed WP3 towards the field trials execution and evaluation of the use cases. This update will be based on the feedback form other project tasks, related to the field trials deployment.

8 References

[1] 5G; Management and orchestration; 5G end to end Key Performance Indicators (KPI) (3GPP TS 28.554 version 15.0.1 Release 15).

[2] 5G Programmable Infrastructure Converging disaggregated network and compUte Resources (5G PICTURE), D2.1 5G and Vertical Services, use cases and requirement, January 2018. https://www.5g-picture-project.eu/download/5g-picture_d21.pdf

[3] Draft new Report ITU-R M. [IMT-2020.TECH PERF REQ] - Minimum requirements related to technical performance for IMT-2020 radio interface(s), February 2017. https://www.itu.int/dms_pub/itu-r/md/15/sg05/c/R15-SG05-C-0040!!MSW-E.docx

[4] 5G White Paper, By NGMN Alliance, 17-February-2015.

[5] NovaGo Service http://www.nova.gr/gr/upiresies-gia-to-spiti/prosthetes-upiresies-/nova-go/

[6] Novaflix service https://www.novaflix.gr/en

[7] Argos, Measuring the video stream quality, https://lab.irt.de/argos/

[8] 5G Metro haul, D2.1 Definition of Use Cases, Service Requirements and KPIs, February 2018. https://www.5g-picture-project.eu/download/5g-picture_d21.pdf

[9] 5G-TRANSFORMER Project, D5.3 Experimentation results and evaluation of achievements in terms of KPIs. http://5g-transformer.eu/wp-content/uploads/2019/06/D5.3_Experimentation_results_and_evaluation_of_achievements_in_terms_of_KPIs.pdf

[10] 3GPP TS 28.554 version 15.0.1 Release 15, 5G; Management and orchestration; 5G end to end Key Performance Indicators (KPI). https://www.etsi.org/deliver/etsi_ts/128500_128599/128554/15.00.01_60/ts_128554v150001p.pdf

[11]5G-TANGO, D7.1 Evaluation strategy and testbed setup report, June 2016. http://5gtango.eu/documents/D71_v1.pdf

[12]5G-XHaul, D2.2 System Architecture Definition, July 2015. https://www.5g-xhaul-project.eu/download/5G-XHaul_D2_2.pdf

[13] 5G-TRANSFORMER Project, D1.2 5G-TRANSFORMER Initial System Design. http://5g-transformer.eu/wp-content/uploads/2018/05/D1.2_5G-TRANSFORMER_Initial_System_Design.pdf

[14] Annex 1 – ref1] Annex 1 - Description of Action (part B), Section, Use Case 4.1: Ultra High-Fidelity (UHF) Media, Page 39.

[15] [Annex 1 – ref2] Annex 1 - Description of Action (part B), Section, Table on Page 42.