H2020 5G-TRANSFORMER Project

Grant No. 761536

Report on vertical requirements and use cases

Abstract

This deliverable reports on the set of identified use cases and the initial requirements coming from vertical industries that are considered relevant for the project. It also analyses key project performance indicators and how they relate to the ones identified by 5G-PPP.

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List of Contributors

Partner Short Name	Contributors
UC3M	Carlos J. Bernardos, Jaime Garcia, Antonio de la Oliva
NEC	Andres Garcia Saavedra, Xi Li
TEI	Paola Iovanna, Teresa Pepe
ATOS	Maria Rubiales Mancheño, David Salama Osborne, Jose Enrique González, Juan Brenes Baranzano
NOK-N	Thomas Deiß
IDCC	Alain Mourad, Charles Turyagyenda
TID	Luis Miguel Contreras Murillo
ORANGE	Thouraya Toukabri, Philippe Bertin
CRF	Giuliana Zennaro, Aleksandra Stojanovic, Armonia Di Biase, Marina Giordanino, Michele Provera
SAMUR	Francisco Javier Quiroga, Fernando Ferreras
BCOM	Cao-Thanh PHAN
NXW	Giada Landi, Marco Capitani
CTTC	Josep Mangues
POLITO	Carla Chiasserini, Claudio Casetti
EURECOM	Adlen Ksentini
ITRI	Chia-Lin Lai

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List of Acronyms

Acronym	Description
3GPP	Third Generation Partnership Project
5G PPP	5G Public Private Partnership
aaS	as a Service
AGC	Automatic Generation Control
AGV	Automated Guided Vehicle
BER	Bit Error Rate
BPON	Broadband Passive Optical Network
CAPEX	Capital Expenditure
OPEX	Operative Expenditure
CDN	Content Delivery Network
CPRI	Common Public Radio Interface
CRM	Customer Relationship Management
CSA	Coordination and support Action
CSC	Communication Service Customer
CSP	Communication Service Provider
C-V2X	Cellular Vehicle-to-Everything (C-V2X)
DCSP	Data Centre Service Provider
DetNet	Deterministic Networking (IETF)
DMS	Distribution Management System
E2E	End-to-end
HER	Electronic Health Record
EPC	Evolved Packet Core
ETP	European Technology Platform
ETSI	European Telecommunications Standards Institute
FLISR	Fault Location Isolation and Service Restoration
HMI	Human Machine Interface
ICT	Information and Communication Technology
IEEE	Institute of Electronics and Electrical Engineering
IETF	Internet Engineering Task Force
IMT	International Mobile Telecommunications

IoT	Internet of Things
IP	Internet Protocol
IPR	Intellectual Property Rights
IRTF	Internet Research Task Force
ISG	Industry Specification Group (ETSI)
IT	Information Technology
ITU-T	International Telecommunications Union - Telecommunications standardization sector
GMS	Game Management System
KPI	Key Performance Indicator
LMR	Land Mobile Radio
LTE / -A	Long Term Evolution / -Advanced (3GPP)
MANO	Management and Organization
MCPTT	Mission Critical Push To Talk
MEC	Multi-Access Edge Computing
MME	Mobility Management Entity
MNO	Mobile Network Operator
MTP	Mobile Transport and Computing Platform
MVNA	Mobile Virtual Network Aggregator
MVNE	Mobile Virtual Network Enabler
MVNO	Mobile Virtual Network Operator
NaaS	Network as a Service
NEP	Network Equipment Provider (NEP)
NFV	Network Functions Virtualization
NFVRG	NFV Research Group (IRTF)
NGMN	Next Generation Mobile Networks
NOP	Network Operator
NSO	Network Service Orchestration
OBSAI	Open Base Station Architecture Initiative
ODL	OpenDayLight
OEM	Original Equipment Manufacturer
OF	Open-Flow (ONF)
ONF	Open Networking Foundation

OPNFV	Open Platform for NFV
OTT	One Trip Time
PCRF	Policy and Charging Rules Function
PMC	Probability of Missing Command
PoP	Points of Presence
PTP	Precision Time Protocol
PUC	Probability of Unwanted Command
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RHB	Right Holder Broadcasters
RO	Resource Orchestration
SCF	Small Cells Forum
SDN	Software Defined Networks
SDNRG	SDN Research Group (IRTF)
SDO	Standard Development Organization
SO	Service Orchestrator
S-/P-GW	Serving / Packet Gateway
SLA	Service Level Agreement
SME	Small Medium Enterprise
Sync-E	Synchronous Ethernet
TDM	Time Division Multiplexing
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to Everything
VAS	value-added services
vEPC	virtual EPC
VISP	Virtualization Infrastructure Service Provider
VNF	Virtual Network Function
VRU	Vulnerable Road User
VS	Vertical Slicer
WG	Working Group
WPF	Wind Power Farm

Executive Summary

The 5G-TRANSFORMER project aims at evolving mobile transport networks toward more flexible and scaling SDN/NFV based transport and communication infrastructures supporting diverse vertical industries. It is expected that 5G-TRANSFORMER enables vertical industries to meet their service requirements within customized slices; and aggregates and federates transport networking and computing fabric, from the edge up to the core and cloud, to create and manage slices throughout a federated virtualized infrastructure.

The scope of this deliverable, which is the first document of WP1, is to describe the Vertical industries (Automotive, eHealth, Entertainment, e-Industry and MNO/MVNO), highlighting the peculiarities and the main characteristics, analysing use cases from different verticals, in order to derive and classify an initial set of requirements for the telecommunication infrastructure and thus guide activities related to the architecture design and the definitions of the services. The final outcome consists in a set of requirements, which will be taken as input for other tasks and the rest of the WPs.

The deliverable introduces and analyses the five Vertical industries involved in 5G-TRANSFORMER using UML design principles. The UML methodology includes needs analysis of the vertical domains, relevant actors and use cases identification, as well as detailed use cases description through Use Case and Sequence Diagrams, which allows the extraction of the usages high-level and detailed requirements.

1 Introduction

The 5G networks are envisioned as means to give rise to a wide range of vertical industries with very diverse and stringent service requirements. To enable such vision of "Internet of Everything", especially from vertical industries, the motto of 5G-TRANSFORMER project is to transform today's mobile transport network into a distributed SDN/NFV-based 5G Mobile Transport and Computing Platform (MTP) capable of simultaneously supporting an extremely diverse range of networking and computing requirements to meet the specific needs of different vertical industries.

Two technologies are being regarded as key pillars for 5G: (i) Slicing [1] enabling per slice management of virtualized resources; and (ii) Multi-access Edge Computing (MEC) [2]. While the main impact of slicing will be on the cost reduction side, MEC will enable low-delay or delay sensitive services that are not currently possible. The infrastructure sharing between different tenants enabled by slicing will highly decrease the costs of operating the network, which will be shared among different actors. In addition to slicing, MEC is the other key technology driving Operative Expenditure (OPEX) reduction in upcoming years by reducing the traffic pushed into the core networks and enabling new services, specifically low latency ones. Large scale deployment of commodity equipment (such as MEC data centres) can enable a 50% improvement in latency and geo-targeted delivery of innovative content and services at the edge, which yields a 35% cost reduction in backhaul and transmission. Network softwarization, virtualization and automation, supported by such commodity hardware, will significantly contribute to reduce both Capital Expenditure (CAPEX) and OPEX between 40- 50% [1].

Considering these two key technologies, the EU H2020 5G-PPP Phase-2 5G-TRANSFORMER project inherits the transport infrastructure of the phase-1 project 5G-Crosshaul[2], defining an integrated network that can transport backhaul and fronthaul over the same transport substrate. In 5G-TRANSFORMER, this network will be extended to better support slicing and MEC, to bring the "Network Slicing" paradigm into mobile transport networks by provisioning and managing MTP slices tailored to the needs of vertical industries (e.g., enterprise, manufacturing, media and entertainment, automotive, healthcare, etc.). In addition, it will include federation of resources from multiple domains, building on top of the research performed on the phase-1 5GEx[3], enabling a creation of end-to-end networks consisting of disjoint resources. The technical approach is twofold: (1) Enable Vertical Industries to meet their service requirements within customized MTP slices; and (2) Aggregate and Federate transport networking and computing fabric, from the edge up to the core and cloud, to create and manage MTP slices throughout a federated virtualized infrastructure.

5G-TRANSFORMER will look into new mechanisms for monetization of the new generation of networks. 5G will not focus only on the end user side facing side (i.e., the RAN), but a large part of its developments are focused on opening the door to vertical industries to use tailor-made slices for their own purposes. New revenues will be generated from providing dedicated tailor-made virtual networks to vertical industries.

[1] Core Analysis. "Mobile Edge Computing 2016," Market report, April 2016.

[2] http://5G-Crosshaul.eu/

[3] http://www.5gex.eu/

In addition, 5G-TRANSFORMER will offer the possibility of hosting over-the-top applications in the network, leveraging time proximity and context information exposed by the network. This represents a unique value which can be exploited for revenue generation by operators and application service providers alike, thus creating new value chains.

1.1 Organization of the document

In this deliverable, 5G-TRANSFORMER introduces five Vertical industries with specific topics covered in 7 sections that are as follows:

1. Introduction
2. Vertical Domains
3. Use Cases
4. High-level Requirements
5. Vertical Applications for 5G-T
6. Analysis of KPIs
7. Conclusion

In the introduction of every section, a methodology is defined and elaborated by each vertical industry.

In the rest of the current Section 1, the key concepts and challenges, as well as the relationship of 5G-TRANSFORMER with other European projects and its Innovation potential (the main technical innovations identified for each of the key modules of the project) are presented. This section mainly elaborates the 5G-TRANSFORMER business ecosystem, the identification of traditional and potential new stakeholders, and the basic relationships among them. The primary references for initiating this analysis are 3GPP and NGMN.

In Section 2, a general overview of each Vertical industry is introduced, along with the main characteristics, possible scenarios, involved actors and their peculiar demands which 5G emerging technology could potentially solve. The aim of this section is to provide a clear picture of all the needs that are specific to a particular vertical industry, describing the key innovation areas that need to be advanced, and thus provide the basis for further consideration of addressing them in the following sections.

Section 3 contains general descriptions of the Use Cases that are addressing the main needs derived from each vertical domain, introduced in Section 2. In this section, representatives from all Vertical industries involved in this project provide their vision on how 5G will enable the development of new Use Cases mapped in three clusters: Mission Critical Services, Massive IoT and Enhanced Mobile Broadband.

In Section 4, general requirements and the key performance indicators (KPIs) are defined. Each vertical industry has its own specific requirements, deriving from the set of identified use cases, both Functional (e.g. latency, reliability, availability) and Non-Functional. These requirements are elaborated addressing expectations of scenarios mentioned in the previous sections. The final goal is to illustrate how 5G will be able to process significantly different requirements contemporary.

Section 5 covers description of five Use Cases, selected for an in-depth study, that will be possible candidates for the final demonstration. The aim of each of the five Verticals is to provide a detailed description, as well as a concrete requirements list. Additionally, early performance evaluation approaches are defined, in order to give a starting point for the upcoming WPs. D1.2 will present a more advanced analysis of these use cases and their technical requirements on the system design, and D5.1 will provide a description of how use cases will be deployed for demonstration and validation.

Section 6 presents 5G-PPP KPIs relevant to the 5G-TRANSFORMER project. This section first provides an initial qualitative assessment of the relevance of each of these KPIs in relation to the planned contributions in the project, classified into performance, societal, and business related KPIs.

Finally, Section 7 provides a summary of the work done in this deliverable through some key conclusions.

This document will be used as an input for the remaining tasks in the 5G-TRANSFORMER project, mainly the D1.2 deliverable that will present a more advanced analysis of the system design that and a description of the high-level architecture of 5G-TRANSFORMER.

1.2 5G-TRANSFORMER initial draft architecture

The initial architecture concept of 5G-TRANSFORMER was presented and described in the DoA. Although it is not in the scope of this deliverable, it is depicted in Figure 1 and described here briefly for clarity in order to provide a background on the work gathered along this document for the different vertical domains. In particular, some vertical use cases may mention or refer to some of the key blocks defined in the DoA architecture. Yet, the detailed work on the architecture as well as on the different blocks will be made in D1.2 and in the corresponding deliverables in WP2, WP3 and WP4.

According to the initial description outlined in the DoA, the 5G-TRANSFORMER architecture will be built around the three following main blocks:

- **Vertical Slicer (VS):** It is a common entry point for all vertical industries into the 5G-TRANSFORMER. It coordinates and arbitrates vertical slice requests for the use of networking and computing resources. Slices are requested at the VS through an intuitive, yet powerful interface using templates or blueprints with simple interconnection models, thus relieving the vertical industry from specifying their slice details. The motivation is to provide a common methodology to the definition of slices from vertical industries enabling easy-to-use mechanisms to deploy the requested slice in a short time-scale. The VS is therefore in charge of mapping the high-level requirements and placement constraints of the slice template into a set of one or more V(N)F graphs and service function chains (SFCs), hiding thus the complexity of the system to the vertical consuming the slice.
- **Service Orchestrator (SO):** It is the main decision point of the system. It manages the allocation and monitoring of all virtual resources to all slices (from vertical industries and others, such as MVNOs). Depending on slice requirements and network context, the SO will interact with other SOs to take decisions on the end-to-end service (de)composition of virtual resources and their most suitable execution environment.

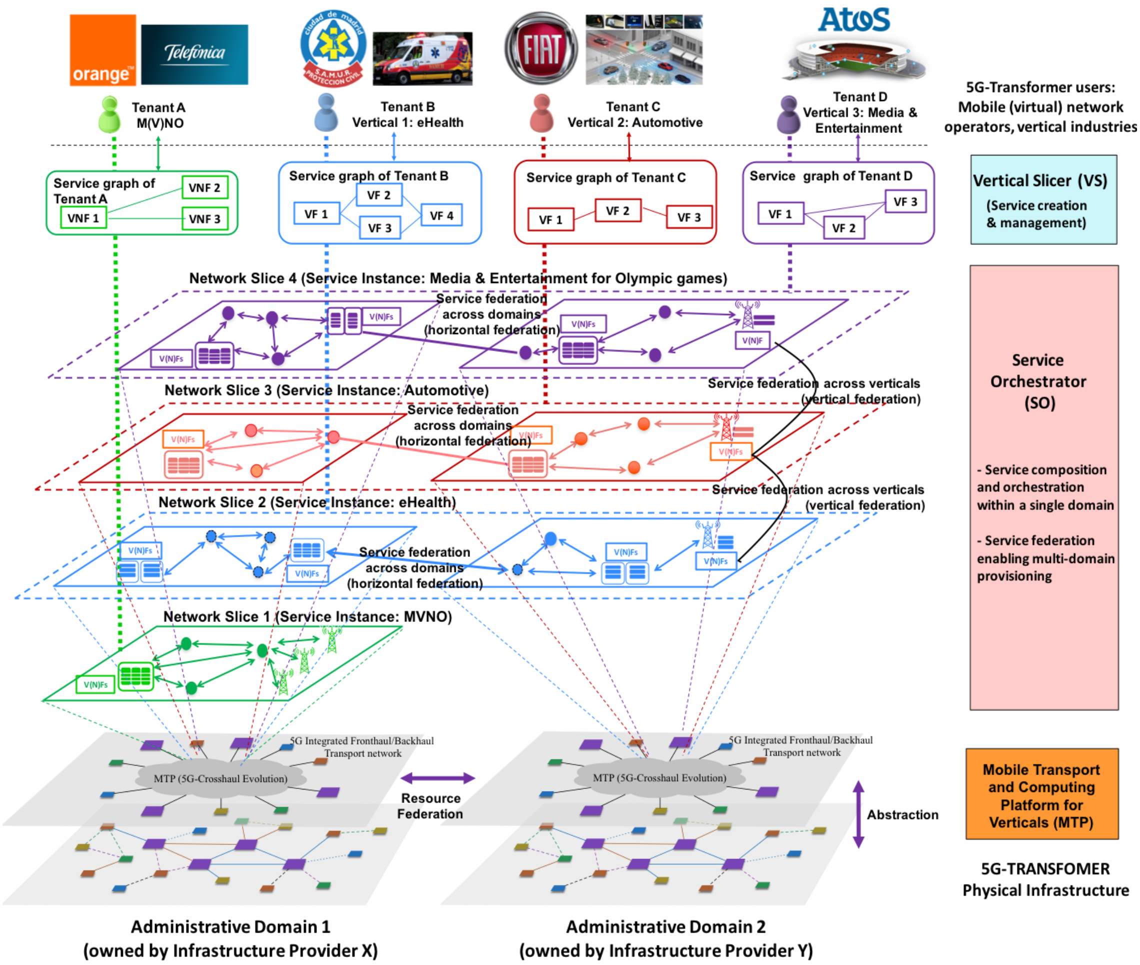


FIGURE 1: 5G-TRANSFORMER INITIAL DRAFT ARCHITECTURE CONCEPT

- **Mobile Transport and Computing Platform (MTP):** It manages the underlying physical mobile transport network and computing infrastructure. It evolves the 5G-Crosshaul solution to integrate MEC resources from multiple domains, and provide support for 5G-TRANSFORMER slicing concept. It enforces slice requirements coming from the SO and provides physical infrastructure monitoring and analytics services. For example, if it detects that the requested slice requirements from the SO cannot be fulfilled with current 5G-Crosshaul network configuration in a given area, it might decide to deploy a different configuration for 5G-Crosshaul network in that area.

1.3 Ecosystem and Stakeholders of 5G-TRANSFORMER

The 5G-TRANSFORMER approach will allow manufacturers, solution integrators, network and service providers, and Small Medium Enterprises (SMEs) to enter the market, by reducing the entry barrier through virtualization and standardized interfaces based on open APIs or protocols. SMEs will be able to provide technological solutions which will be compatible with the overall system, e.g., new hardware components in the infrastructure or software components in the Management and Organization (MANO) layers. Manufacturers and solution integrators could use the quick deployment enabled by the virtualization and the standardized interfaces to increase the level of innovative solutions popping up in the market. Mobile Network Operators (MNOs) and infrastructure providers will open the door to vertical industries to create tailored slices for their specific functionalities and requirements. With this, they will gain new sources of revenue from providing dedicated tailored virtual networks to vertical industries and from offering Over-The-Top applications in the network, while reducing capital and operational expenditures (i.e., CAPEX and OPEX) leveraging on the multi-tenancy paradigm enabling more efficient resource management and sharing.

This section elaborates on the 5G-TRANSFORMER business ecosystem including identification of traditional and potential new stakeholders, and basic relationships among them. Two primary references are used to initiate this analysis: the 3GPP [3] and NGMN ([4], [5], [7]).

1.3.1 Ecosystem and stakeholders in 3GPP

3GPP is defining a number of business roles to be participant of the next generation network services. These roles are:

- Communication Service Customer (CSC): stakeholder that demands communication services.
- Communication Service Provider (CSP): actor providing communication services. It has the capability of designing, building and operating its communication services to be offered to CSCs.
- Network Operator (NOP): actor that provides network services. It has total responsibility for designing, building and running its networks to offer such services.
- Virtualization Infrastructure Service Provider (VISP): this stakeholder provides virtualized infrastructure services, including virtual networks. This actor designs, builds and operates its virtual infrastructure(s). The VISPs may also offer their virtualized infrastructure services to other types of customers including to CSPs directly, i.e. without going through the NOP.
- Data Centre Service Provider (DCSP): actor which provides data center services, taking care of designing, building and operating the data centers under its responsibility.
- Network Equipment Provider (NEP): stakeholder representing the suppliers of network equipment. In 3GPP the VNF Supplier is considered as a kind of NEP.
- NFVI Supplier: this actor supplies network function virtualization infrastructure to its customers.
- Hardware Supplier: stakeholder that supplies hardware.

Some of these roles could be played by the same organization. Figure 2 shows graphically the relationships among all these actors.

According to 3GPP, in addition to the role relationships shown in the figure, there could also be relationships between non-neighboring roles in the diagram. Furthermore, network operators may also base their offering not just on virtual infrastructure, but also on physical infrastructure. Additionally, some of the above roles may be combined into a single organization.

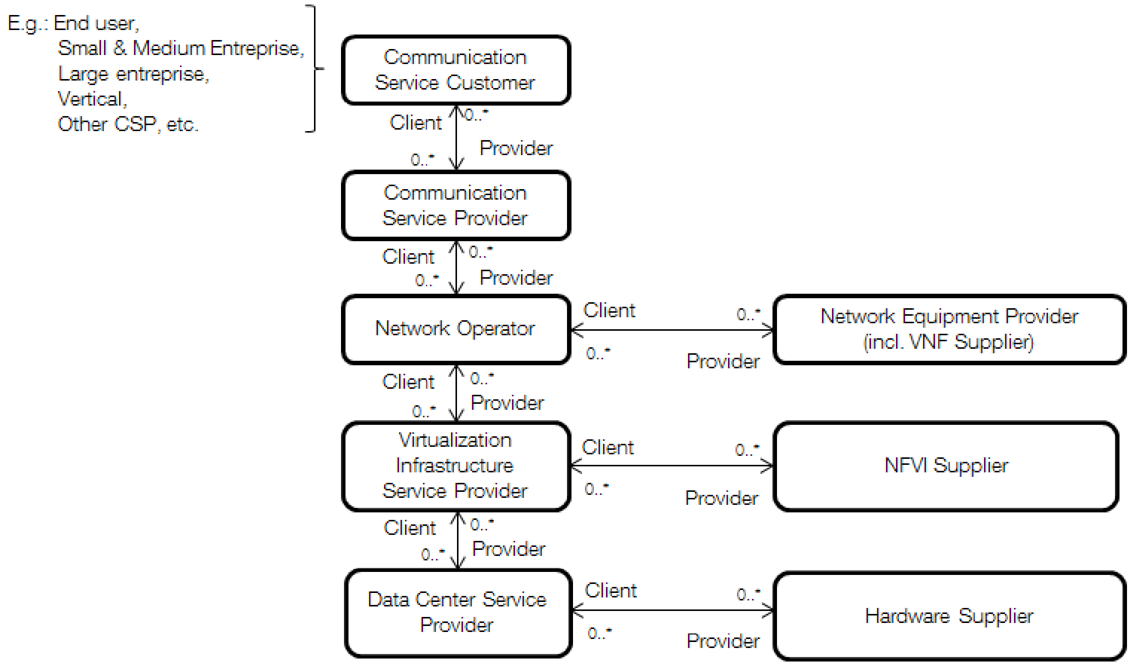


FIGURE 2: ROLE MODEL OF 3GPP [3]

1.3.2 Ecosystem and stakeholders in NGMN

NGMN has also defined a number of roles and envisioned business models [4], [5], [7]. These are presented in Figure 3.

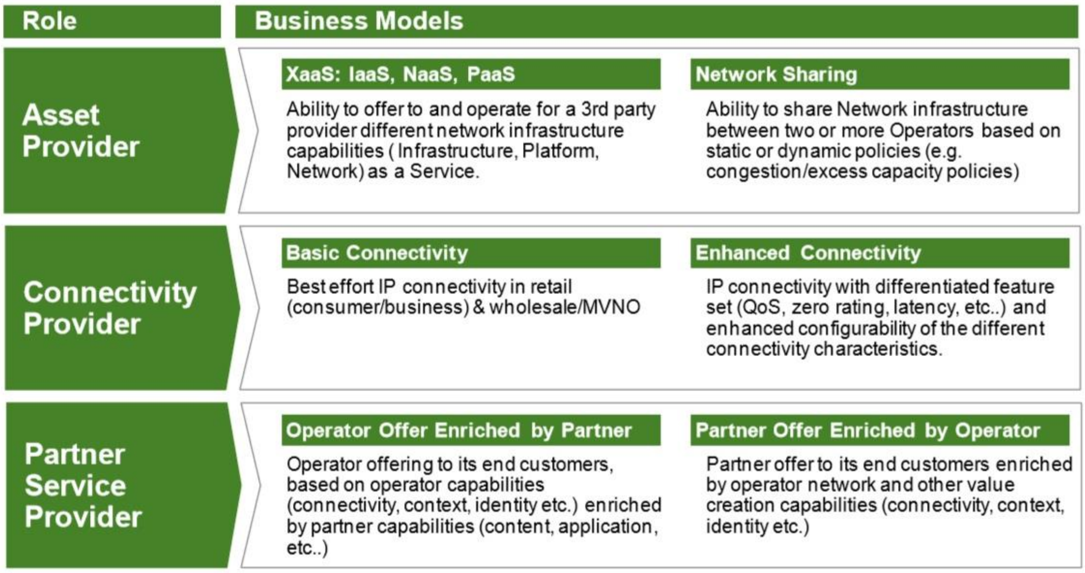


FIGURE 3: NGMN ROLES AND BUSINESS MODELS [7]

The Asset Provider acts as provider of infrastructure with the required capabilities for provisioning and operating such infrastructure at different levels, like Infrastructure, Platform or Network as a Service. A step beyond goes in the direction of enabling the sharing of such infrastructure based on policies.

The Connectivity Provider role provides connectivity, either basic Best Effort or with enhanced-differentiated capabilities. Basic connectivity is considered for wholesale/MVNO as well as retail customers. On the other hand, enriched connectivity is considered to extend the existing business models by providing enhanced connectivity, in terms of performance, flow differentiation and configurability for supporting the emerging 5G services.

Finally, the Partner Service Provider envisions two variants. The first variant directly addresses the end customers of an operator, where the operator provides integrated service offerings based on operator capabilities (connectivity, context, identity, etc.) enriched by content and specific applications offered by partners (like 3rd party OTTs). The second variant empowers partners (3rd parties / OTTs) to complement their own offer to the end customers by considering the capabilities of a network operator. Example of both variants could be video streaming service in the first case, and remote health monitoring in the second.

1.3.3 Gaps in 3GPP and NGMN ecosystem modeling with respect to 5G-TRANSFORMER

After reviewing both 3GPP and NGMN propositions, it becomes evident that multi-domain aspects are not sufficiently covered. In other words, the models in [3] and [4] focus on single domain service provision. It is then required to incorporate the multi-domain dimension into those models.

To this respect, [5] introduces the notion of partnership between two providers, where one (named P-Hosted) provides a slice to a customer, and negotiate with another provider (named P-Hosting) for complementing such offering with the setup of a complementary slice (or sub-slice) using functions and resources from the hosting domain for globally composing the final slice offered to the customer. This multi-domain scenario is similar to the one ambitioned by 5G-TRANSFORMER, and should be integrated into the project ecosystem and stakeholders modelling.

Additionally, the roles defined by 3GPP are mostly focused on communication services, and so, are defined from the point of view of an operator. On the other hand, more flexible relationships are considered by NGMN (e.g., operator-enhanced partner offerings). Since the focus of 5G-TRANSFORMER is to serve vertical industry needs, which may be diverse, and not just, communication service-oriented, the more flexible approach offered by NGMN better reflects the various possible customer-provider relationships between verticals and operators.

1.3.4 Mapping 5G-TRANSFORMER components to 3GPP and NGMN models

The differentiation of actors done by 3GPP will be taken as reference for defining the 5G-TRANSFORMER stakeholders. 5G-TRANSFORMER defines in its early high-level architecture three basic components: the Vertical Slicer, the Service Orchestrator, and the Mobile Transport Platform (briefly introduced and described in sub-section 1.2). It is then necessary to match the 3GPP actors to the 5G-TRANSFORMER components to further developing the functional architecture of the project driven by this ecosystem.

At the time of mapping components to actors it is necessary to differentiate two different levels of orchestration, as defined by [6]: Network Service Orchestration (NSO) and Resource Orchestration (RO). Both levels of orchestration have different scope. The NSO is responsible for the lifecycle management of a Network Service, e.g., the decision on the sequence in which VNFs are created. On the other hand, the RO is in charge of coordinating the resources necessary for creating the service.

Attending to such differentiation, Table 1 represents the mapping of 3GPP and NGMN models to the 5G-TRANSFORMER high-level architecture, and helps to identify functional capabilities to be considered in each of the three main components of the project.

TABLE 1: Mapping of NGMN and 3GPP models to 5G-TRANSFORMER components

<table>
<tr><th>NGMN model</th><th>3GPP model</th><th>5G-T model</th><th>Comments</th></tr>
<tr><td>Partner Service Provider (Partner offer enriched by operator)</td><td>Communication Service Customer (CSC)</td><td>Vertical Customer</td><td>Customer external to 5G-TRANSFORMER requesting a service</td></tr>
<tr><td rowspan="2">Partner Service Provider (Operator offer enriched by partner)</td><td rowspan="2">Communication Service Provider (CSP)</td><td>Vertical Slicer</td><td>Business relationship</td></tr>
<tr><td>Service Orchestrator (NSO)</td><td>Orchestration of network services, including those in different domains, and operational isolation of customers</td></tr>
<tr><td rowspan="2">Connectivity Provider</td><td rowspan="2">Network Operator (NOP)</td><td>Service Orchestrator (RO)</td><td>Orchestration of resources, including multi-domain ones and isolation of slices</td></tr>
<tr><td rowspan="6">Mobile Transport Platform</td><td>Provision of connectivity, including transport and service nodes</td></tr>
<tr><td rowspan="5">Asset Provider</td><td>Virtualization Infrastructure Service Provider (VISP)</td><td rowspan="5"></td></tr>
<tr><td>Data Centre Service Provider (DCSP)</td></tr>
<tr><td>Network Equipment Provider (NEP)</td></tr>
<tr><td>NFVI Supplier</td></tr>
<tr><td>Hardware Supplier</td></tr>
</table>

Two of the 3GPP roles can play different (even simultaneously) functions in 5G-TRANSFORMER. The Communication Service Provider (CSP) can incorporate the function of Vertical Slicer, for honoring Customer requests of services, and at the same time, playing the role of Service Orchestrator for the lifecycle management of 5G-TRANSFORMER network services. In addition, the Network Operator Provider (NOP) can play the role of Service Orchestrator for orchestrating the resources even across multiple administrative domains, and/or the role of Mobile Transport Platform, focused on connectivity of transport and service nodes.

Furthermore, two kinds of infrastructures can be identified as relevant for the project: transport network infrastructure and computing infrastructure. The NOP can be considered to play the role of transport network (physical) infrastructure provider, while the Data Centre Service Provider (DCSP) can be considered to play the role of (physical) computing infrastructure provider. However, for the Virtualization Infrastructure Service Provider (VISP), differentiation on the type of virtualized infrastructure can be required, in order to distinguish among e.g. federation of data centres or interconnection of transport networks.

Finally, for the scope of the project, some simplifications can be done when considering the 3GPP actors falling into the NGMN Asset Provider category. A first simplification is to collapse the role of NFVI Supplier and Hardware supplier into the roles of DSCP and NOP as providers of infrastructure. The second one is to integrate the scope of Network Equipment Provider (NEP) as PNF supplier into NOP as well, since the implementation of network functions can be assumed to be an essential part of NOP.

In summary, 5G-TRANSFORMER stakeholders are defined in Table 2.

TABLE 2: 5G-TRANSFORMER stakeholders

5G-T stakeholder	5G-T component	Comments
5G-TRANSFORMER Service Customer	Vertical Customer	In 5G-TRANSFORMER, the main role considered as consumer of services is the vertical.
Service Provider	Vertical Slicer	The VS provides the one-stop shop to request services.
	Service Orchestrator	For the use case of M(V)MNO, the SO plays the role of service provider.
Network Operator - Service Orchestrator (NOP-RO)	Service Orchestrator and / or Mobile Transport Platform	Resource Orchestration capabilities can be present or not at 5G-TRANSFORMER SO component level, depending on the specific use case. According to this, a CSP could be at the same time NOP-RO if it additionally requires orchestrating resources. In any case, RO capabilities will be always needed at 5G-TRANSFORMER MTP component level.
Network Operator - Transport Platform (NOP-TP)	Mobile Transport Platform	All these roles fit into the Asset Provider category defined by NGMN. Different actors can be present in the 5G-TRANSFORMER ecosystem and they can be considered for defining the techno-economic model (business
Data Centre Service Provider (DCSP)		
Virtualization		

Infrastructure Service Provider - Transport Infrastructure (VISP-T)		model, monetary flows, etc.).
Virtualization Infrastructure Service Provider - Computing Infrastructure (VISP-C)		

2 Vertical Domains

According to [8], 5G will create an ecosystem for technical and business innovation involving vertical markets such as automotive, energy, food and agriculture, city management, government, healthcare, manufacturing, public transportation, and many more. It will serve a larger portfolio of applications with a corresponding multiplicity of requirements ranging from high reliability to ultra-low latency going through high bandwidth and mobility.

In this section, a general overview of automotive, entertainment, eHealth, e-Industry and mobile network operation (MNO) verticals are introduced. For all the domains the main characteristics, with the possible application scenarios, are presented. In each scenario, different actors are involved, with their features and their peculiar needs relating with the new emerging technologies. The final goal is to illustrate how 5G can address such new challenges.

In this section, each of the five Vertical domains is analyzed, providing the following information:

- An overview of the vertical industry that highlights the main challenging characteristics, identifying eventually different operating scenarios;
- An UML Diagram illustrating the involved actors;
- A list of high-level needs that should be addressed by the 5G technologies;
- A description of the future challenges.

2.1 Automotive

In the global context of road transport, connectivity will be a critical enabler to support the take-off of new opportunities as the advance toward higher automation levels.

The automotive industry sees two main trends with relevance for the 5G automotive vision: (1) automated driving and (2) road safety, infotainment and traffic efficiency services.

These trends pose significant challenges to the underlying communication system, as information must reach its destination reliably within an exceedingly short time frame - beyond what current wireless technologies can provide. 5G, the next generation of mobile communication technology, holds promise of improved performance in terms of reduced latency, increased reliability and higher throughput under higher mobility and connectivity density.

Both real-time safety and non-safety applications require understanding the dynamics of the network topology characteristics. Automotive domains come with several challenging characteristics:

- **Highly dynamic topology**: due to high speed of movement between vehicles, the topology is always changing.
- **High number of connected nodes**, with variable characteristics.
- **Interaction with on-board nodes**, which can be automotive sensors, or devices brought into the car, by the driver or by passengers.
- **Interaction with on-street sensors**: knowledge of street conditions and about road users can enhance the vehicle context awareness.

- **Always reliable connectivity**: safety applications must be always available, not only under cellular coverage.
- **Standardization:** cooperative applications are based on information exchanged among vehicles of different carmakers, therefore a common language is needed.

Needs and Actors of the automotive domain are correlated to the possible operating scenarios, which are strongly characterized and with their own peculiarities. For instance, as discussed in [9], the distribution of lethal vehicle crashes is different in case of urban or rural scenarios, as it is different the nature of the accident and the involved actors, shown in Figure 4.

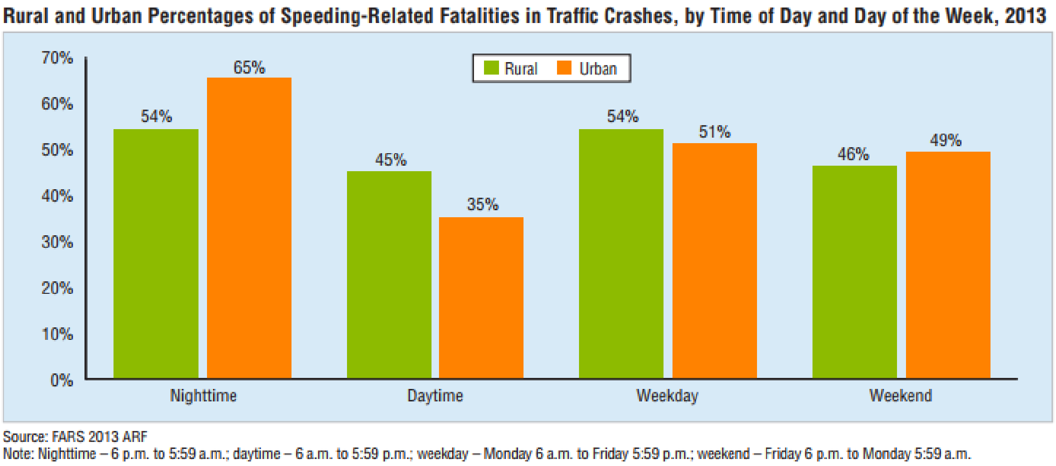


FIGURE 4: RURAL AND URBAN PERCENTAGES OF SPEEDING-RELATED FATALITIES IN TRAFFIC CRASHES

Crashes vary also according to the class of vehicles involved and the environmental context, as reported by IIHSHLDI (Insurance Institute for Highway Safety Highway Loss Data Institute) in [10], and summarized in the following Table 3.

TABLE 3: MOTOR VEHICLE CRASH DEATHS BY VEHICLE TYPE AND LAND USE

Motor vehicle crash deaths by vehicle type and land use (FARS 2015)						
	Rural		Urban		Total*	
	Deaths	%	Deaths	%	Deaths	%
Cars and minivans	6,845	52	5,402	41	13,116	100
Pickups	3,095	69	1,159	26	4,467	100
SUVs	2,716	60	1,567	34	4,560	100
Large trucks	421	70	155	26	600	100
Motorcycles	1,915	41	2,299	49	4,693	100
Pedestrians	1,160	22	3,704	69	5,376	100
Bicyclists	214	26	492	60	817	100
Total*	17,114	49	15,362	44	35,092	100

Motor vehicle crash deaths by vehicle type and land use (FARS 2015)						
	Rural		Urban		Total*	
	Deaths	%	Deaths	%	Deaths	%
**Total includes other and/or unknowns*						

To outline the automotive domain, its operating scenarios should be described and taken into account:

- Urban
- Rural
- Highway
- Transversal

In order to better analyse the needs of the automotive domain versus the incoming communication technology, this section introduces five main scenarios quite different for their peculiar features outlining the key aspects that impacts the 5G.

The summarization of all the actors that will be mentioned in the scenarios, and the relationships among them, are presented in Figure 5, Figure 6, Figure 7, Figure 8:

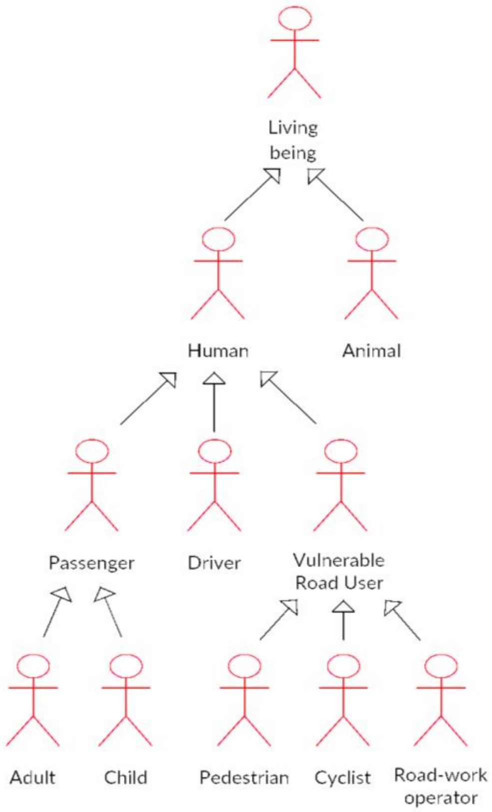


FIGURE 5: AUTOMOTIVE ACTORS - LIVING BEINGS

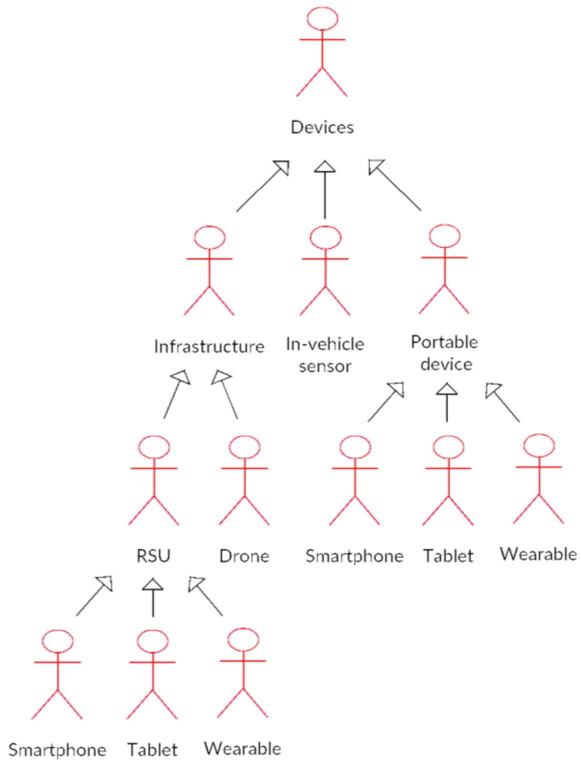


FIGURE 6: AUTOMOTIVE ACTORS - DEVICES

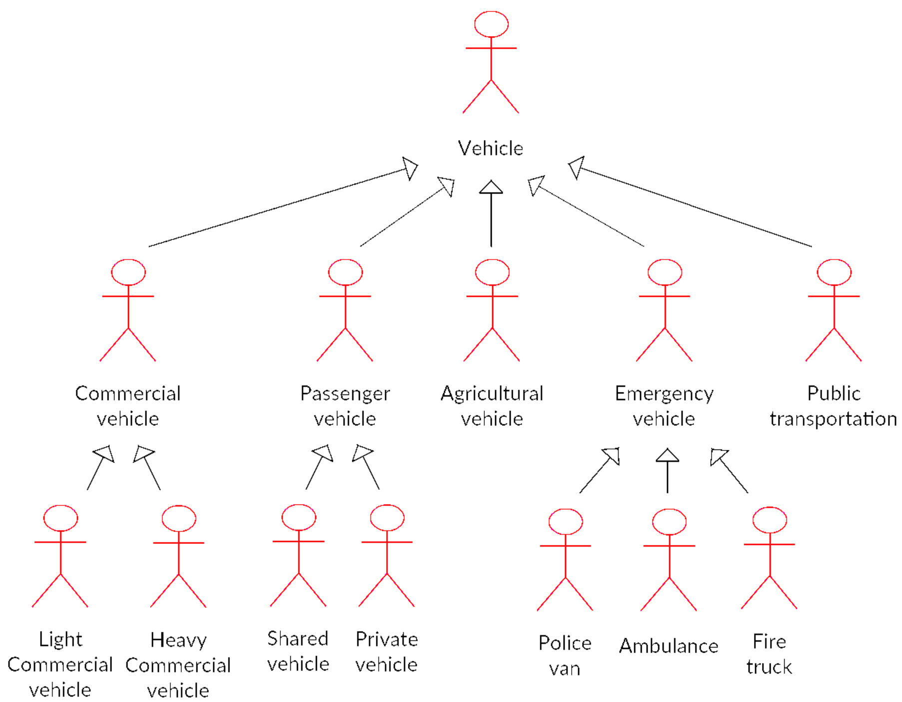


FIGURE 7: AUTOMOTIVE ACTORS - VEHICLES

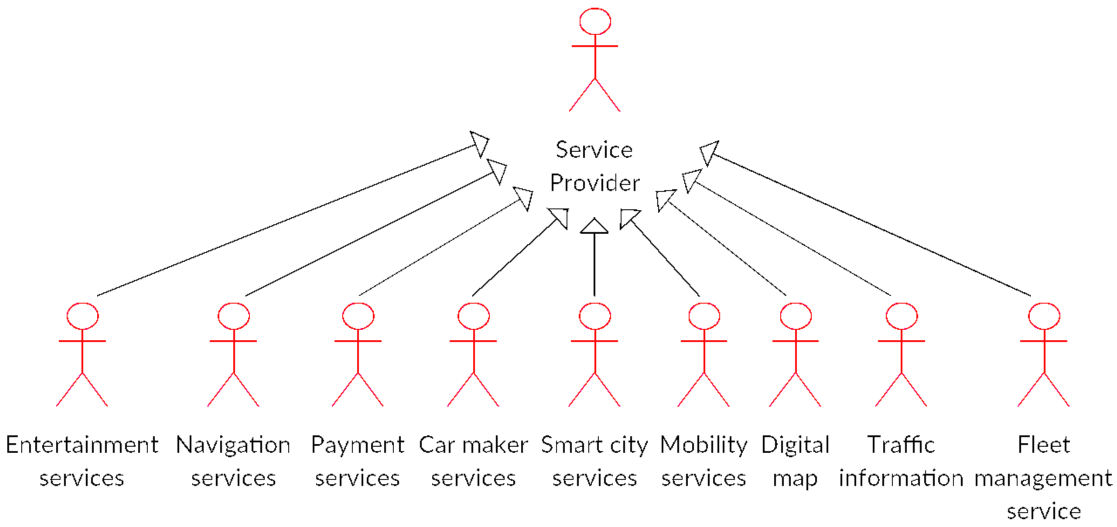


FIGURE 8: AUTOMOTIVE ACTORS - SERVICE PROVIDERS

2.1.1 Urban

As defined in the National Geographic Encyclopaedia, an urban area is the region surrounding a city. Most inhabitants of urban areas have non-agricultural jobs. Urban areas are very developed, meaning there is a density of human structures such as houses, commercial buildings, roads, bridges and railways. Many urban areas are called metropolitan areas, or "greater," as in Greater New York or Greater London. When two or more metropolitan areas grow until they combine, the result may be known as a megalopolis.

Actors of mobility in Urban environment, besides vehicles and drivers, are:

- Road users like pedestrians, bikers, cyclists.
- Public transport vehicles, like buses, trams, taxis.
- Emergency vehicles, like ambulances or fire trucks.
- Road mobility management objects, like traffic lights.
- Adult passengers (but quite often the driver is alone).
- Children or elderly people.
- Smart-city.
- Road-works operators.
- Commercial vehicles.

The road topology is composed by intersections, traffic lights, roundabouts, zebras, reserved lanes for public transportation or for bicycles; traffic flow can be very different, due to a presence of pedestrian and ZTL zones, very low speed zones (near schools for instance) and of roads with higher speed zones and less severe congestion (like in sub-urban areas). Traffic is congested in specific timeframes and specific zones; the mobility is highly impacted if any exceptional event occurs (like road maintenance); the weather events have an impact on the mobility, but less relevant than in urban/suburban zones. Industrial zones can host company headquarters, and therefore can be interested by incoming/outcoming traffic flows in specific timeframes. In general, very poor mobility information is available, but this could change in the future with the advent of smart cities. The presence of surface public transportation can slow down the traffic and introduce unexpected crossing pedestrians. Hazardous manoeuvres can be originated by the traffic congestions and could lead to low speed accidents.

Typical personal vehicle usage is for short distances and periodic paths; in any case it is linked to the working day routines. Usually the driver is alone in the vehicle or is together with a recurrent passenger (children brought to school, colleagues). The vehicle march follows a “stop&go” pattern, with frequent unexpected events. The urge to reach the destination (shops, office, primary school, etc.) brings to an impatient driving style, while being absorbed by daily duties impinges on driver’s concentration, who is often involved in a multitasking attitude. Daily duties can be performed in a short time, when the vehicle needs to be parked. The activity of searching (and paying) a parking lot is a typical urban annoying driver’s task.

Main needs of the urban scenario therefore are:

- Informed mobility.
- Lean mobility.
- Enhanced real time awareness (e.g. of vulnerable road users, other vehicles behavior or intentions, road status...).
- Path optimization.
- Convenience in parking.
- Reduction of the frequency and severity of crashes.
- Seamless and Convenient integration with daily life.
- Entertainment.
- Accessible and reactive Emergency Services.
- Economical saving.

2.1.2 Rural

As defined in the National Geographic Encyclopaedia, a rural area is an open swath of land that has less domestic or other buildings and less people. Rural areas have a very low population density. Many people live in a city, or an urban area. Their homes and businesses are located very close to one another. In a rural area, there are fewer people, and their homes and businesses are located far away from one another. Agriculture is the primary industry in most rural areas. Most people live or work on farms or ranches. Hamlets, villages, towns, and other small settlements are in or surrounded by rural areas.

Actors of mobility in Rural environment, besides vehicles and drivers, are:

- Road users like bikers, cyclists.
- Agricultural vehicles.
- Heavy Commercial vehicles, like trucks transporting dangerous goods.
- Public transport vehicles, like inter-city buses.
- Adult passengers.
- Children.
- Road-works operators.
- Animals.

The road topology is composed by very few (or not at all) intersections and roundabouts; there are larger sections with high speeds allowed, but at the same time often the presence of agricultural vehicles (e.g. tractors) slows down the traffic. Low-speed driving (or sudden stops) can occur also due to big trucks with very limited speeds (e.g. 70km/h). Extra caution is required on certain sections where the animal's road crossings are frequent. For example, collision with large wildlife or livestock animal (deer, cow) can result in major vehicle damage and serious injuries. The lack of precise mapping and bad connectivity can lead to drivers getting lost, arriving to sections where the road is closed or possibly ending up on difficult or dangerous roads. The weather eventsmay have high impact on the road conditions (e.g., snowy roads). Agricultural burning might produce smoke on the road (visibility may be suddenly reduced). In some parts, one lane per direction requires additional precautions (especially when overtaking). Roads may have many slopes and uphills that create blind spots in the route ahead. Help may be difficult to reach in the event of an accident. Speed limits vary a lot compared to urban areas. In general, maintenance of the roads is much worse than in urban/sub-urban /highway areas.

Usage of the road and of the vehicle is usually for long distances (e.g. connecting two destinations, commuters) or for daily purposes (inhabitants performing everyday tasks). The length of the journey could be relevant, and the dullness of the trip may induce drowsiness or boredom. On the other side, the panorama could be joyful and nice to be seen, and the journey could be a nice experience without any rush to reach the destination.

In summary, the main needs of this scenario are:

- Informed mobility.
- Enhanced real time awareness (e.g. of vulnerable road users, other vehicles behavior or intentions, road status...).
- Reduction of the frequency and severity of crashes.
- Entertainment.
- Accessible and reactive Emergency Services.
- Economical saving.

2.1.3 Highway

Highway scenario refers to main roads with fast-moving traffic, having limited access, separate carriageways for vehicles travelling in opposite directions, and usually a total of four or six lanes.

Actors of mobility along Highways, besides vehicles and drivers, are:

- Emergency vehicles, like ambulances or fire trucks, police.
- Highway Information Service.
- Adult passengers.
- Children.
- Heavy Commercial vehicle.
- Dangerous Goods or Exceptional size Transportation.
- Road-works operators.
- Bikers.

The road topology is typically composed by entry/exit lanes, possibly with access gates, and without any intersection (with rare exceptions). Road maintenance is high and they are suitable for high speed vehicle flows. Roads are used both for personal mobility or goods transportation; therefore, the presence of trucks can be relevant, especially in working days. Objects can fall down from trucks, and can be cause of serious accidents, especially in case of dangerous good transportation. The traffic can be intense, both in working or festive day. Close to payment gates (if they are present), long queues can be present. The infrastructure is well equipped, with sensors and with informative panels. There are zones along the road where vehicles can stop, in case of any necessity. Due to its length, the road can go across different conditions, in terms of weather or regulation (inter-state roads).

Usage of the road and of the vehicle is usually linked to high speed, for both long and short journeys. In case of short ones, the target is to reach the destination as soon as possible; in case of long ones, more options are possible, as it could be a work travel performed by a passenger car or by a truck, (trucks or employees that must reach their destination) or could be a holiday travel. Seldom the travel is thought to be pleasant.

In summary, the main needs of this scenario are:

- Informed mobility.
- Lean Mobility.
- Enhanced real time awareness (e.g. of vulnerable road users, other vehicles behaviour or intentions, road status...).
- Reduction of the frequency and severity of crashes.
- Entertainment.
- Accessible and reactive Emergency Services.
- Easiness to access to under payment services.
- Economical saving.

2.1.4 Transversal Domain

In the fast-moving world of innovation, 5G will enable new services, connect devices, and empower new user experiences to support an extreme variation in use cases which spans over a massive number of connected things. Thanks to technology evolution, the vehicle can be thought as a connected object in this world, relating it to a moving sensor.

The need to collect as much information grows day by day, in order to improve awareness and make the vehicles evolve along with technology. Therefore, with the transversal domain is intended the scenario of all collected information regarding the vehicle status, insuring continuous monitoring, processing and analysis of the vehicle and maintenance data, from the design project to the daily revision, which would be beneficial for all the involved actors.

The main actors of this domain are:

- The owner.
- The manufacturer.
- Fleet manager.
- Automobile Service Centre.
- Customers.

The owner expects to have an up-to-date vehicle with perfectly working functionalities. In that sense, the maintenance is an element of crucial importance, since it can prevent potential issues before they even occur. For example, when traveling, many people can have wrong estimation about fuel level or battery level and that can lead to unplanned shutdown of the car in the middle of the road. In order to increase availability and lifetime of the system, the owner has the need to expand its vehicle's maintenance functions, which, in the long term, can have a positive impact on the economical aspect. The owner can demand an increase of convenience in the vehicle, in according to the current driver and the mood of the moment. Furthermore, a continuous monitoring of vehicle's status can be needed, to constantly supervise vehicle's integrity (e.g. antitheft systems) or provide the exact location of the car in every moment.

The car maker is involved in the design, development, manufacturing, marketing, and selling vehicles. Hence, the manufacturer's goal is to collect as much information as possible about its vehicles and their drivers, by utilizing advanced technologies. Car makers mainly have the need to: (1) offer a higher quality product and (2) increase customers' satisfactions. More information about malfunctions and gathered statistics regarding certain vehicles models, can address the manufacturer to understand where the problems mainly arise. Manufacturers need to collect information about drivers' desires and habits, to offer more personalized contents and to understand what are the most utilized services.

Furthermore, by updating telematics vehicle components, the owners can benefit from the newest contents, which directly increases their satisfactions, that is one of the primary targets for the car maker. Since lifetime of the electronic elements is much smaller than vehicle's and it is very important to keep the vehicles in the track with the latest innovations, continuous updating is a necessity. For example, ten years ago the smartphones did not even exist, on the other side, ten years old cars are still in use.

Transport industry, involving fleet, is one of the sectors where development of the "connected world" (including the IoT) is progressing fastest. Fleet includes car rental, car sharing, company cars and any other innovation regarding smart cities transportation.
According to online encyclopaedia, fleet management can include a range of functions, such as vehicle financing, vehicle maintenance, vehicle telematics (tracking and diagnostics), driver management, speed management, fuel management and health and safety management.

The main need of any fleet is to be aware in every moment about the status of all the vehicles. Also, highlighting "bad drivers" and their dangerous habits is crucial and could help in improving fleet security. Upgraded and constant supervision is also very important, since the frequent occurrence of robberies. Car sharing management faces tremendous obstacles when collecting the vehicles that need to be maintained or returned at a specific location. For example, when the customers leave the vehicle far away from the place where it should be situated, or if there is more than one vehicle that needs to be transported. Therefore, improving overall transport efficiency is a necessity.

Different Automobile Service Centers (depending on the brand) offer a variety of services to their customers, which can facilitate maintenance of vehicles. Since the technology is evolving on daily bases, regular updates are necessary, and one of the main needs of this section is managing bug fixes and other software issues when the vehicle is far away from any Service Centre (e.g. on the trip, highway…). It is a well-known fact that performing vehicle maintenance on time, keeps vehicles on the road and running efficiently, saving both time and money. Nowadays, as a consequence of a fast lifestyle, often can happen that people forget about regular testing and check-ups about vehicles "health" and status of all the components, and by the time they notice the potential problem it can become more serious or irreparable. Also, many people can have wrong estimation (or ignorance) about oil level and the adequate time for change, which can lead to severe damage of engine.

Main needs of this domain are:

- Accessible and reactive Emergency Services.
- Accessible and reactive Maintenance Services.
- Seamless and convenient integration with daily life.
- Increase of vehicle lifetime.
- Vehicle security and control.
- Vehicle Monitoring.
- Vehicle easy pick-up.
- Economical saving.

2.1.5 Future Challenges

Evolution of IoT has affected the most automotive industry, with the introduction of connected cars. Currently, connected cars are offering just some services and entertainment opportunities, but sharing of sensor data will completely revolutionize the market, enabling new opportunities for both customers and manufacturers.

Constant increase of number of connected devices entails increasing of the demands. Experience of driving is changing, alongside deployment of new use cases. The expectation of 5G technology (with all the new wide array of possibilities that are introduced) is that it will turn cars into more comfortable and safer "connected world". Integrated cameras, sensors and other connectivity components are making IoT interesting for both, customers and car manufactures. 5G will also enable a possibility for creation of intelligent infotainment systems.

The goal is to get rid of (or decrease as much as possible) human error, therefore making the Quality of Experience (QoE) significantly convenient and safer via constant connectivity. To make it possible, high speed mobile network is also required. Cloud functionality and MEC deployment are "pushing" the performances towards perfection by bringing new solutions that will revolutionize the driving experience. One of the most important key factors is that no physical connection is needed.

As the performance (due to seamless connection) will increase, simultaneously the number of data collected from the cars will be increased. The 5G technology is introducing a new solution for data rates, ability to store, process and manage the Big data within the minimal latency.

Regarding the concern about data privacy that comes along with connected cars, there are different requirements depending upon the area of deployment. (ex. demands in America, Europe and Asia vary from region to region), but at the same time, benefits of sharing data are numerous.

Sharing generic roadway information/situation is one of the possibilities, resulting in a better driver experience.

One of the main concerns that should be resolved is how connected cars will be protected from cyberattacks. Reliability is a necessity, which requires the existence of methods for developing connected car applications.

Quick adaptation to different scenarios is also a necessity.

According to 3GPP, [11], introducing the C-V2X Transmission Mode, the whole new "world" of possibilities is emerging. The possibility of involving the pedestrians in the communication (including motorcyclists) brings out new performances and simultaneously increases and improves awareness (involvement) in a specific environment, since the constant awareness is of crucial importance.

2.2 Entertainment

Entertainment vertical is a wide topic that covers lot of areas of interest related to human entertainment and leisure. Current analysis will focus on and specific area of the entertainment domain as it is Sport Events, and especially in all related to fan interaction, known as FAN ENGAGEMENT.

The main goal of fan engagement is making the venue smart and following the fan along the fan journey. Give the fans more interaction, more engagement and make them feel like they are more part of the game than they ever could be before.

Fan Engagement is about generating interactions and emotions through contextualized content and data, as shown in Figure 9.

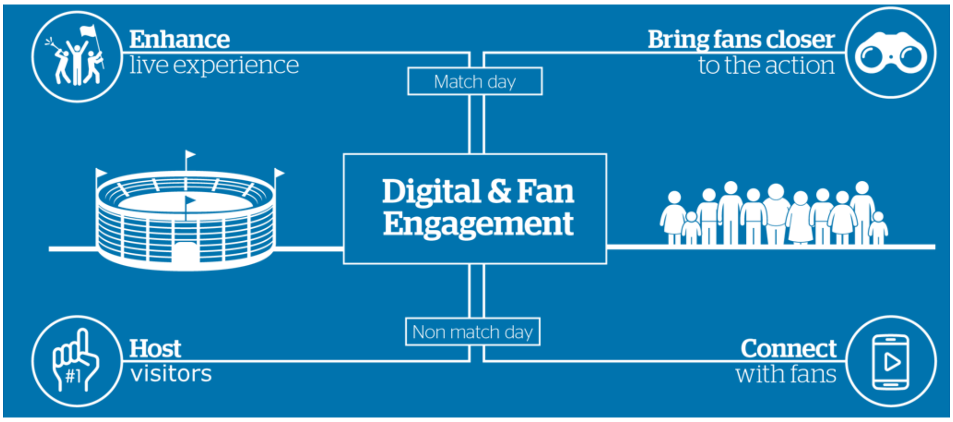


FIGURE 9: FAN ENGAGEMENT

As per today, existing technologies provides connectivity and content distribution according the following specifications in the following table.

TABLE 4: CURRENT SPECIFICATIONS (WITHOUT 5G)

	Massive video content distribution	Low latency local content
Traffic	Https (HLS)	RTSP/RTP Multicast UDP
Codec	Video: H.264 & H.265, Audio: AAC Stereo	Video: H.265 (low latency) Audio: AAC
Avg bandwidth (per user)	3 Mbit/s	4 Mbit/s
Potential source of content	Internet Base: CDN Local Cache servers: Venue	Venue cameras Low latency encoders Low latency stream servers
Latency	50 ms to 100 ms	20 ms to 50 ms
Additional miscellaneous data	XML, json, images	XML, json, images
Audience (usage dimension)	40% of the venue forum	40% of the venue forum

To meet with the coming fan expectations and content requirements, networks must evolve incrementally to higher throughput and lower latency, depending on available radio spectrum and service demands.

Many of the biggest changes in fan engagement will be driven by technology, and 5G will encourage new forms of engagement for all the actors into the ecosystem, from sport fans (on-site and remote), athletes and journalists. Sport events are the perfect showcase for how mobile can be used effectively and in a variety of ways.

To outline the automotive domain, its operating scenarios should be described and taken into account:

- Closed Venues (Stadium)
- Open Venues (Courses, Races, Olympic venues)

The summarization of all the actors that will be mentioned in the scenarios, and the relationships among them, is presented in the following diagrams (Figure 10, Figure 11):

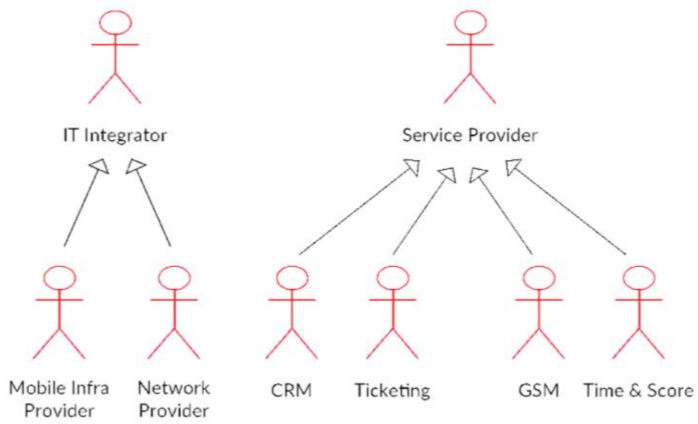


FIGURE 10: ENTERTAINMENT ACTORS - IT INTEGRATOR & SERVICE PROVIDER

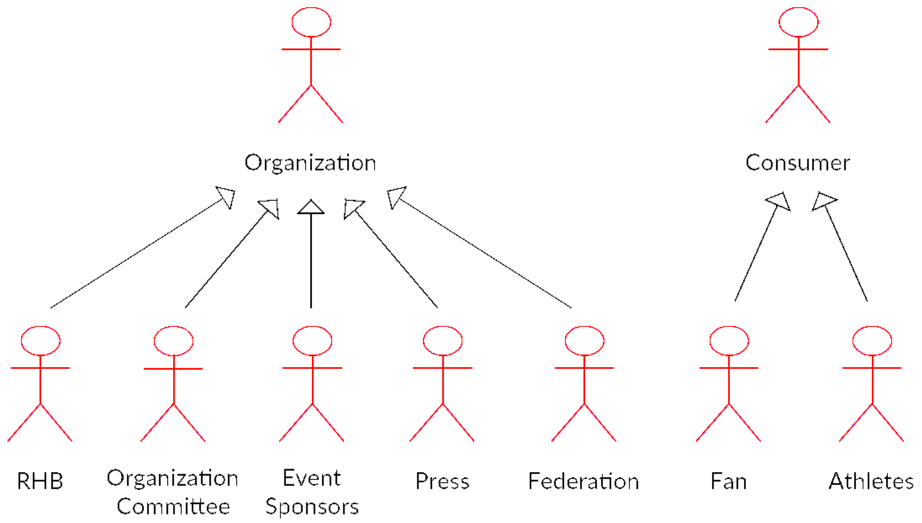


FIGURE 11: ENTERTAINMENT ACTORS - ORGANIZATION AND CONSUMER

2.2.1 Closed venues (Stadium)

Very dense urban indoor environment, where 5G users could experience services demanding extremely high data rate, such as virtual reality and ultra-high definition video in indoor environments. This scenario matches with the "Dense Urban 5G-PPP" use case family, as described in [12].

2.2.2 Open venues (Courses, Races, Olympic venues)

Open areas, where broadband access every-where with very high data rates (+50 Mbps) and low latency is required. This scenario matches with the "Broadband everywhere 5G-PPP" use case family, as described in [12].

There are several actors around fan engagement in sport environment, applying to both scenarios, closed and open venues. The key ones are:

- Sport Fans: These are the most relevant actors for the proposed UCs since they are the final consumers.
- Mobile Infrastructure provider: In the events, there could be one or more mobile operators. Currently, the clubs or venue owners collaborate with the mobile providers who deploy additional infrastructure during the events. Especially for venues within the cities, nevertheless normally there are network congestions.
- Network Provider: Depending where the event is actually hosted, there could be specific communication lines require to communicate the venues with a remote data centres and/or third parties. In our UCs, most of the services will be provided from services deployed in cloud environments.
- Main IT integrator: Organization that wins a tender and becomes the official integrator for a given event or set of events.

Other actors are:

- GMS provider: Most of the Sport Events require a Game Management System (GMS). This is an application that manage:
    - Sport Schedules.
    - Sport Entries.

  - Accreditation can be integrated in the Apps.
  - Volunteers: registration, selection, training.
  - Workforce Management.
- Organizing Committee / Organization: Organization that actually organizes the event. It could depend from a parent organization, like in the IOC and local committees. Normally this is the main customer.
- Ticketing provider: Company involved with the sales of the tickets, nowadays they target different platforms.
- Time & Scoring provider: The sport results are provided by a company or several companies that deploy data entries and/or sensors to collect and distribute the results.
- CRM provider: Large events or concurrent events are interested to have a Customer Relationship Management to support long terms revenues flows.
- Event Sponsors: Events Sponsors provides resources to the event (economic or otherwise), but normally they also participate in the business models.
- Federation: The sport federations are involved in the preparation of the event, can define the sport rules and it has a big impact on the sport consumption.
- Athletes: Besides being the most relevant actors for the sport event, they can also be consumers in a similar manner that the fans.
- Press: In all events, there is Press personnel, who cover the sport events.
- RHB: Right Holder Broadcasters personnel have on top of the Press needs, specific needs related to audio visual information, logistics to deploy cameras and communication.

Both scenarios, a stadium or an open venue, are uniquely demanding environments, especially if fans are using data-heavy apps or streaming video.

The growing adoption of smartphones and mobile content consumption has a great impact, specifically on the sports and entertainment industry. Venues, clubs, and leagues are already creating applications and social networking sites for fans to get stats, the latest scores, and highlights, and to access fantasy sports and view videos of other matches.

The concentrated increase in the use of smartphone data applications within a venue can strain the capabilities of 3G/4G networks and not only do not provide the proper fan experience, but interfere with their voice and text services.

The standard Wi-Fi networks within most of the venues are not typically designed to provide the increased coverage or capacity needed to accommodate data service offload.

Current advanced connectivity and content distribution solutions in venues are supported by High Density Wi-Fi Solutions.

The Wi-Fi network is essentially partitioned into many micro Wi-Fi cells, each supporting a given set of users. This tighter packing of micro Wi-Fi cells enables a greater number of mobile data users to be supported than conventional Wi-Fi network.

Main issue is that, in the best of the cases, every access point serves around 50 users for high-speed access, what means a huge deployment for large (even medium) size venues. The high cost of equipment (whether talking about 3G/4G or Wi-Fi) has to be amortized by smart business models adapted to each stadium. This will likely be shared between sponsorship, app revenues (additional food & beverages, ticket upgrade, merchandising…) and pure investment, what make the solution not always possible.

In addition, calibrating all the access points in a concrete bowl is an incredibly complicated task and reliability can be a problem.

Multicasting as networking technology could greatly reduce the cost of distributing over any wireless network. If a 1,000 people want to see the same content, rather than sending the same content 1,000 times, multicast will allow all 1,000 devices to register and receive a single sending of the data. Essentially it allows a one-to-many distribution of content (e.g. video) rather than having to replicate data requests from multiple users.

Reality is that no two sports fans are alike, and sports organizations should be agile in adapting and evolving to provide customize content to fans, so they have the control to select what, when and where they want to consume. Multicasting is not a fan oriented solution at all.

These new technologies will require a robust network if they are to accommodate a densely-packed environment filled with data-hungry customers. 5G has the potential to offer a cheap solution to the problem stadium's present.

Fans, hungry for media-rich content, want:

- Immersive experiences.
- High-quality content (4k/8k UHD).
- Virtual reality.
- Greater control over what they are watching.
- A clearer picture of what is happening on the field with meaningful information.
- More interactivity with friends, athletes and experts.

Therefore, main needs for a proper fan experience are:

- N1: to enable high-quality contents and services (4k8k UHD).
- N2: to ensure real time services (immerse experience, virtual reality.)
- N3: to improve fan experience closed venues (stadiums).
- N4: to improve fan experiences in open areas where fan is on mobility (courses).

2.2.3 Future challenges

Network access at anytime and anywhere is transforming the entertainment industry and has a critical impact in venue environments. 5G technology will enable flexible, reliable, and secure wireless networks to connect people with all applications, services, and things.

Key requirements can be identified from three dimensions: number of connections, latency, and throughput. These three dimensions together will bring challenges to future 5G networks:

- Number of connections. Although a 4G network provides thousands of connections for each cell, a 4G network cannot meet the connection needs of fan requirements. A 5G network provides up to a million connections per square kilometer. This will bring an exponential increase in the number of connections.

- Latency. The latency on a 4G network, 50ms, is half of that of a 3G network, however, some real-rime applications, such as augmented reality, and time-critical M2M communications, such as remote control and monitoring, will impose very stringent requirements on end to end latency. A 5G network should be able to reduce latency down to 1 ms.

- Throughput. A higher throughput will better meet fan needs. The throughput of a 4G network is 10 times higher than that of a 3G network, but once 4K video services become popular, the 4G network cannot meet the new throughput demands. 5G will bring average throughputs of 10 Gbps.

If previous requirements are met, 5G will transform the way people view and interact with live events in a number of ways, including:

- Visitors can access more immersive experiences from player perspectives to 360-degree views and behind-the-scenes content.
- Viewers can use virtual reality (VR) to enjoy live events while at home or on the move or go over immersive experiences.
- The resolution of virtual reality image and immersive video needs to approximate to the amount of detail the human retina can perceive. This requires that the throughput be 300 Mbps and above, almost 100 times higher than the current throughput supporting HD video services.
- Venue owners can use connected systems to manage visitor traffic and effectively react to emergency situations.
- Service providers can ensure they meet visitors' increased connectivity demands.
- Venue owners and service providers can access new revenue opportunities.

2.3 eHealth

eHealth can be defined as the delivering of health services by means of information and communication technologies (ICT). Some examples of services that can be provided by eHealth systems are: health information networks, electronic health record (EHR), telemedicine services, wearable and portable systems which communicate and health portals [13].

The ETSI project e-HEALTH has identified the following actors, involved in eHealth [14]: citizen, health professional and health authority. Citizens who receive health services are known as Patients, while there are different classes of health professionals: wellness professionals, paramedics, doctors, surgeons and nurses. This classification is shown in Figure 12, where it is important to highlight that some actors may represent both a human or a machine (i.e. a doctor does not need to be a human being).

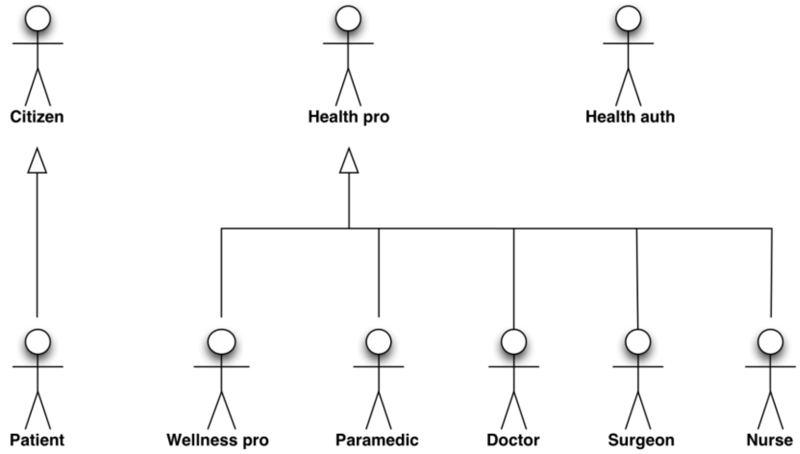


FIGURE 12: EHEALTH ACTORS

In some scenarios, the patient could delegate in other 3rd parties, extending the previous relationship as shown in Figure 13. In such cases, the health authority must validate such relationship, while some other actors, like a wellness agent, could register to such 3rd party.

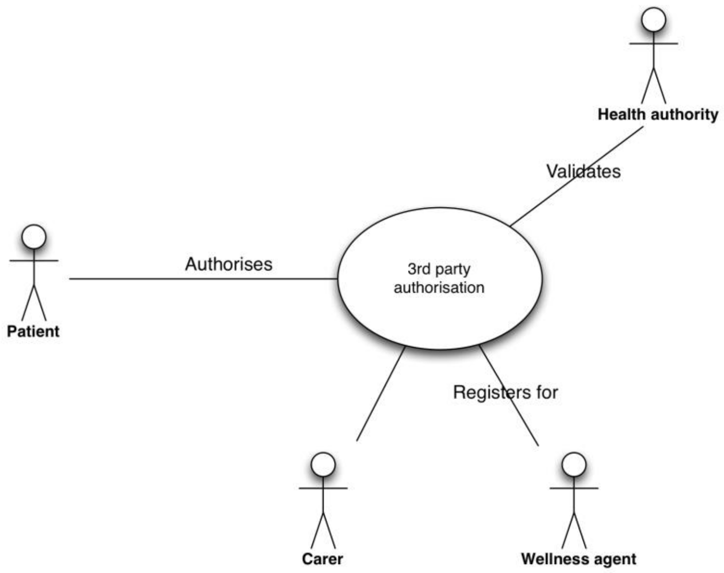


FIGURE 13: PATIENT DELEGATES TO 3RD PARTY

The main goal of eHealth is to improve the flow of information exchanged by these actors, supported by information and communication technologies (ICT). All this information will be used to update and analyse the electronic health record (EHR) of each individual patient. By following a standardized model, the EHR could be used to improve the response time when necessary: to reduce hospitalization times, to receive the necessary information in emergencies, etc.

In order to have a better view of the challenges that can be covered by eHealth, it is possible to split it in two scenarios: *static* and *mobile*. In the former, all actors are static and mobility is not an issue. In this scenario, patients could be at home or in a hospital, as well as doctors and nurses. A fix infrastructure may be deployed in these scenarios, although ad-hoc infrastructures are possible in case a fix infrastructure is too expensive to deploy. On the other hand, mobile scenarios are those where any actor can move and mobility is an important issue that has to be considered. The mobile scenario is challenging, because the communication infrastructure has to be available or deployed when necessary. In a mobile scenario, we usually talk about mHealth instead of eHealth.

The needs of the different actors can be summarized in the following, based on the aforementioned two scenarios (NSx are the needs for the static scenario and NMx are the needs for the mobile scenario):

- **Static**
  - NS1 - Health issue detection.
  - NS2 - Share EHR between actors.
  - NS3 - Remote interventions.
  - NS4 - Detect (potential) dangers for the health.
  - NS5 - Remote prescription.

- **Mobile**
  - NM1 - Health issue detection.
  - NM2 - Share EHR between actors.
  - NM3 - Remote interventions.
  - NM4 - Fast reaction after an emergency.
  - NM5 - Remote prescription.
  - NM6 - Reliable communications after disasters.

It is important to highlight that, even though there are different needs that have their counterparts in different scenarios, the requirements to satisfy each of them may be different too.

5G will address all these challenges, providing a common framework to exchange the eHealth information from patients to health professionals and vice-versa. For example, technologies like network slicing will provide dedicated networks for different eHealth services: low latency slices for remote interventions, ad-hoc secure slices to exchange private information like the EHR, deployment of ad-hoc networks after disasters or when an emergency is detected, etc. 5G technologies like MEC will help providing eHealth services when low latency is required, in emergency scenarios, for example. Device-to-device communications are also useful in emergencies, to establish communications where an infrastructure is not available.

2.4 e-Industry

New emerging technologies (e.g., mobile network, cloud computing, robotics, machine intelligence, and big data) have led to imminent changes in the industry landscape, in particular, in the production and manufacturing industry.

We are facing a true industrial revolution that will impact all the industrial segments. Such revolution is usually regarded as Industry 4.0.

This can be synthetically sketched as follows (as shown in Figure 14). At the beginning of 20th century there was the advent of mass production. The handicraft manufacturing was substituted by production lines that, through the availability of electricity, allowed the realization of goods in a very repeatable and predictable way. This is the advent of mass production that led as primary effect the dramatic fall of production costs and make goods affordable by a large amount of population in developed countries. This is usually regarded as the “Fordism”, which was a model followed gradually by many industries, not only automotive. Cars that were affordable only for top classes became affordable for the middle class and eventually for working class. The key topic was “standard production”. The other side of the medal was a very limited variety of products.

In the last decades, there is an increasing need of many industries for “customization”, which basically means provide the market a bigger and bigger variety of products. Industry 4.0 is the new paradigm allowing facing that challenge: mass customization at the same cost of mass production through the digitization of factory operations. This can be achieved leveraging on full digitalization and automation of industrial process. To achieve that it is essential to monitor all the elements of an industrial manufacturing plant, through wireless connectivity (in order to avoid cabling that further increase complexity) and information processing (including big data and analytics technologies). Last but not least, ingredient to realize all of that is the virtualization of control that allow to centralize all the intelligence of the operations in order to increase flexibility and facilitate the changes of the manufacturing plants.

In logistics, in large area (i.e. in the optimization of maritime, ground, air transportations, as well as to optimize port operations and goods production processes), there is a similar need to increase the productivity and the efficiency of the processes to cut production costs and become more and more competitive.

In this way, the advent of smart energy grids is an essential technology towards the goal of maximizing productivity and efficiency of industrial processes by leveraging innovation in the communications sector.

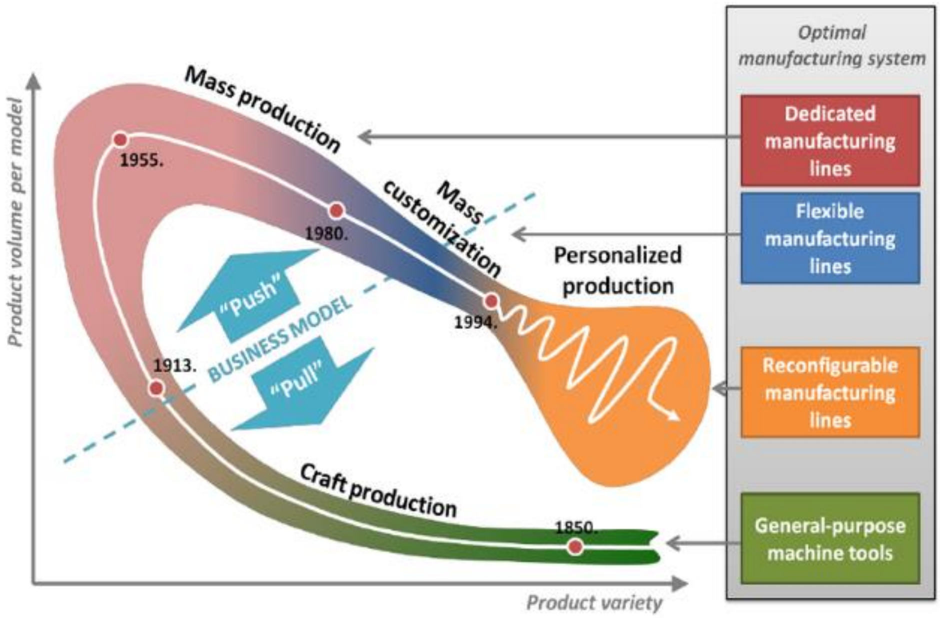


FIGURE 14: MANUFACTURING SYSTEM

2.4.1 Cloud robotics for industrial automation

Cloud robotics became a key element in industrial automation and logistics. Robots are beginning to appear in all industries, performing not only hazardous jobs or operations that require a high degree of precision but also to carry out a wide variety of tasks. While, in the past, robots in factories and warehouses required extremely structured environments performing tasks in quite relative isolation; nowadays, robots are required to work closely with and around people, interacting also with the external environments.

Cloud robotics is a paradigm that leverages the powerful computation, storage and communication resources of modern data centers to enhance the capabilities of robots. Cloud robots are controlled by a “brain” in the cloud that may constitute: a data center, a shared knowledge base, artificial intelligence and deep learning algorithms, information processing, task planners, environment models, etc. The benefits of cloud robotics include.

- Enhanced intelligence through a shared information base across multiple agents, i.e. humans, robots, smart objects and other machines.
- Offloading computationally intensive tasks to the cloud e.g., voice and image recognition, environmental mapping, motion planning, etc. This will lower the power consumption and hardware requirements of robots making them low cost, light weight and smaller.
- The shared cloud infrastructure provides a platform through which multiple robots can collaborate to execute the same task.

Robots have been applied to several vertical domains, such as: logistics for example Automated Guided Vehicle (AGV); security and surveillance; personal assistance, care and guidance for example Softbank’s Romeo; education, entertainment and companionship for example Asus Zenbo; etc.

Generally, a cloud robotics application interacts with its ambient environment using sensors and actuators. The data generated by the sensors is transmitted to a cloud data center using a packet data network e.g. LTE (Figure 15), 5G, Wi-Fi etc. Cloud robotics networking requirements are largely driven by the performance requirements of the individual applications. Figure 17 presents a characterization of the network requirements for some robotic applications.

The cloud data center subsequently processes the raw data to determine the action of the actuators and conveys the results to the robot via a return or feedback path. The data conveyed between the robot and the data center can be broadly grouped into three categories.

- Robot management data used to provide actuator instructions for the robot, e.g. motion, rotation, etc.
- Low bandwidth data generated by sensors on board the robot e.g. temperature, humidity, luminosity, etc.
- High bandwidth data generated by high resolution cameras on board the robot.

Depending on the application scenario each type of data can processed locally, at an edge data center or a distant cloud data center (Figure 16).

In the context of 5G-TRANSFORMER, the Mobile Transport and Computing Platform (MTP) is made up of: Radio Access Network (RAN) functions, transport network functions, core network functions, multi-access edge computing (MEC) infrastructure and computing resources.

Considering an exemplary use case of warehouse automation where the different types of data may be processed at various points within the 5G-TRANSFORMER MTP. For instance, the low latency robot management and control could be executed and the edge data center while the delay tolerant sensor data may be processed at the cloud data center.

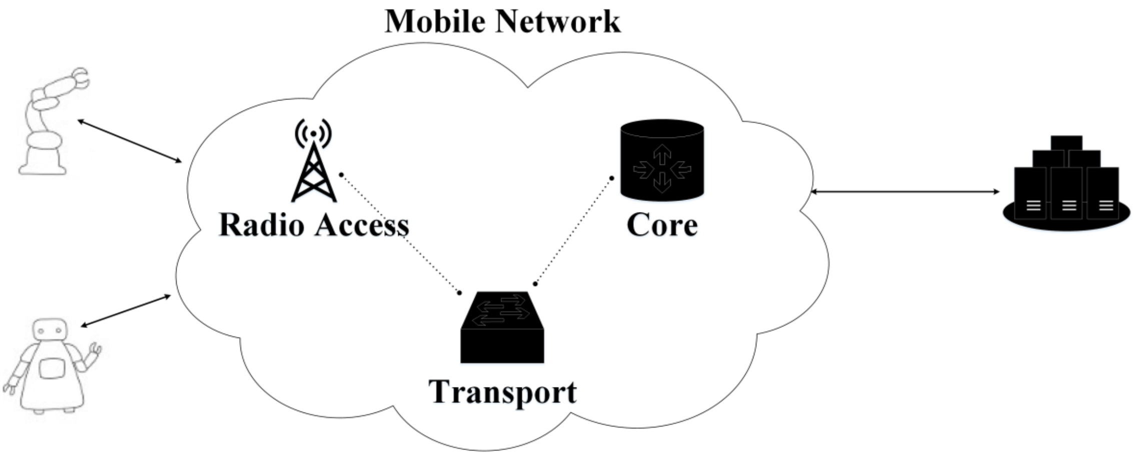


FIGURE 15: CLOUD ROBOTS CONNECTED BY MOBILE NETWORK

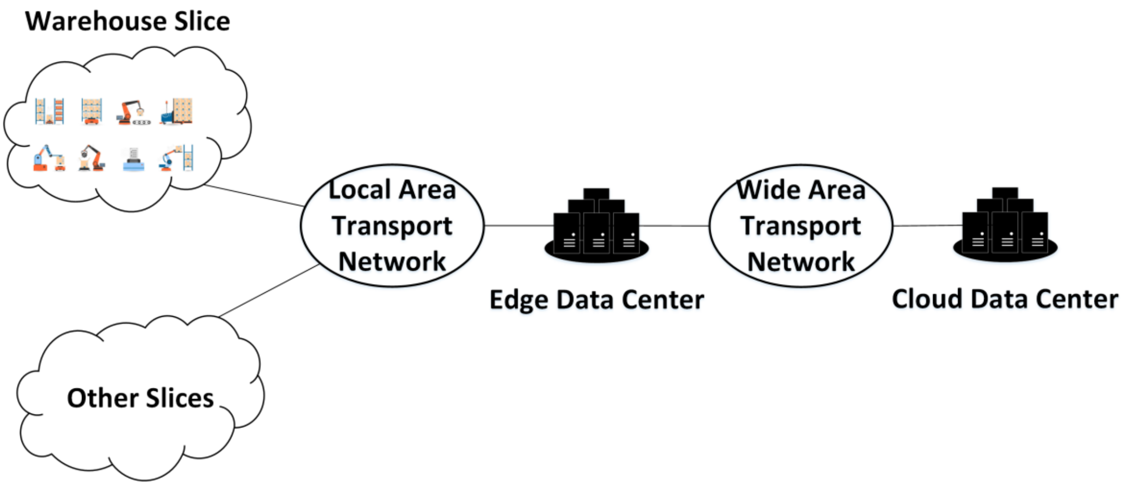


FIGURE 16: TIERED TRANSPORT NETWORK

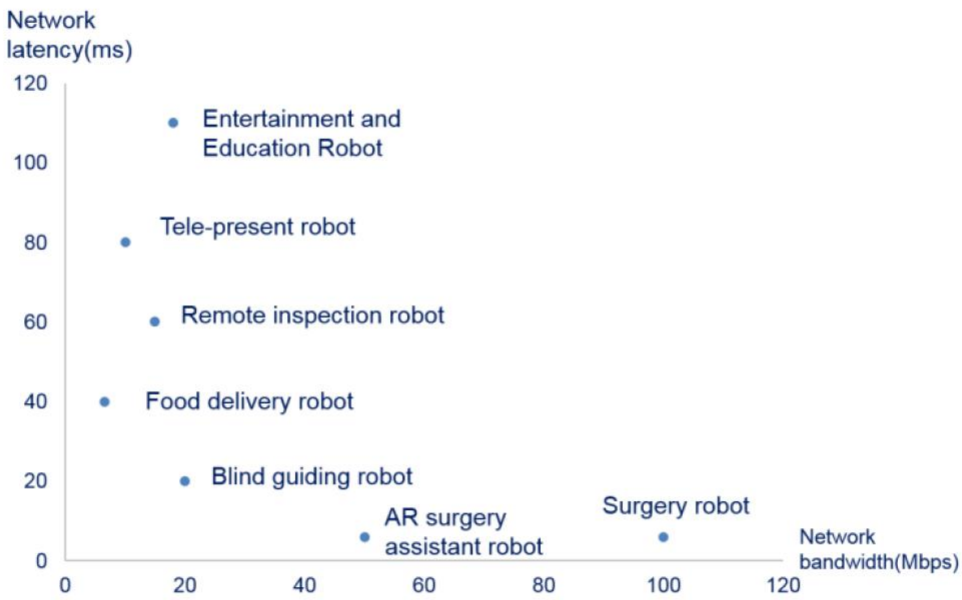


FIGURE 17: NETWORK REQUIREMENTS FOR CLOUD ROBOTIC APPLICATIONS [15]

The summarization of all the actors that will be mentioned in the scenarios, and the relationships among them, is presented in the following diagram (Figure 18):

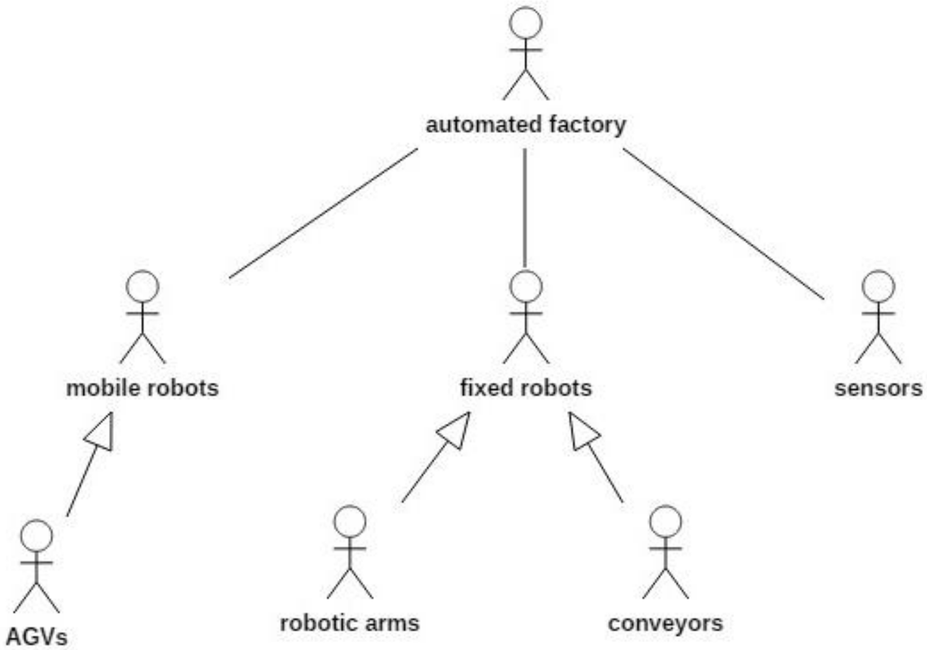


FIGURE 18: E-INDUSTRY ACTORS - CLOUD ROBOTICS

Needs and actors are related to the possible operating scenarios. In particular, two possible macro scenarios can be considered:

- Indoor
- Outdoor

Indoor

Robots are used for automation of operations inside the factory and internal production area. In particular, moving robots are used to transport goods or semi-finished parts among different work cells of a production line and/or to and from depots and loading bays for finished products. It is expected that, in future, automated guide vehicles (AGV) will replace the conveyor belts making the re-configuration of a production line more flexible and optimized.

The following Figure 19 sketches an AVG bringing an object from a robotic arm to another, replacing the conventional conveyor.

FIGURE 19: INDOOR SCENARIO REPRESENTATION

Summarizing, the main actors of automation, in an indoor scenario, are:

- Fixed robots.
- Sensors.
- Conveyors.
- AGVs.

The use of this kind of robots, controlled and coordinated in cloud, in an indoor facility is easier than their use outdoor. Indoor, in fact, is a controlled environment where possible obstacles are removed on the robot path and where the quality of the wireless connectivity (mandatory to enable cloud robotics) can be better controlled and protected by interferences.

The main needs in an indoor scenario are:

- Increase flexibility in a production line.
- Reduce infrastructures.
- Maintain the equipment in optimum working condition, preventing any unplanned downtime due to breakdowns.

Outdoor

Applications of cloud robotics outdoor are extensive and are mainly referred to big autonomous vehicles that can, for example, move a container in a port area. In this scenario, a seaport control center asks for a vessel unloading operation to assigned to AGVs, remotely assisted and coordinated by a dedicated control center which creates and optimizes swarms and platoons of vehicles (depending on tasks and goods to move). During all operations, data from many sensors and cameras are processed with analytics functions to detect criticalities for safety and to actively stops operations in case of danger, to takes recovery actions, and inform workers and seaport control center if needed. The following Figure 20 sketches a simple cloud robotics scenario for handling logistics in a port area.

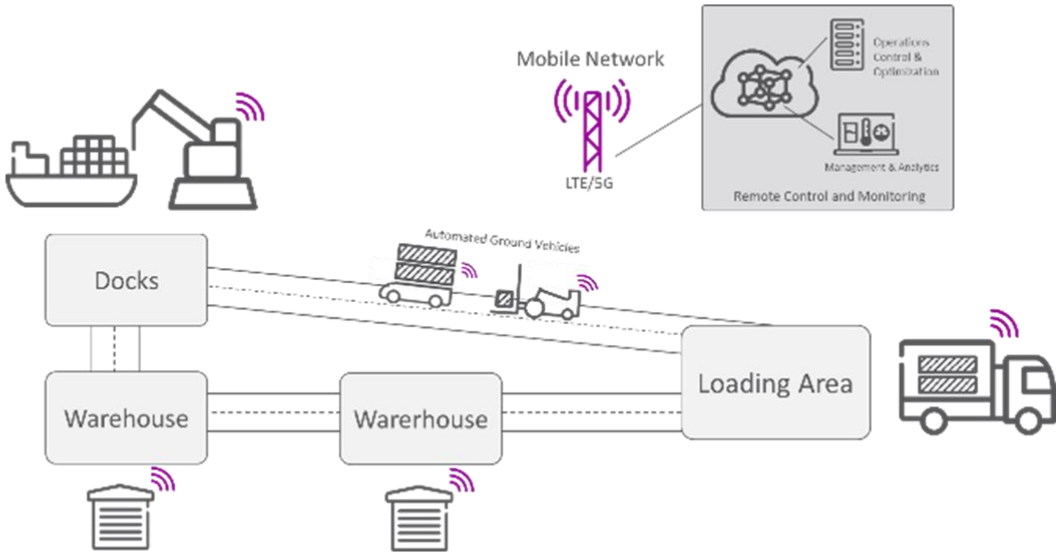


FIGURE 20: OUTDOOR SCENARIO REPRESENTATION

Summarizing, the main actors of automation, in an outdoor scenario, are:

- Fixed and mobile robots.
- Sensors.
- AGVs.
- Connected vehicles and machines (e.g., forklift, truck, crane).

While cyber-security can be better controlled in an indoor facility, the outdoor scenario is more critical and the assessment of node-to-node security and end-to-end security are mandatory. Resilience of the network against signaling based threats, including overload (DoS), robustness against smart jamming attacks of the radio signals and channels is also required. These outdoor machines, in fact, are extremely dependent by GPS positioning which, as well known, is prone to jamming attacks the can partially impair the positioning capabilities of the robots.

The main needs in an outdoor scenario are:

- Increase the amount of the handled containers in a given area.
- Reduce the waiting time for trucks and trains serving the port area.
- Include the safety especially in handling dangerous materials.
- Provide robotic assistance for safe and heavy operations and automated container load/unload (e.g. fine positioning of trucks under the cranes).

2.4.2 Electrical utilities

Many systems that an electrical utility deploys today rely on high availability and deterministic behavior of the underlying networks. Here we present Transmission, Generation (with the particular use case of wind generation) and Distribution scenarios. Most of the use cases and requirements presented in this section are presented in [16]. Figure 21 illustrates the relationship between the different scenarios. In addition, the relationship between these scenarios and the main actors that will be referred to later on is depicted in Figure 22.

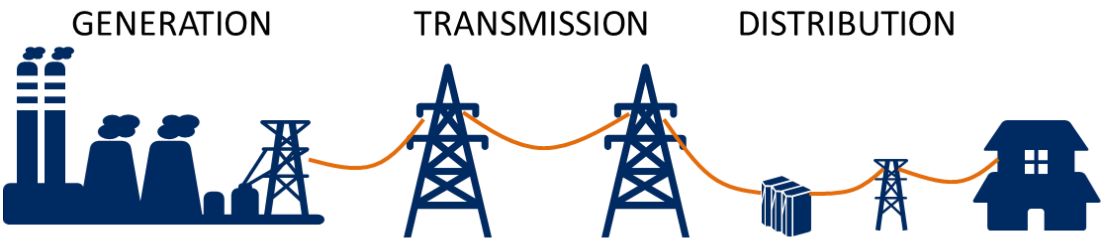


FIGURE 21: ELECTRICAL UTILITIES USE CASES

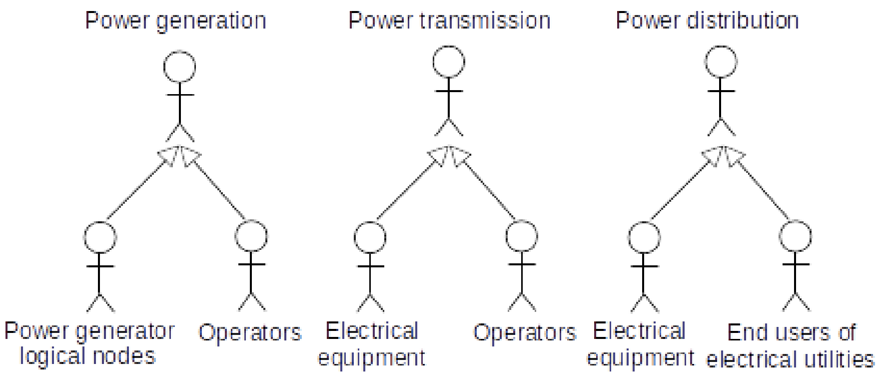


FIGURE 22: ELECTRICAL UTILITIES MAIN ACTORS

Generation scenarios: Energy generation systems are complex infrastructures that require control of both the generated power and the generation infrastructure. Here we focus on the energy generated by Wind Power Farms (WPF). The standard IEC 61400-25 [17] covers all components required for the operation of WPFs including the electrical subsystem, the meteorological subsystem and the WPF management system.

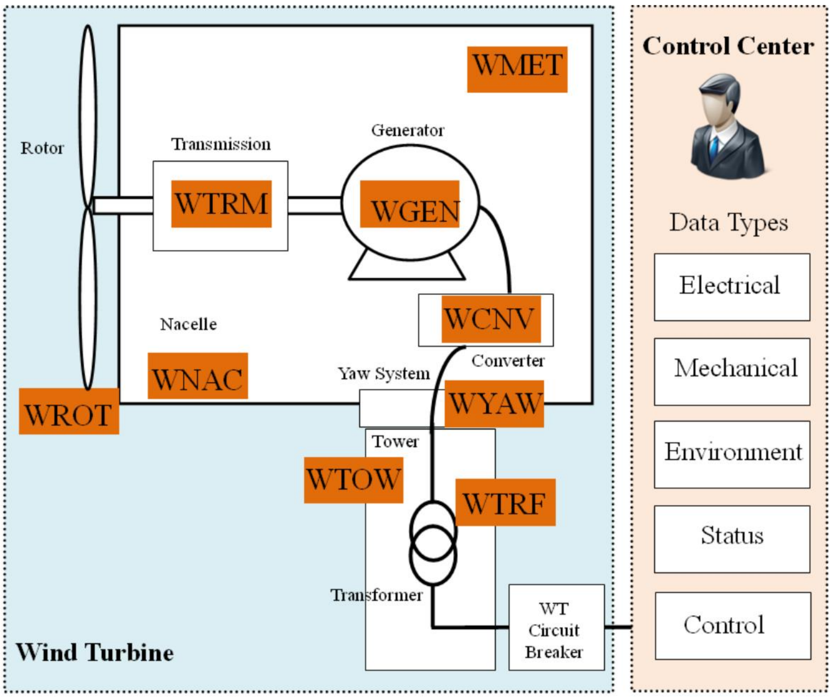


FIGURE 23: WIND POWER GENERATOR LOGICAL NODES.

The main actors of the wind power generation scenario are:

- Wind Power Farm logical nodes specified in Table 5.
- Facility operators.

TABLE 5: LOGICAL NODES OF A WIND TURBINE

Logical nodes	Description
WROT	Wind turbine rotor
WTRM	Wind turbine transmitter
WGEN	Wind turbine generator
WCNV	Wind turbine converter
WTRF	Wind turbine transformer
WNAC	Wind turbine nacelle
WYAW	Wind turbine yawing
WTOW	Wind turbine tower
WMET	Wind power farm meteorological node

More details are available in Appendix 9.1.1.

In summary, the main needs in a generation scenario are:

- Control of generated power
- Protection of generation infrastructure

Transmission scenarios: The main need of the transmission segment of an electrical system is protection. Protection means not only the protection of human operators, but also the protection of the electrical equipment and the preservation of the stability and frequency of the grid. If a fault occurs in the transmission or distribution of electricity then severe damage can occur to human operators, electrical equipment and the grid itself, leading to blackouts. Communication links in conjunction with protection relays are used to selectively isolate faults on high voltage lines, transformers, reactors and other important electrical equipment. The role of the Teleprotection system is to selectively disconnect a faulty part by transferring command signals within the shortest possible time. The key criteria for measuring Teleprotection performance are command transmission time, dependability and security. These criteria are defined by the IEC standard 60834 as follows:

- Transmission time (Speed): The time between the moment where state changes at the transmitter input and the moment of the corresponding change at the receiver output, including propagation delay. Overall operating time for a Teleprotection system includes the time for initiating the command at the transmitting end, the propagation delay over the network (including pieces of equipment) and the selection and decision time at the receiving end, including any additional delay due to a noisy environment.
- Dependability: The ability to issue and receive valid commands in the presence of interference and/or noise, by minimizing the probability of missing command

(PMC). Dependability targets are typically set for a specific bit error rate (BER) level.

- Security: The ability to prevent false tripping due to a noisy environment, by minimizing the probability of unwanted commands (PUC). Security targets are also set for a specific bit error rate (BER) level.

Additional elements of the Teleprotection system that impact its performance include: (i) Network bandwidth, and (ii) Failure recovery capacity (aka resiliency). Most power line equipment can tolerate short circuits or faults for up to approximately five power cycles before sustaining irreversible damage or affecting other segments in the network. This translates to total fault clearance time of 100ms. As a safety precaution, however, actual operation time of protection systems is limited to 70- 80 percent of this period, including fault recognition time, command transmission time and line breaker switching time. Some system components, such as large electromechanical switches, require particularly long time to operate and take up the majority of the total clearance time, leaving only a 10ms window for the telecommunications part of the protection scheme, independent of the distance to travel. Given the sensitivity of the issue, new networks impose requirements that are even more stringent: IEC standard 61850 limits the transfer time for protection messages to 1/4 - 1/2 cycle or 4 - 8ms (for 60Hz lines) for the most critical messages. Teleprotection channels which are differential must be synchronous, which means that any delays on the transmit and receive paths must match each other. Teleprotection systems ideally support zero asymmetric delay; typical legacy relays can tolerate delay discrepancies of up to 750us.

In summary, the main actors of these scenarios are:

- Human operators.
- Transmission equipment.
- Electricity users.

The main needs are:

- Protection of human operators.
- Protection of electrical equipment.

Distribution scenarios: Fault Location, Isolation, and Service Restoration (FLISR) refers to the ability to automatically locate the fault, isolate the fault, and restore service in the distribution network. This will likely be the first widespread application of distributed intelligence in the grid. Static power switch status (open/closed) in the network dictates the power flow to secondary substations. Reconfiguring the network in the event of a fault is typically done manually on site to energize/de-energize alternate paths. Automating the operation of substation switchgear allows the flow of power to be altered automatically under fault conditions. FLISR can be managed centrally from a Distribution Management System (DMS) or executed locally through distributed control via intelligent switches and fault sensors.

In summary, the main actors of distribution scenarios are:

- Electrical equipment.
- End users of electrical utilities.

The main need is:

- Fault Location Isolation and Service Restoration (FLISR).

5G mobile systems are an ideal candidate for condition monitoring systems of large-scale wind turbines due to its flexibility, simpler deployment and CAPEX/OPEX costs. However, in order to 5G to serve this purpose, it needs to guarantee stringent requirements such as deterministic latencies and reliability.

2.5 MNO/MVNO

Nowadays, the network of a mobile operator is typically built using a variety of network appliances. These include network entities for control and data planes, the surrounding platforms used to control and charge the services offered to the end-users, and management functions, as well as the infrastructure needed to deliver services going beyond pure connectivity (e.g., IP multimedia subsystem (IMS)). All these entities are typically based on dedicated hardware devices which are deployed and configured depending on operational needs. Hence, telecommunication networks are typically dimensioned based on load foreseen at peak hours on a yearly basis. Increasing the network capacity requires dimensioning and deployment of new entities in specific network sites, which is a costly and time-consuming process. Such telecom environments are then considered being too much monolithic and static and they need to evolve toward more flexibility, supporting for instance cloud like elasticity or on-demand services.

The evolution toward 5G brings opportunity to solve these issues through the convergence of mobile networks and cloud infrastructures. Such a convergence creates the capability for mobile operators to use network function virtualization (NFV) concepts and cloud-based infrastructures in order to virtualize and decentralize their network entities. This will allow coping with the upcoming traffic demands enabling elastic on-demand networks creation along with their lifecycle management. These expectations pose new requirements on the design of future networks for implementation in a cloud computing environment and their use in “as a Service” (aaS) mode.

Hence, different types of network can be composed on demand, depending on operational and end-users services needs and expectations. Such networks will allow the happening of new role models and value chain separation. In the following, starting from traditional MVNO model, we foresee the evolution toward the deployment of “as a service” mobile core network for either typical mobile network operator services or more specific ones like the advent of Mission Critical Push To Talk services on a shared 5G infrastructure.

An MVNO is a business model that emerges when the traditional mobile value chain is ruptured. Therefore, new players can participate in the mobile value chain and extract value to leverage their valuable assets. As shown in Figure 24, the traditional mobile value chain can be separated into two main areas:

- The Radio access network that is exclusively exploited by MNOs (Mobile Network Operators) and requires a licensed spectrum granted by the regulatory authority.
- The rest of the elements required to deliver the service to the customer.

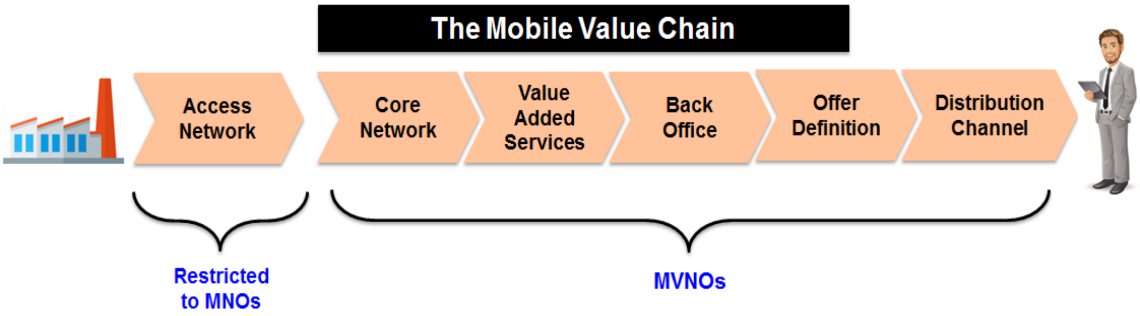


FIGURE 24: THE MOBILE VALUE CHAIN

MVNOs bring the opportunity to telecom and non-telecom companies to participate in the mobile sector. New players in the MVNO area can extract more value from their current customers by adding a new revenue stream and/or strengthening their current value proposition.

There are three groups of players that have taken advantages of the MVNO business model: Telecom companies, non-telecom companies and investors. In particular, MNOs can benefit from the MVNO model by serving untapped segments that their current value proposition is unable to attract. Additionally, telecom operators in general (fixed and/or mobile) can use the MVNO opportunity to enter to new geographies through a wholesale business based on a Mobile Virtual Network Enabler (MVNE) model. Finally, telecom operators with no mobile offering can strengthen their value proposition providing a 4-play offer.

The different business models in the MVNO market are based on how the value chain is restructured. Mainly four main business models emerge (see Figure 25)

- **Branded Reseller**: this model is the lightest MVNO type in which the MVNO can potentially offer its own value-added services (VAS), but holds no assets in the partnership with the MNO. Specifically, the MNO keeps the ownership of the client, the infrastructure and the SIMs. This model does not give the MVNO the ability to set prices. The branded reseller model enables the MVNO to reap the benefits of operating under its own brand (or co-branded with the MNO). The branded reseller is responsible for the costs of branding, sales, and distribution and shares revenues with the partner MNO. The branded reseller model requires the lowest investment for a new venture, therefore the fastest to implement. However, most of the business levers remain with the network provider (MNO or MVNE). Therefore, the new venture has a very limited control of the business levers and value proposition of the service
- **Light-MVNO:** It is an intermediate model between branded reseller and Full MVNO. The MVNO still does not own the network infrastructure, but it has control over the marketing and sales areas and, in some cases, increases the level of control over the back-office processes and valued-added services definition and operations. The light MVNO’s revenues come from both inbound and outbound traffic, and here, the MVNO is responsible for the same costs paid under the service provider model - e.g., rate structures, IT platforms, branding, sales, and distribution
- **Full-MVNO:** It is possible for an MVNO to operate like an MNO virtually in all ways except for ownership of the radio access network. The Full MVNO is the

most complete model for a new venture, where the MNO just provides the access network infrastructure and, sometimes, part of the core network, while the new venture provides the rest of the elements of the value chain. At this end of the spectrum, the full MVNO gets the benefits associated with owning the network-switching infrastructure and also incurs the costs of these network elements. This MVNO business model is typically adopted by telecom players that could gain synergies from their current business operation.

- **Network enablers (MVNE):** typically known as Mobile Virtual Network Enablers (MVNE), this is a third party provider focused on the provision of infrastructure that facilitate the launch of MVNO operations. An MVNE can be positioned between a host MNO and an MVNO venture to provide services ranging from value added services and back office processes to offer definition. MVNEs reduce the entry barriers of MVNO ventures, given that an MVNE aggregates the demand of small players to negotiate better terms and conditions with the MNO. They pass on some of these benefits to their MVNO partners. Some MVNE models are also called **Mobile Virtual Network Aggregator (MVNA),** depending on the range of services offered or whether they aggregate different MNOs. MVNE models range from telco-in-a-box offering, where the MVNE just offers core network, value added services and back office services, to full MVNE.

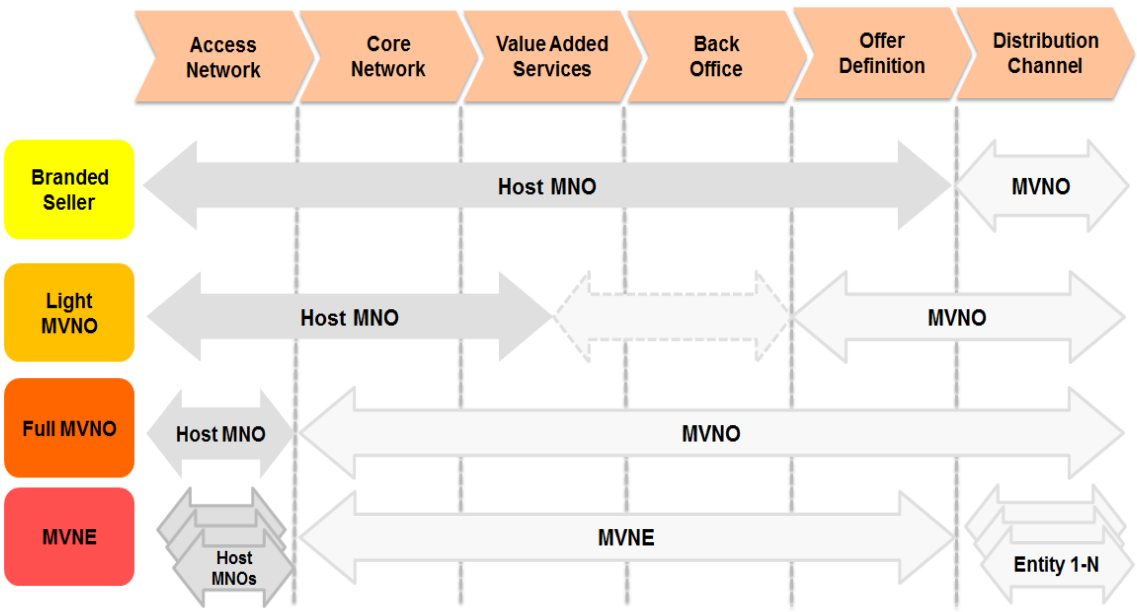


FIGURE 25: MVNOS BUSINESS MODELS

There is a large number of MVNOs proliferating all over the world and most of them provide low bandwidth at low price. With the advent of 5G, network slicing is definitely an opportunity for both MNOs and MVNOs to empower their capability of tailoring fine-grained subscription plans and services that can better meet users' demands. Hence, Network slicing would ease the creation of tailored services with fine grained bandwidth, application Latency, QoS and security policies. With regards to MVNOs business models and use cases, network slicing would allow offering a dedicated slice for an MVNO to carry its traffic, but the MVNO could then deploy its own virtual network functions (VNFs) depending on the MVNO type and its level of the network infrastructure ownership. Likewise, an MVNO can profit from network slicing to create specific and tailored service offers to its customers.

Based on the above description of the MVNO domain, its actors and business models, we can clearly understand that the MVNO/MNO player in 5G-TRANSFORMER has a different role compared to the other verticals. In fact, it cannot be considered only as a vertical player as the MVNO/MNO needs, with regards to slicing, strongly depend on the role they are playing and the business model to which it can be mapped. For instance, in the case of a Full MVNO or an MVNE business model, the role of the MVNO exceeds that of a simple vertical service provider and can include the role of a Network service provider. Likewise, the role of an MNO that would like to host an MVNO is mainly built on the offering of a Network as a service and also of a mobile transport infrastructure as a service. In addition, verticals can be seen as customers of an MNO or an MVNO. These interdependent roles and relations between MNO, MVNO and verticals are shown in Figure 26. As a consequence, the MVNO/MNO domain should be seen as a particular domain in 5G-TRANSFORMER as the actors can play different and complementary roles at different levels of the 5G-TRANSFORMER slicing architecture.

Based on these roles relation between MNO, MVNO and the verticals, we can differentiate two types of services that could be offered by either MNO or MVNO:

- The Network Service.
- The Vertical Service.

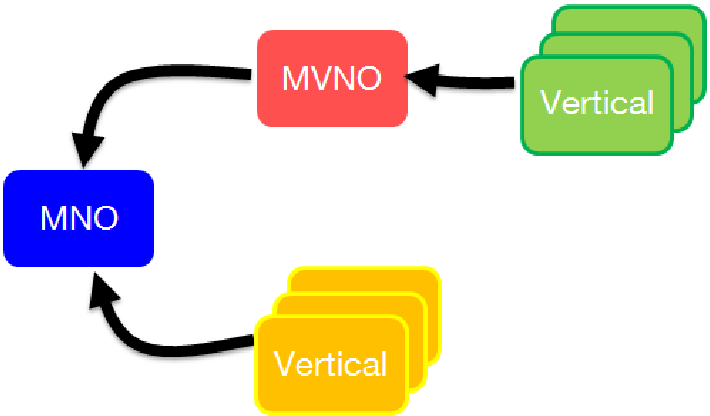


FIGURE 26: MVNO AND MNO ROLES MODEL WITH VERTICALS

In the following sub-sections, we provide a description of few Network services that can be deployed “as a Service” by a 5G MVNO or MNO and benefit from slicing in order to adapt service configuration and meet better the customers’ expectations. Thus, we address the following scenarios:

- “EPC as a Service” use case, relevant for any MNO/MVNO use case and also for verticals that can be customers of the MNO/MVNO.
- MCPTT (Mission Critical Push To Talk) use case which is a more specialized MVNO approach dedicated to critical services with more specific needs.
- Traffic monitoring as a Service in MNO/MVNO slices as we anticipate, with the advent of virtualization and on demand network services, the need for new approaches for operator networks monitoring.

Figure 27 shows the actors diagram of the MNO/MVNO domain. It details the different actors involved in the before-mentioned scenarios and which will be described in the following sub-sections.

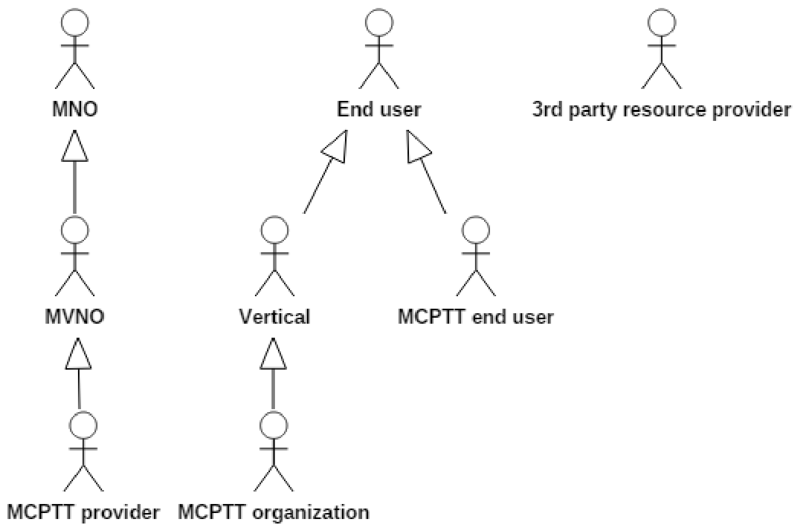


FIGURE 27: ACTORS DIAGRAM FOR MNO/MVNO DOMAIN

2.5.1 EPC as a Service (EPCaaS)

EPC as a Service (EPCaaS) is defined as the implementation option of the Evolved Packet Core (EPC) over a cloud infrastructure and providing it as a Service. It is worth pointing out that EPCaaS is an implementation of the 3GPP's EPC, and as such, needs to implement all the standardized reference points and functions, so that, from the perspective of another legacy EPC or individual EPC legacy nodes, it will behave transparently as a non-cloudified implementation of EPC, with full compliance with the 3GPP standards. Future evolution toward the next generation core network coming with 5G will remain compliant with such aaS mode.

The direct and first utility of EPCaaS consists of a cloud-enabled MVN that we call MVNO. With regards to the business models described earlier in this section, MVNOs need to perform different functions that can either be handled in-house by an MVNO itself or outsourced to a mobile network operator (MNO). In contrast to an MVNO, an MNO owns a mobile network infrastructure, which includes implementation of all relevant network entities, from EPC itself, through the surrounding platforms used to manage and charge the services offered to the end-users, to the infrastructure needed to deliver services going beyond pure connectivity. The cloudification of EPC creates the opportunity for an MNO to move to a completely different network paradigm, where the network functions that are used to be implemented on physical devices and deployed on specific points of presence (PoPs), become software appliances running on top of a cloud infrastructure. Hence, with the advent of network slicing, EPCaaS becomes not only an interesting opportunity for MNOs and MVNOs, but also a network and business enabler for verticals.

In the original design of EPC, the intention was to clearly separate user data processing functional entities (e.g., SGW and PGW) from pure control functional entities (e.g., MME, HSS, and policy and charging rules function (PCRF)). Currently, both types of entities are implemented in hardware-based devices, but specialized for the different types of processing. In particular, S/PGWs are designed to achieve high throughput of user packets, while performing traffic analysis and applying filtering policies. MME and other control plane entities usually have fewer requirements in terms of throughput capacity, but stricter requirements in terms of processing latency and computation. With regards to these differences, the implementation of EPCaaS can also include the implementation of the different EPC functional entities in a Software as a Service (SaaS) mode. Hence, from a virtualization point of view, different virtual EPC (vEPC) implementation approaches can be foreseen, from a full virtualization of each EPC functional entities (see Figure 28), to the split of legacy vEPC entities allowing partial virtualization, for instance virtualizing control plane entities only. The latter approach requires separating legacy SGW (and PGW) entities between control plane related functionalities from user plane related one's, for instance following the CUPS (Control and User Plane Separation of EPC nodes) standard [20]. Additional needs are also driving innovation and network evolution like the advent of cloud based storage and processing distributed in the operator's network. This trend initiated with MEC will require the ability in 5G networks to handle traffic locally when necessary, e.g. to allow the user getting access to personalized application processing and/or its own personal data storage at the edge of the access network. The separation between control plane and user plane entities will facilitate the implementation of such a flexibility to locally route the traffic to edge resources. It can also allow more direct communication between end users devices (e.g. with local switching rules at the first user plane entity), avoiding to route the traffic through the whole MNO network.

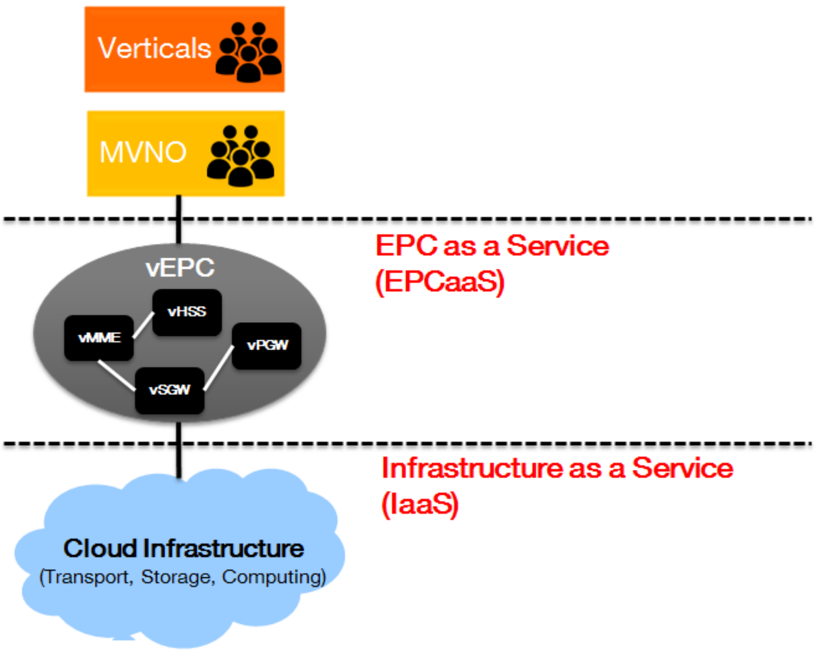


FIGURE 28: EPC AS A SERVICE WITH FULL VIRTUALIZATION OF EPC ENTITIES

These different trends outline that 5G will come with the expectation of a high-level of flexibility in terms of networks deployment, configuration and traffic control. This will require the support of different types of configuration (e.g. full or partial virtualization) but also different types of openness and provision of networks services, from the RAN to edge and core network elements. The future types of MNO/MVNO will leverage on such flexibility.

The needs for this use case scenario can hence be summarized as follows:

- Configurable and on-demand creation of a virtual EPC for an MVNO, following MVNO needs and requirements.
- Increase network capacity and network elasticity through the virtualization of network functions.
- Possibility to choose to deploy all or only relevant vEPC network entities, depending of the end user's needs.
- Address verticals requiring ultra-reliable connectivity (like critical business activities in the industry) and/or ultra-low-latency (like Mission Critical services called MCPTT).
- Need to tailor fine grained services for verticals with on-demand QoS and adapted charging policies based on vertical services requirements.
- Need for efficient MEC-like infrastructures at the edge networks to host appliances like video analytics or geo-messaging servers.
- Need for local content/video processing resources at the network edges in order to answer to new market needs like vehicular services and smart cities.
- Provide users Data as close as possible of the users for URLLC services in order to reduce end to end latency.
- Need for dynamic vertical services creation, management and configuration tools.
- Ability to deploy services over federated network infrastructure resources when the network infrastructure is owned by another MNO or non telco player (federation at the MTP level).
- Need for efficient and strong security mechanisms especially for critical services like MCPTT.
- Need for the capability at the MNO level to distribute network functions inside a vertical slice at the most suitable places, e.g. third party owned IT infrastructures.
- Need for the capability to interface to the 3rd party assets.

2.5.2 Mission Critical Push To Talk

Land Mobile Radio (LMR) systems denote infrastructures that are used by emergency first responder organizations such as police, fire, and ambulance services, public works organizations, dispatched services such as taxis, or companies with large vehicle fleets or numerous field staff.

A large portion of LMR users is expected to adopt LTE and 5G systems as it gets harder to keep and maintain dedicated frequencies or technologies (GSM-R, TETRA …) and to compete with existing commercial mobile networks in terms of bandwidth, network coverage and application availability.

MCPTT (Mission Critical Push to Talk) systems are a specific category of LMR systems that are deployed to transport mission critical communications. In this context, a MCPTT operator appears as a new type of MVNO providing mission critical services (group call services, MCData - Mission Critical Data - services…) to its customers (police forces, public safety organizations…) through business agreements established with one or several MNOs also called PLMN operators as shown on Figure 29.

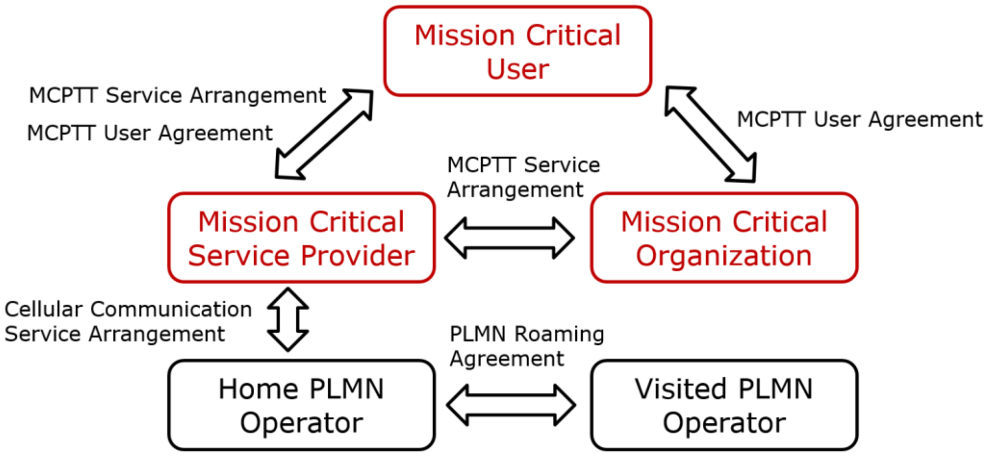


FIGURE 29: BUSINESS RELATIONSHIPS FOR MCPTT

The MCPTT user belongs to a single mission critical organization based on a MCPTT user agreement between the MCPTT user and the mission critical organization. The MCPTT user can have MCPTT user agreement and MCPTT service arrangement directly with a single MCPTT service provider.

The mission critical organization can have MCPTT service arrangements with several MCPTT service providers. In this case, a MCPTT user of a mission critical organization is always served by only one MCPTT service provider. The MCPTT service provider can have MCPTT service arrangements with several mission critical organizations.

The MNO can have MNO service arrangements with multiple MCPTT service providers and the MCPTT service provider can have MNO service arrangements with multiple MNOs. As part of the MNO service arrangement between the MCPTT service provider and MNO, network subscription arrangements can be provided which allows the MCPTT UEs to register with the MNO home network.

Also, Mission Critical service providers can establish business agreements, allowing users belonging to different MCPTT organizations to be involved in the same data or voice group call.

The Mission Critical Service Provider often acts as a full MVNO due to the fact that it usually brings its own assets to offer group calls and/or eMBMS capabilities to its customers. It will hence pose additional requirements in terms of expected as a service networks deployment and management with high expectations in terms of availability to guarantee the support of critical services.

The needs for this use case scenario can be summarized as follows:

- Need to address verticals requiring ultra-reliable connectivity (like critical business activities in the industry) and/or ultra-low-latency (like Mission Critical services called MCPTT).
- Need for horizontal slicing capability at the MNO level to enable SLA commitment to each Mission Critical Service Provider and allow complete isolation between MC and non-MC traffic.
- Need for the capability to dynamically instantiate a virtual network to provide communication services locally to an emergency intervention depending on Mission Critical Service Provider consumption demand

- Need for an on-demand MCPTT vertical network slice deployment spanning both MCPTT Service Provider and MNO networks. The instantiation of the slice shall be completed within minutes.
- Need for strong security and confidentiality mechanisms due to the particular nature of the data being transported in MCPTT services.
- Need for means/tools to adjust in real time calls priority and QoS depending on user state, role, location, incident severity, etc.
- Need for the capability to federate external resources (brought by MCPTT SP or provided by a private party) with those made available by the MNO to provide the service.

2.5.3 Network Monitoring as a Service

In legacy mobile networks, network functions run over physical appliances and operators deploy their own passive traffic monitoring solutions based on two main functions: traffic mirroring (TAP) performed with passive hardware cards/devices connected on optical infrastructure (e.g. on a standardized control interface like S11 interface in the EPC architecture between a Serving Gateway and a MME); traffic probing (probes devices) able to analyze the mirrored traffic and extracting data necessary to monitoring and troubleshooting tools.

In NFV, cloud based principles are applied to VNF placement and deployment:

- “Multi-tenancy” (several VNF administrators may use through isolation the same NFVI).
- “Location independency” (the VNF administrator ignores the physical location of his VNFs).

VNF-to-VNF traffic is no more delivered through physical optical ports but may be handled directly by virtual bridges provided by the NFVI. Thus, the legacy monitoring infrastructure (physical optical TAP and probes devices) becomes useless. For example, on standard S11 interface, the control plane traffic will be delivered between vSGW and vMME appliances, over virtual bridges instantiated “somewhere” in the NFV infrastructure. VNF location in the cloud platform being not deterministic; cloud management tools instantiate virtual machines where appropriate resources (compute, servers….) are available.

In order to provide MNO/MVNO with adapted monitoring tools, virtual TAP and virtual probes appliances need to be instantiated dynamically in the MTP layer, depending on the operator’s needs (traffic passive analysis, troubleshooting, operations…). This is illustrated in Figure 30 where the traffic going between VNF1 and VNF2 is mirrored on virtual interfaces at the vTAP level to be duplicated toward the Probe VNF.

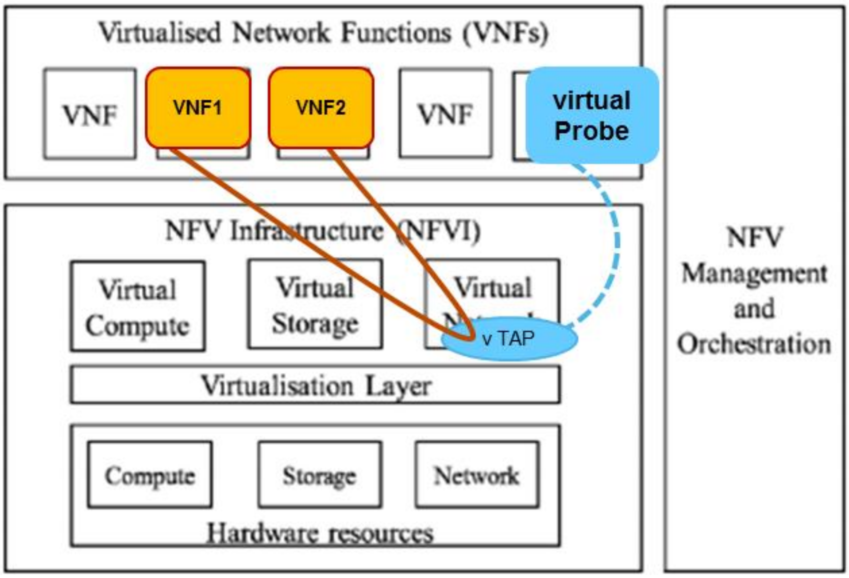


FIGURE 30: EXAMPLE OF VIRTUALIZED TRAFFIC MONITORING FOR MVNO

The needs for this use case scenario can be summarized as follows:

- Need for tools and solutions for data monitoring at different levels of the architecture in order to enforce network policies and help data harnessing and network data analytics.
- Need for traffic probing systems able to monitor either the control plane or the data plane traffic that is delivered at any point in the network (i.e. though physical links or virtualized one's), feeding analysis, monitoring and troubleshooting applications.

3 Use Cases

For each vertical domain introduced in the previous Section 0, several use cases can be realized. In this Section 3, we describe these use cases following the methodology described in the following table:

UC X.XX	UC NAME
Goal in context	<PICTURE>
Cluster	Enhanced Mobile Broadband / Mission Critical Services / Massive Internet of Things
Addressed Needs	Coming from Vertical Scenario
Operating Scenario	IF APPLICABLE
Primary actors	<actors>
Secondary actors	<actors>
Preconditions	<preconditions>
General Description	<description>
General Requirements	<requirements>

- **UC ID** [X.XX]: a unique identifier for the use case. It is built with the uppercase initial of the domain the use case belongs to and a sequential number (i.e "A.01" is the first use case described for the Automotive domain)
- **UC NAME**: a short title for the use case (i.e. "V2I Safety Application")
- **GOAL IN CONTEXT**: a brief description of the use case goal and insertion of a picture that represents it
- **CLUSTER**: indication of the cluster to which the use case belongs. Three clusters have been defined: "*Enhanced Mobile Broadband (eMBB)*", "*Mission Critical Service*" and "*Massive Internet of Things (Massive IoT)*".
- **ADDRESSED NEEDS**: list of high-level needs addressed by the use case
- **OPERATING SCENARIO**: the scenario/s where the specific use case operates if applicable
- **PRIMARY ACTORS**: list of the primary actors of the use case
- **SECONDARY ACTORS**: list of the secondary actors of the use case
- **PRECONDITIONS**: descriptions of the eventual preconditions that should be verified for the execution of the use case
- **GENERAL DESCRIPTION**: a textual description of the use case
- **GENERAL REQUIREMENTS**: list of operative requirements addressed by the use case

3.1 Automotive

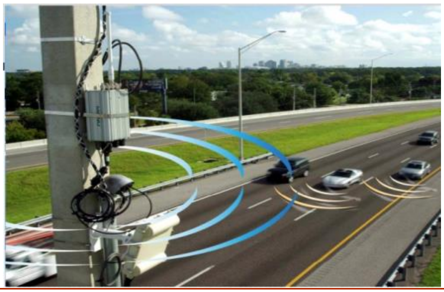
5G will allow the support of several relevant services in the automotive domain, which span from safety to entertainment and may involve automated (partially or full) as well as autonomous vehicles. Taking into account automotive needs described in section 2.1 and taking into account KPIs addressed by 5G technology, automotive use cases can be classified based on the following heterogeneous domains:

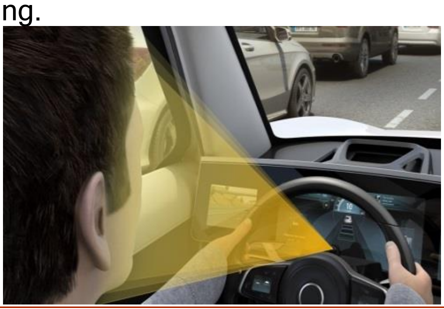
- **Safety**: through the exchange and processing of safety messages, warnings and traffic information, the risk of accidents involving vehicles as well as vulnerable roads users (pedestrians, cyclers, …) can be significantly reduced;
- **Mobility**: vehicle navigation and delivery of information on traffic intensity and parking availability can significantly reduce drivers' stress and improve the quality level of daily driving experience;
- **E-road**: information on the road status and driving conditions can significantly reduce the risk of accidents and ease the driving experience in harsh situations;
- **Entertainment**: passenger can enjoy a vast range of applications including, video streaming and mobile gaming, possibly with an enhanced experience through augmented reality;
- **Digitalized Vehicles**: vehicles can automatically download software updates when needed, as well as exploit data collected through on-board sensors for remote vehicle monitoring and for enabling predictive maintenance;
- **Automated Driving**: vehicle control can be performed by an electronic system instead of a human driving in the case of, e.g., car overtaking, intersection crossing and vehicle platooning.

3.1.1 Automotive - Safety

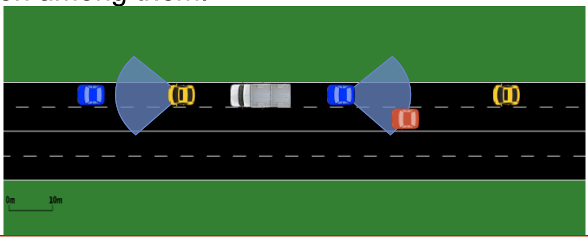
UC A.01	Cooperative V2V Safety application
Goal in context	The aim is to prevent the occur of dangerous situations or to mitigate their effect, thanks to cooperation among vehicles. 
Cluster	Mission Critical Services
Addressed Needs	• Enhanced real time awareness (e.g. of vulnerable road users, other vehicles behaviour or intentions, road status...). • Reduction of the frequency and severity of crashes.
Operating Scenario	Urban, Highway, Rural
Primary actors	Host Vehicle, Connected Vehicles
Secondary actors	Host Vehicle Driver
Preconditions	Host Vehicle is fully aware of the context it is moving in: • Road Geometry and Permanent Attributes. • Connected Vehicles position and path. • Host Vehicle Position and path.
General Description	Communication among vehicles increases their awareness of the presence of other vehicles. Thanks to the exchanged data, alarm/warning messages can be generated upon which a vehicle (or its driver) can properly react.
General Requirements	Low Latency. High Reliability.

	High Node Speed.

UC A.02	V2I Safety application
Goal in context	The aim is to prevent the occur of dangerous situations or to mitigate their effect, thanks to cooperation among vehicles and infrastructures. 
Cluster	Mission Critical Services
Addressed Needs	• Reduction of the frequency and severity of crashes. • Enhanced real time awareness (e.g. of vulnerable road users, other vehicles behavior or intentions, road status...).
Operating Scenario	Urban, Highway, Rural
Primary actors	Host Vehicle, Connected Vehicles, Infrastructures
Secondary actors	Host Vehicle Driver
Preconditions	Infrastructure is fully aware of the context the host vehicles are moving in: • Road Geometry and Permanent Attributes. • Host Vehicle is a Connected Vehicle. • Connected Vehicles position and path.
General Description	Communication among vehicles and infrastructures will provide additional information about road conditions. Appropriate alarm/warning messages can be generated upon which a vehicle (or its driver) can properly react.
General Requirements	Low Latency. High Reliability. High Node Speed.

UC A.03	Driver monitoring application
Goal in context	The aim is to monitor driver's status (e.g. drowsiness, distraction, physical diseases) and to predict when he is not capable of driving. 
Cluster	Massive IoT
Addressed Needs	Reduction of the frequency and severity of crashes

Operating Scenario	Urban, Highway, Rural
Primary actors	Host Vehicle, Host Vehicle Driver
Secondary actors	Wearable devices
Preconditions	Devices fully aware of the driver's status: • Able to recognize different behaviors. • Able to send a warning to the driver. • Availability of a data fusion system, fed with heterogeneous signals, for driver status monitoring. • HMI in-vehicle system able to recover driver attention.
General Description	To monitor physiological status such as attentiveness or drowsiness of the driver, recognizing different stages of its behavior and be capable to send a warning, when necessary. According to the complexity of the algorithm, the processing could be realized either on board or remotely.
General Requirements	High Reliability. High Node Speed.

UC A.04	**See through (Safety)**
Goal in context	The goal is to achieve bilateral awareness of road conditions. Vehicles are able to see through the obstacle, thanks to cooperation among them. 
Cluster	Mission Critical Services
Addressed Needs	• Reduction of the frequency and severity of crashes. • Enhanced real time awareness (e.g. of vulnerable road users, other vehicles behaviour or intentions, road status...).
Operating Scenario	Urban, Highway, Rural
Primary actors	Host Vehicle, Connected Vehicles
Secondary actors	Host Vehicle Driver, OEM backend (optional)
Preconditions	Host Vehicle is fully aware of the obstacles it is encountering: • Obstacles positions. • Connected Vehicles position and path.
General Description	Exchanging the information among vehicles, it is possible to see through an obstacle. Streaming information should be provided to all the vehicles that want to access to it. This information can be used to identify eventual obstacles that cannot be detected though on-board sensors. OEM backend could be involved depending on specific Car Maker UC design.
General Requirements	High Reliability. High Throughput. High Node Speed.

UC A.05	Vulnerable Road User (VRU) Discovery
Goal in context	Being able to detect vulnerable road users (pedestrians, bicyclists, etc.) through connectivity. 
Cluster	Mission Critical Services
Addressed Needs	• Reduction of the frequency and severity of crashes. • Enhanced real time awareness (e.g. of vulnerable road users, other vehicles behaviour or intentions, road status...).
Operating Scenario	Urban
Primary actors	Host Vehicle, Connected road users
Secondary actors	Host Vehicle Driver
Preconditions	Host Vehicle is fully aware of road conditions it is encountering: • Detection of positions and paths of vulnerable users.
General Description	Exchanging the information among devices (e.g. a vehicle and a VRU device), it is possible to warn both the driver and the VRU if a dangerous situation is detected, in order to avoid critical situations.
General Requirements	High Reliability.

3.1.2 Automotive - Mobility

UC A.06	Cooperative Navigation & Distributed Mobility Management
Goal in context	The goal is to avoid traffic jam in case of more people are using a navigator for the same destination. 
Cluster	Massive IoT/ Enhanced Mobile Broadband
Addressed Needs	• Lean mobility. • Informed mobility.
Operating Scenario	Urban, Highway, Rural
Primary actors	Host Vehicle, Connected Vehicles, Navigation devices
Secondary actors	Host Vehicle Driver
Preconditions	Host Vehicle is fully aware of:

	• Road Geometry and Permanent Attributes • Connected Vehicles position and path determined in real-time. • Host Vehicle Position and path determined in real-time.
General Description	Thanks to connectivity and communication among navigation devices, traffic jams can be avoided or reduced as much as possible, by recalculating the route that each vehicle is following for reaching a specified destination.
General Requirements	High Reliability. High Node Speed. High Node Speed.

UC A.07	Dynamic Reserved Lane Management (Emergency vehicle, Public transportation)
Goal in context	The goal is to facilitate mobility of an Emergency vehicles, or any other Public transportation, in their reserved lane. 
Cluster	Mission Critical Services
Addressed Needs	• Informed mobility • Lean mobility • Accessible and reactive Emergency Services
Operating Scenario	Urban, Highway
Primary actors	Host Vehicle, Connected Vehicles, emergency vehicle or public transportation
Secondary actors	Host Vehicle Driver, Infrastructure (optional)
Preconditions	• Connected Vehicles are able to receive a warning if their position and path interferes with the approaching vehicle from its reserved lane. • Host Vehicle position and path is sent to all connected vehicles sharing the same route.
General Description	Thanks to connectivity and communication between vehicles and eventually infrastructure, when an emergency vehicle is approaching, all other vehicles ahead in the same line receive a warning message, in order to clear the line as soon as possible. The line status becomes temporally “reserved”.
General Requirements	High Reliability. Low Latency. High Node Speed.

UC A.08	Collaborative Parking
Goal in context	Accurate insight of the parking spots, providing input for on-road parking services.

	
Cluster	Enhanced Mobile Broadband
Addressed Needs	Convenience in parking
Operating Scenario	Urban
Primary actors	Host Vehicle, Connected Vehicles
Secondary actors	Host Vehicle Driver, OEM backend (optional)
Preconditions	• Host Vehicle is fully aware of available parking spots and their exact position. • Connected Vehicles able to send its parked location.
General Description	Thanks to connectivity, radars and communication among vehicles, on-road parking spots can be easily detected and shared.
General Requirements	High Reliability.

UC A.09	Smart Cities
Goal in context	Improved efficiency of services, providing the ability to extract all information (regarding the smart city capabilities) that can be useful to the driver. 
Cluster	Massive IoT
Addressed Needs	• Lean mobility • Informed mobility
Operating Scenario	Urban
Primary actors	Host Vehicle, Connected Vehicles, Infrastructure
Secondary actors	Host Vehicle Driver
Preconditions	Integration with Smart Cities service provider
General Description	Connected vehicles can benefit from the data and services managed by smart cities, by integrating the information they receive from sensors and infrastructures.
General Requirements	High Reliability.

UC A.10	See ahead
Goal in context	The goal is to achieve bilateral awareness of road and traffic

	conditions, therefore improving mobility. Vehicles are able to see far away from their location, by communicating with each other. 
Cluster	Enhanced Mobile Broadband
Addressed Needs	• Informed mobility. • Enhanced real time awareness (e.g. of vulnerable road users, other vehicles behaviour or intentions, road status...).
Operating Scenario	Urban, Highway, Rural
Primary actors	Host Vehicle, Connected Vehicles
Secondary actors	Vehicle Driver, OEM backend (optional)
Preconditions	• Vehicles sharing the same route are able to send and receive information related to traffic condition.
General Description	Thanks to connectivity and communication among vehicles, it is possible for a vehicle with limited visibility, to see in real-time what is happening situation on the part of the route that is far away from it.
General Requirements	High Reliability. High Availability. High Bandwidth. High Node Speed. Low Latency.

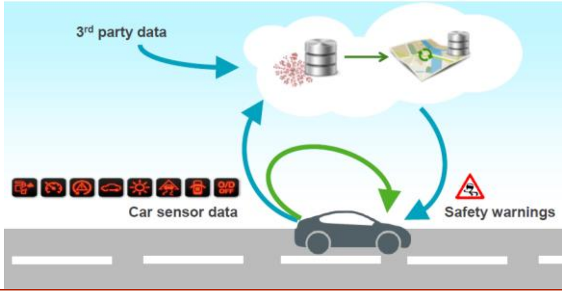
3.1.3 Automotive - e-Road

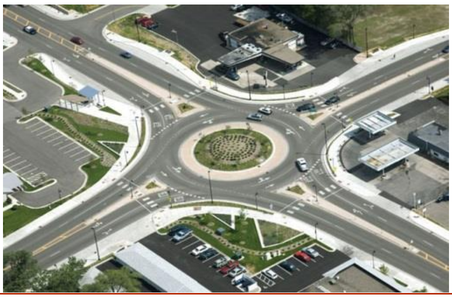
UC A.11	**Road Issues Identification & Notification**
Goal in context	Vehicles able to identify the issue that is occurring on a particular section of the road and send a warning to other connected vehicles that are sharing the same route. 
Cluster	Mission Critical Services
Addressed Needs	Reduction of the frequency and severity of crashes.
Operating Scenario	Urban, Highway, Rural
Primary actors	Host Vehicle, Connected Vehicles, OEM backend
Secondary actors	Host Vehicle Driver, Infrastructure

Preconditions	Host Vehicle is fully aware of the context it is moving in: • Road Geometry and Permanent Attributes. • Connected Vehicles position and path. • Host Vehicle Position and path.
General Description	Considering the behavior of the vehicle on a certain section of the road (e.g. Electronic Stability Control is on), the system is able to detect a problem (like, slippery road) and alert all future users of this route.
General Requirements	Low Latency. High Reliability. High Node Speed.

UC A.12	Black Spot Identification & Notification
Goal in context	Vehicles able to identify dangerous section of the road (black spot) and send a warning to other connected vehicles that are sharing the same route. 
Cluster	Mission Critical Services
Addressed Needs	Reduction of the frequency and severity of crashes
Operating Scenario	Urban, Highway, Rural
Primary actors	Host Vehicle, Connected Vehicles, OEM backend
Secondary actors	Host Vehicle Driver, Infrastructure
Preconditions	Host Vehicle is fully aware of the context it is moving in: • Road Geometry and Permanent Attributes. • Connected Vehicles position and path. • Host Vehicle Position and path.
General Description	Collected information for some particular section of the road (e.g. number of activated air bags or heavy braking) can be used to classify them as a black spot (permanent or temporary). That information can be used either to feed infrastructure data base or as notification to the approaching vehicles.
General Requirements	High Reliability. High Node Speed.

UC A.13	Dynamic High Definition Map Update
Goal in context	High Definition map able to integrate real time updates, based on information from the connected vehicles and on other sources.

	
Cluster	Massive IoT/Enhanced Mobile Broadband
Addressed Needs	• Enhanced real time awareness (e.g. of vulnerable road users, other vehicles behaviour or intentions, road status...). • Path optimization.
Operating Scenario	Urban, Highway, Rural
Primary actors	Host Vehicle, Connected Vehicles, OEM backend, Infrastructure
Secondary actors	Host Vehicle Driver
Preconditions	Host Vehicle is fully aware of the context it is moving in: • Road Geometry and Permanent Attributes. • Connected Vehicles position and path. • Host Vehicle Position and path.
General Description	Vehicles receive real time updates based on data from other vehicles and other devices. This allows to enhance traffic condition awareness and facilitate several other applications that make driving more efficient, safer and more comfortable.
General Requirements	Low Latency. High Bandwidth. High Node Speed.

UC A.14	Bird's Eye View
Goal in context	Providing streaming information, from bird's eye perspective, to approaching vehicles. 
Cluster	Mission Critical Services
Addressed Needs	• Reduction of the frequency and severity of crashes. • Enhanced real time awareness (e.g. of vulnerable road users, other vehicles behaviour or intentions, road status...).
Operating Scenario	Urban, Highway, Rural
Primary actors	Host Vehicle, Connected Vehicles, Infrastructure
Secondary actors	Vehicle Driver

Preconditions	Host Vehicle is fully aware of the context it is moving in: • Road Geometry and Permanent Attributes. • Connected Vehicles position and path. • Host Vehicle Position and path.
General Description	With the help of connectivity, cameras, sensors and Infrastructure, vehicles will be able to receive information about road conditions on every merge-in location (e.g. Intersections), from a bird's eye perspective.
General Requirements	Low Latency. High Bandwidth. High Reliability. High Node Speed.

3.1.4 Automotive - Entertainment

UC A.15	Personalized & Contextual Information
Goal in context	Vehicle able to create personal data field of interest, based on drivers' routines, preferences and actions. 
Cluster	Massive IoT
Addressed Needs	Seamless and convenient integration with daily life
Operating Scenario	Urban, Highway, Rural
Primary actors	Host Vehicle Driver
Secondary actors	Host Vehicle, OEM backend
Preconditions	• Host Vehicle or OEM backend is able to learn driver's preferences and habits • Host Vehicle is fully aware of its Position and path.
General Description	Connected Host Vehicle, thanks to the availability of connected services, is able to offer all information that may be of relevance to the driver's field of interest. (e.g. learning from his habits and common routes, ...), simplifying his daily travels.
General Requirements	High Bandwidth. High Node Speed.

UC A.16	Video streaming
Goal in context	Vehicle able to provide a stream for multimedia contents.

	
Cluster	Enhanced Mobile Broadband
Addressed Needs	Seamless and convenient integration with daily life
Operating Scenario	Urban, Highway, Rural
Primary actors	Host Vehicle Passengers
Secondary actors	Host Vehicle, OEM backend
Preconditions	• Constant connectivity. • System able to receive data.
General Description	Multimedia content (such as movies, tv shows, …) available to the passengers.
General Requirements	High Bandwidth. High Node Speed.

UC A.17	On line gaming
Goal in context	Vehicle able to provide a stream for on line gaming. 
Cluster	Enhanced Mobile Broadband
Addressed Needs	Seamless and convenient integration with daily life
Operating Scenario	Urban, Highway, Rural
Primary actors	Host Vehicle Passengers
Secondary actors	Host Vehicle, OEM backend
Preconditions	• Constant connectivity. • System able to receive and send data.
General Description	On line gaming available to the passengers.
General Requirements	High Bandwidth. High Node Speed.

UC A.18	Augmented reality
Goal in context	The aim is to enhance entarteinment features trough augmented reality.

	
Cluster	Massive IoT/Enhanced Mobile Broadband
Addressed Needs	Seamless and convenient integration with daily life
Operating Scenario	Urban, Highway, Rural
Primary actors	Host Vehicle Passengers
Secondary actors	Host Vehicle, OEM backend
Preconditions	• Constant connectivity.
General Description	All contents (movies, tv shows, games…) available to the passengers are offered in augmented reality.
General Requirements	High Bandwidth. High Node Speed.

3.1.5 Automotive - Digitalized vehicles

UC A.19	**OTA Sw Upgrade**
Goal in context	Vehicles able to identify the problem on software, if existing, repair it instantly and receive an update promptly. 
Cluster	Mission Critical Services
Addressed Needs	Accessible and reactive Maintenance Services
Operating Scenario	Urban, Highway, Rural, Transversal
Primary actors	On-board system, OEM backend, Service Provider
Secondary actors	Infrastructure
Preconditions	• On-board system able to transmit diagnostic data. • On-board system able to update instantly.
General Description	Delivering new updated features, applications or bug fixes Over-the-air enables fast repair/upgrade.
General Requirements	High Bandwidth. High Node Speed.

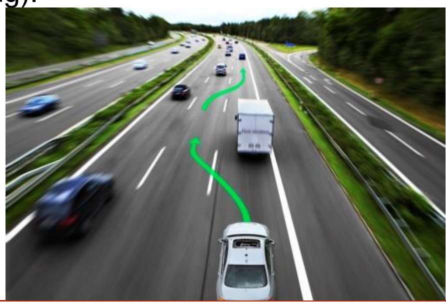
UC A.20	**Remote Driving**
Goal in context	Vehicles able to control and transmit the vehicle information (e.g., the battery level, oil level) to a backend server, therefore it can provide to drivers additional information and possible solutions.

	
Cluster	Massive IoT
Addressed Needs	Accessible and reactive Maintenance Services
Operating Scenario	Urban, Highway, Rural, Transversal
Primary actors	On-board system, OEM backend, Service Provider
Secondary actors	Vehicle Driver
Preconditions	• On-board system able to control and transmit vehicle information.
General Description	Information related to status and health of different components can be detected or even predicted and transmitted to the backend server.
General Requirements	High Bandwidth. Low Latency. High Node Speed.

UC A.21	**Remote Processing for Vehicles**
Goal in context	Remotization of the process load from the vehicle to the cloud, with reduction HW requrements and enhacement of processing capabilities. 
Cluster	Massive IoT
Addressed Needs	• Seamless and convenient integration with daily life. • Accessible and reactive Maintenance Services.
Operating Scenario	Urban, Highway, Rural, Transversal
Primary actors	On-board system, OEM backend, Service Provider
Secondary actors	Vehicle Driver
Preconditions	• On-board system able to control and transmit vehicle information.
General Description	Each application with high processing load and strict latency requirements can transfer, if needed, the computation on OEM Server.
General Requirements	High Bandwidth. Low Latency. High Node Speed.

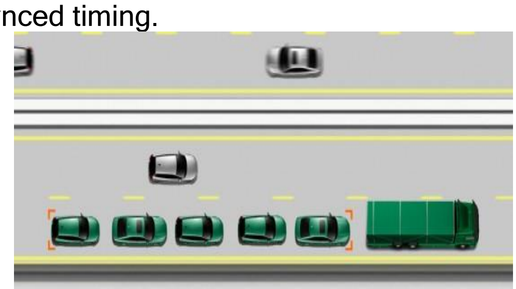
UC A.22	Floating Car Data for Predictive Maintenance
Goal in context	Vehicle able to monitor and predict future Maintenance problems. 
Cluster	Massive IoT
Addressed Needs	Accessible and reactive Maintenance Services
Operating Scenario	Urban, Highway, Rural, Transversal
Primary actors	On-board system, OEM backend, Service Provider
Secondary actors	Vehicle Driver
Preconditions	• On-board system able to monitor and transmit vehicle information.
General Description	Data captured by multiple sensors on the connected car, sent to the Cloud/OEMs backend servers, are continuously aggregated and analyzed to help predicting faults and errors in advance. Alerts are sent to driver when maintenance and repair actions are necessary.
General Requirements	High Bandwidth. High Node Speed.

3.1.6 Automotive - Automated Driving

UC A.23	Automated overtake
Goal in context	The ability to activate the autopilot at a certain moment (e.g. when overtaking). 
Cluster	Mission Critical Services
Addressed Needs	Reduction of the frequency and severity of crashes
Operating Scenario	Highway, Rural
Primary actors	Host Vehicle, Connected Vehicles
Secondary actors	Host Vehicle Driver
Preconditions	Host Vehicle is fully aware of: • Road Geometry and Permanent Attributes. • Connected Vehicles position, speed and path determined in real-time. • Host Vehicle Position, speed and path determined in real-time.

General Description	Thanks to connectivity and cooperation among vehicles, it will be possible to perform (automated) overtake manoeuvers safely.
General Requirements	High Reliability. High Bandwidth. Low Latency. High Node Speed.

UC A.24	Cooperative Collision Avoidance
Goal in context	The ability to exchange trajectories and other essential data in order to avoid a collision. 
Cluster	Mission Critical Services
Addressed Needs	Reduction of the frequency and severity of crashes
Operating Scenario	Urban, Highway, Rural
Primary actors	Host Vehicle, Connected Vehicles
Secondary actors	Vehicle Driver
Preconditions	Host Vehicle is fully aware of: • Road Geometry and Permanent Attributes. • Connected Vehicles position, speed and path determined in real-time. • Host Vehicle Position, speed and path determined in real-time.
General Description	Using the information provided by cooperation among vehicles, collisions can be prevented. When a collision risk is detected, all involved vehicles should undertake to compute the optimal collision avoidance or, when it's not possible, collision mitigation actions and apply them in a cooperative manner.
General Requirements	High Reliability. High Bandwidth. Low Latency. High Node Speed.

UC A.25	High-Density Platooning
Goal in context	Vehicles cooperating and driving very close to each other, with their own synced timing. 

Cluster	Mission Critical Services
Addressed Needs	• Reduction of the frequency and severity of crashes. • Economical saving.
Operating Scenario	Highway
Primary actors	Host Vehicle, Connected Vehicles
Secondary actors	Vehicle Driver
Preconditions	Host Vehicle is fully aware of: • Road Geometry and Permanent Attributes. • Connected Vehicles position, speed and path determined in real-time. • Host Vehicle Position, speed and path determined in real-time.
General Description	The ability of closely placed multiple-vehicles chains can lead to many benefits (such as fuel saving, accident prevention, etc.). In order to maintain the platoon, constant cooperation among all participants is necessary.
General Requirements	High Reliability. High Bandwidth. Low Latency. High Node Speed.

3.2 Entertainment

For each operating scenario, several UCs can be identified:

UC E.01	On-site live event experience
Goal in context	To provide a better fan experience to users attending (on-site) to an event. 
Cluster	Enhanced Mobile Broadband
Addressed Needs	N3: to improve fan experience in closed venues (stadiums)
Operating Scenario	Closed Venue
Primary actors	Fans, network provider, mobile infrastructure provider, IT integrator
Secondary actors	Athletes, GMS provider, event sponsors, RHB, Organization, ticketing provider, time, & scoring provider, press
Preconditions	High number of simultaneous connections. High user data rate. Minimum latency.
General Description	Large scale event sites, such as stadiums are more and more being connected in order to give better experience to their customers (replay, choose a specific camera, language, augmented reality to bring additional information, etc.)
General Requirements	High User Data Rate. High Reliability. Low Latency.

	High Density.

UC E.02	Ultra-high fidelity media
Goal in context	To guarantee a high-quality of content experience for Ultra High Fidelity Media in both closed and open venues. 
Cluster	Enhanced Mobile Broadband
Addressed Needs	N1: to enjoy high-quality contents and services (4k/8k UHD) N3: to improve fan experience in closed venues (stadiums) N4: to improve fan experiences in open areas where fan is on mobility (courses)
Operating Scenario	Closed Venue / Open Venue
Primary actors	Fans, network provider, mobile infrastructure provider, IT integrator
Secondary actors	Athletes, GMS provider, event sponsors, RHB, Organization, ticketing provider, time, & scoring provider, press
Preconditions	High number of simultaneous connections. High user data rate. Minimum latency.
General Description	The next generation of media consumption will be driven by the high definition. Consumers (fans) will demand 4k and 8k quality in their media consumption through their user devices. Both linear (e.g. live programming, streaming) and non-linear (e.g. on-demand) content will be used for providing this Ultra High Fidelity Media experience.
General Requirements	High User Data Rate. High Reliability. Low Latency. High Density.

UC E.03	Immersive and Integrated Media
Goal in context	To provide the fans with immersive experiences from player perspectives to 360-degree views and behind-the-scenes content . 
Cluster	Enhanced Mobile Broadband
Addressed Needs	N2: to ensure real time services (immerse experience, virtual reality). N3: to improve fan experience in closed venues (stadiums). N4: to improve fan experiences in open areas where fan is on

	mobility (courses).
Operating Scenario	Closed Venue / Open Venue
Primary actors	Fans, network provider, mobile infrastructure provider, IT integrator
Secondary actors	Athletes, GMS provider, event sponsors, RHB, Organization, ticketing provider, time, & scoring provider, press
Preconditions	High number of simultaneous connections. High user data rate. Minimum latency.
General Description	Media will become immersive and highly interactive to provide ambient media consumption on-site but also on the move, with content capable of following the users and adapt to his ambient for viewing (e.g. stadium, course, race, etc.) New 5G capabilities will enable immersive video experience, to retransmit holographic type video beyond telepresence (2D) closer to a virtual presence experience in 3D.
General Requirements	High User Data Rate. High Reliability. Low Latency. High Density.

UC E.04	User Generated Content
Goal in context	People and objects are and will capture more and more content in order to share it with others in the cloud. 
Cluster	Enhanced Mobile Broadband
Addressed Needs	N3: to improve fan experience in closed venues (stadiums) N4: to improve fan experiences in open areas where fan is on mobility (courses)
Operating Scenario	Closed Venue / Open Venue
Primary actors	Fans, network provider, mobile infrastructure provider, IT integrator
Secondary actors	Athletes, GMS provider, event sponsors, RHB, Organization, ticketing provider, time, & scoring provider, press
Preconditions	High number of simultaneous connections. High user data rate. Minimum latency.
General Description	People and objects are and will capture more and more content in order to share it with others in the cloud via social networks. Video and virtual reality will be the killer contents of the “user generated content” evolution. Fans will create and consume content generated by them in any sport venue.
General	High User Data Rate.

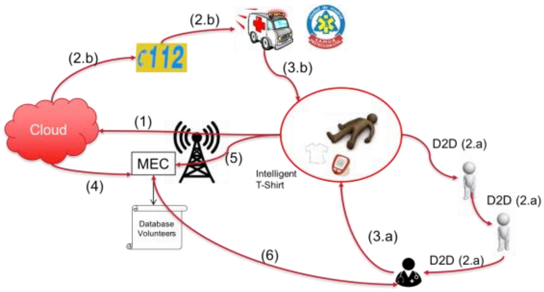
Requirements	High Reliability. Low Latency. High Density.

As a summary, Table 6, shows a mapping of the different UCs with the operating scenarios:

TABLE 6: USE CASES SUMMARY

OPERATING SCENARIO	USE CASES FAMILIES	USES CASES
CLOSED VENUE	DENSE URBAN	UC E01 - On-site live event experience UC E02 - Ultra-high fidelity media UC E03 - Immersive experience UC E04 - User generated content
OPEN VENUE	BROADBAND EVERYWHERE	UC E02 - Ultra-high fidelity media UC E03 - Immersive experience UC E04 - User generated content

3.3 eHealth

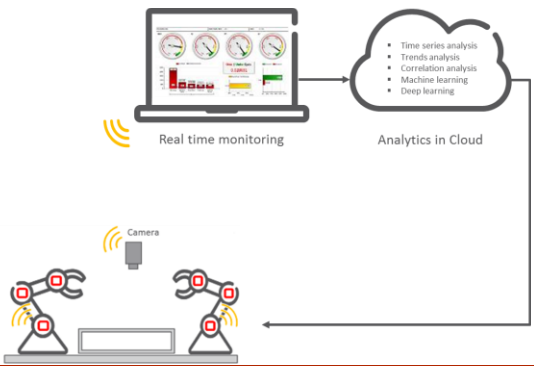
UC H.01	Heart attack emergency
Goal in context	The goal of this use case is to test the request and instantiation of different network slices with different requirements: a network to upload user data from a smart shirt to the cloud; a network to exchange video, audio, patient's electronic health record, etc. between paramedics and doctors in the hospital; and, a network to detect volunteers in the surrounding area to help the patient. 
Cluster	Mission Critical Services
Addressed Needs	NM1 to NM6
Operating Scenario	Mobile
Primary actors	Patient, Paramedic
Secondary actors	Doctor, Nurse, Surgeon
Preconditions	• The user has a wearable with eHealth sensors. • The wearable is connected to the communications network.
General Description	After a heart attack, time is extremely important. In order to guarantee fast response for high risk cardiac patients, they could wear special underwear vests or smartwatches, with sensors and 5G network cards providing connectivity with other devices. With the first symptoms of a heart attack, the user equipment sends an alarm to the eHealth service using any of the available connections (device-to-device communication, 5G cells, etc.). After this initial message, the user equipment and the server

	have to exchange information like the location of the user (which can be provided by the 5G network if this service is available), heart rate, position of the patient (horizontal/vertical), etc. The server may contact the patient by sending a message to his/her mobile phone to detect false alarms. If the user does not answer back the request or confirms the alarm, the provided information is then processed at the server. Then, the eHealth server contacts the proper medical staff, based on where they are located, the equipment they are carrying, etc., no matter if they are in service or not. This staff selection may result in the mobilization of several equipments: doctors, ambulances, police, etc. The eHealth service should establish an ad-hoc communications network for all these public services, sending the proper commands to all of them, coordinating all the process. When the first members of the staff arrive where the patience is located, they have to start with the first aid maneuvers and broadcasting information about the state of the patient becomes crucial. In this case, transmitting video may be helpful for other members of the medical staff to understand the situation. They also receive the patient's clinic history in their tablet, which is valuable information to select the following steps.
General Requirements	High Reliability. Low Latency.

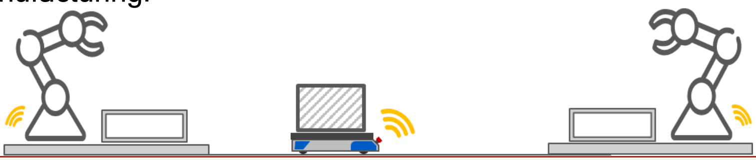
UC H.02	Enviromental information
Goal in context	IoT to generate environmental information that can be analyzed by eHealth servers to detect in advance potential problems of users, that can be informed about areas that should be avoided. 
Cluster	Massive IoT
Addressed Needs	NM1, NM2 and NM5
Operating Scenario	Mobile
Primary actors	Patient
Secondary actors	Doctor (machine)
Preconditions	Sensors are deployed in cities.
General Description	Sensors deployed in a city send information about different parameters, like pollen and pollution degree. This information is analyzed in processing units. After detecting high-levels of a given substance, and based on EHR and location of users, the proper users would receive an alarm in their devices.
General Requirements	Massive connected devices.

UC H.03	Remote surgery
Goal in context	This use case imposes very high requirements to network slices, basically in terms of delay and reliability. 
Cluster	Mission Critical Services
Addressed Needs	NS3
Operating Scenario	Static
Primary actors	Patient and Surgeon
Secondary actors	Nurses
Preconditions	No preconditions
General Description	A surgeon may help other local surgeons, or completely replace local surgeons to perform remote surgeries, managing local robots. This use case requires haptic technologies, which requires high bandwidth and low latency in the underlying communication network.
General Requirements	High Bandwidth. Low Latency.

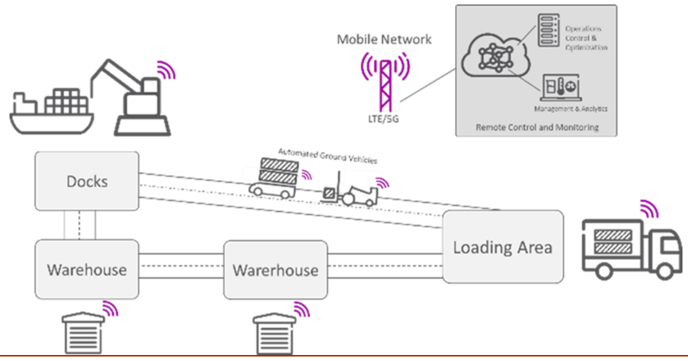
3.4 e-Industry

UC I.01	Monitoring
Goal in context	Sensors are used to constantly monitor essential production line equipment and the production status. Collected data are processed in real time in cloud by analytics functions for preventive maintenance. 
Cluster	Massive IoT
Addressed Needs	Maintain the equipment in optimum working condition, preventing any unplanned downtime due to breakdowns.
Operating Scenario	Indoor controlled scenario, factory, warehouse
Primary actors	Fixed robots, Automated Guided Vehicles, sensors, inertial measurement units

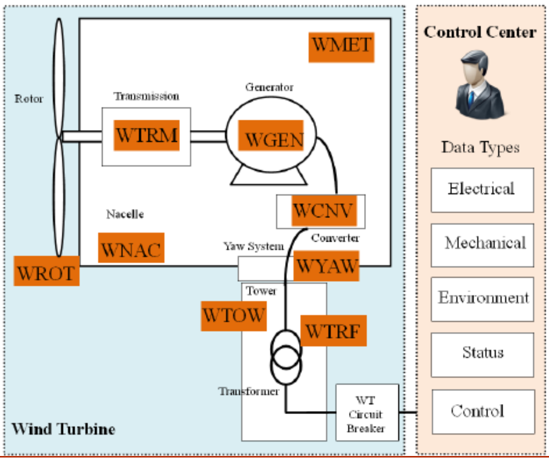
Secondary actors	Supervision personnel
Preconditions	Connection of sensors, possibly wireless, control of electromagnetic noise.
General Description	Enable remote monitoring in real time, for preventive maintenance, with wireless connected sensors, and provides analytics in cloud to centralize the information processing.
General Requirements	Bandwidth: 2-3 Mbit/min

UC I.02	Cloud robotics
Goal in context	Highly automation of the factory plant is provided moving the control of the production processes and of the robots functionalities in cloud, exploiting wireless connectivity to minimize infrastructure, optimize processes, implement lean manufacturing. 
Cluster	Mission Critical Services
Addressed Needs	• Increase flexibility in a production line. • Reduce infrastructures.
Operating Scenario	Indoor controlled scenario, factory, warehouse
Primary actors	Fixed robots interacting with AGVs
Secondary actors	
Preconditions	Wireless communication, control of electromagnetic noise
General Description	The controlling functionality of the robots is moved to the cloud, in order to utilize its massive computing power. This requires the development of an innovative system architecture, which allows the robots to 'talk' to the cloud, via a wireless network infrastructure. In order for the robots to be able to interact with their environment in real-time, huge amounts of information will have to be transferred instantaneously. With lower latency and higher bandwidth than other forms of wireless connectivity, 5G is the optimal choice.
General Requirements	• Latency: time delay between data being generated at a sensor and the same data being correctly received by the actuator, whatever there is in between. • Reliability: capability of guaranteeing successful message transmissions within a defined latency budget or delay. In industrial automation, only one message in one billion data transfers may be lost or delayed within the given latency budget. • Availability: is the probability that a system will work as required in a given period. This typically imposes a "5-nines" availability on wireless links.

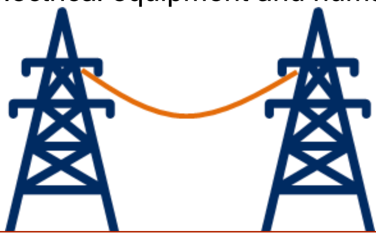
UC I.03	Automated logistics

Goal in context	Robotized logistics in a port environment to enhance efficiency in the logistic chain in the port and in the infrastructures connecting the port area. 
Cluster	Mission Critical Services
Addressed Needs	• Increase the amount of the handled containers in a given area. • Reduce the waiting time for trucks and trains serving the port area. • Include the safety especially in handling dangerous materials. • Provide robotic assistance for safe and heavy operations and automated container load/unload (e.g. fine positioning of trucks under the cranes).
Operating Scenario	Large area outdoor, like port
Primary actors	Automated ground vehicles, sensors, ships, pilots, cranes
Secondary actors	Trucks, pedestrians, ship passengers, bikers, cyclists, depots, warehouses
Preconditions	Regulations that authorized the use of autonomous vehicles
General Description	Sea ports are remarkable “smart spaces” where people, sensors, and vehicles interact. Functions and services are targeted to humans and machines and services depend on the chain connecting sensors and information systems through networks. Use of cloud robotics will bring more efficiency in the logistic chain in the port and in the infrastructures connecting the port area. For example, a container has just been unloaded from the vessel. Instead of contacting the distribution center by phone and asking them to move the container to a specific destination, an intelligent infrastructure allows the container to communicate directly with both the target destination and all the automated machines and humans along the supply chain. Coordination and control in cloud will ensure that an automatic vehicle with deliver the container at the desired destination, being a truck or a warehouse.
General Requirements	• Latency: time delay between data being generated at a sensor and the same data being correctly received by the actuator, whatever is in between. • Reliability: capability of guaranteeing successful message transmissions within a defined latency budget or delay. In industrial automation, only one message in

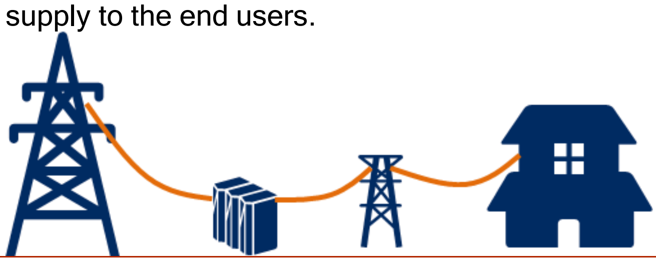
	one billion data transfers may be lost or delayed within the given latency budget. • Availability: is the probability that a system will work as required in a given period. This typically imposes a “5-nines” availability on wireless links. • Support of narroband technologies with extremely low energy consumptions (e.g. NB-IoT) for connecting tags or sensors which needs to transmit few bytes.

UC I.04	Electrical utilities: Generation
Goal in context	The remote control of the power generation process is critical to maximize net revenue, particularly in wind power farms where the energy income is volatile. 
Cluster	Mission Critical Services
Addressed Needs	• Control of generated power. • Protection of generation infrastructure
Operating Scenario	Wind Power Farm
Primary actors	Wind Power Farm logical nodes and facility operators
Secondary actors	N/A
Preconditions	N/A
General Description	The electrical power generation frequency must be maintained within a very narrow band. Deviations from the acceptable frequency range are detected and the required signals are sent to the power plants for frequency regulation. Automatic Generation Control (AGC) is a system for adjusting the power output of generators at different power plants, in response to changes in the load. Moreover, the control of the generation infrastructure combines requirements from industrial automation systems and energy generation systems.
General Requirements	• One way maximum delay: time delay between data being generated at a sensor and the same data being correctly received by the actuator, whatever is in between. • Availability: is the probability that a system will work as required in a given period. This typically imposes a “4-nines” availability on wireless links. • Support of narrowband technologies with extremely low energy consumptions (e.g. NB-IoT) for connecting tags or

	sensors which needs to transmit few bytes. • Packet loss rate: generally around 1%. • Precise time synchronization.

UC I.05	Electrical utilities: Transmission
Goal in context	Remote control of electrical equipment over large distances in the transmission domain of an electrical supplier to ensure the protection of the electrical equipment and human operators. 
Cluster	Mission Critical Services
Addressed Needs	• Protection of human operators. • Protection of electrical equipment.
Operating Scenario	Transmission segment of an electrical network
Primary actors	Human operators and transmission equipment
Secondary actors	Electricity users
Preconditions	N/A
General Description	The key criteria for measuring Teleprotection performance are command transmission time, dependability and security. These criteria are defined by the IEC standard 60834 as follows: Transmission time (Speed): The time between the moment where state changes at the transmitter input and the moment of the corresponding change at the receiver output, including propagation delay. Overall operating time for a Teleprotection system includes the time for initiating the command at the transmitting end, the propagation delay over the network (including pieces of equipment) and the selection and decision time at the receiving end, including any additional delay due to a noisy environment. Dependability: The ability to issue and receive valid commands in the presence of interference and/or noise, by minimizing the probability of missing command (PMC). Dependability targets are typically set for a specific bit error rate (BER) level. Security: The ability to prevent false tripping due to a noisy environment, by minimizing the probability of unwanted commands (PUC). Security targets are also set for a specific bit error rate (BER) level. Additional elements of the Teleprotection system that impact its performance include: (i) Network bandwidth, and (ii) Failure recovery capacity (aka resiliency).
General Requirements	Most power line equipment can tolerate short circuits or faults for up to approximately five power cycles before sustaining irreversible damage or affecting other segments in the network. This translates to total fault clearance time of 100ms. As a safety precaution, however, actual operation time of protection systems is limited to 70- 80 percent of this period, including fault recognition time, command transmission time and line breaker switching time. Some system components, such as large

	electromechanical switches, require particularly long time to operate and take up the majority of the total clearance time, leaving only a 10ms window for the telecommunications part of the protection scheme, independent of the distance to travel. Given the sensitivity of the issue, new networks impose requirements that are even more stringent: IEC standard 61850 limits the transfer time for protection messages to 1/4 - 1/2 cycle or 4 - 8ms (for 60Hz lines) for the most critical messages. Teleprotection channels which are differential must be synchronous, which means that any delays on the transmit and receive paths must match each other. Teleprotection systems ideally support zero asymmetric delay; typical legacy relays can tolerate delay discrepancies of up to 750us. Some tools available for lowering delay variation below this threshold are: • For legacy systems using Time Division Multiplexing (TDM), jitter buffers at the multiplexers on each end of the line can be used to offset delay variation by queuing sent and received packets. The length of the queues must balance the need to regulate the rate of transmission with the need to limit overall delay, as larger buffers result in increased latency. • For jitter-prone IP packet networks, traffic management tools can ensure that the Teleprotection signals receive the highest transmission priority to minimize jitter. • Standard packet-based synchronization technologies, such as 1588-2008 Precision Time Protocol (PTP) and Synchronous Ethernet (Sync-E), can help keep networks stable by maintaining a highly accurate clock source on the various network devices.

UC I.06	Electrical utilities: Distribution
Goal in context	Remote and automated fault recovery in the distribution domain of an electrical supplier to ensure ubiquitous and continuous energy supply to the end users. 
Cluster	Mission Critical Services
Addressed Needs	Fault Location Isolation and Service Restoration (FLISR)
Operating Scenario	Distribution domain of an electrical network
Primary actors	Electrical equipment and end users of electrical utilities
Secondary actors	N/A
Preconditions	N/A
General Description	Fault Location, Isolation, and Service Restoration (FLISR) refers to the ability to automatically locate the fault, isolate the fault, and restore service in the distribution network. This will likely be the first widespread application of distributed intelligence in the

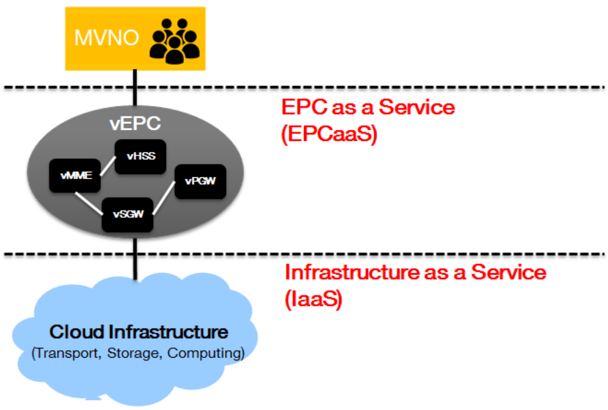
	grid. Static power switch status (open/closed) in the network dictates the power flow to secondary substations. Reconfiguring the network in the event of a fault is typically done manually on site to energize/de-energize alternate paths. Automating the operation of substation switchgear allows the flow of power to be altered automatically under fault conditions. FLISR can be managed centrally from a Distribution Management System (DMS) or executed locally through distributed control via intelligent switches and fault sensors.
General Requirements	• Latency: time delay between data being generated at a sensor and the same data being correctly received by the actuator, whatever there is in between. • Jitter: Variability in latency performance. • Availability: is the probability that a system will work as required in a given period. This typically imposes a "4-nines" availability on wireless links. • Redundancy. • Packet loss: Ratio of packet losses, generally around 0.1% • Precise synchronization.

3.5 MNO/MVNO

In the following, we detail several considered use cases, classified between:

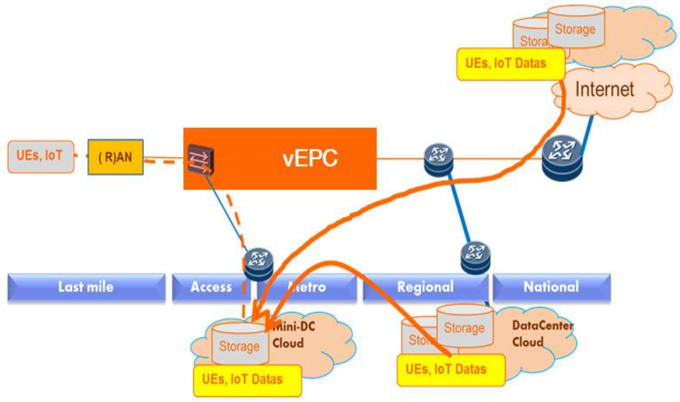
- The most generic use cases for MNO/MVNO operations, that can serve as basis for serving in a slice different types of 5G network services. It has to be noticed that these use cases remain quite generic, the can serve MVNO purposes but also other verticals ones'. They allow addressing different types of clusters.
- More specific use cases for the case of MVNO building a MCPTT service.

3.5.1 Typical MVNO use cases

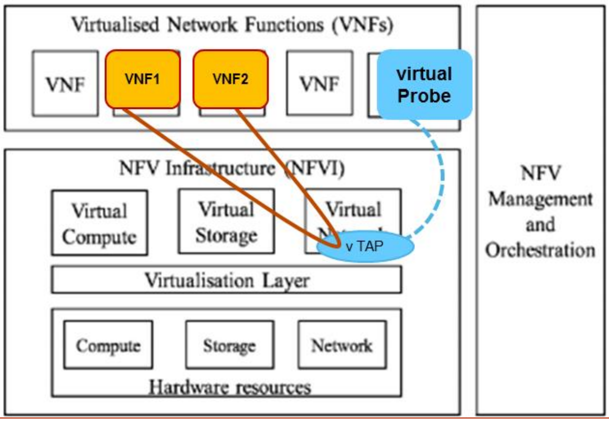
UC M.01	**vEPCaaS**
Goal in context	Build of a MVNO service through the deployment and operation of a network slice with a vEPC in as a Service mode. 
Cluster	Enhanced Mobile Broadband, Massive IoT
Addressed Needs	• Configurable and on-demand creation of a virtual EPC for an MVNO, following MVNO needs and requirements.

	• Increase network capacity and network elasticity through the virtualization of network functions. • Possibility to choose to deploy all or only relevant vEPC network entities, depending of the end user's needs. • Address verticals requiring ultra-reliable connectivity (like critical business activities in the industry) and/or ultra-low-latency (like Mission Critical services called MCPTT). • Need to tailor fine grained services for verticals with on-demand QoS and adapted charging policies based on vertical services requirements. • Need for dynamic vertical services creation, management and configuration tools. • Ability to deploy services over federated network infrastructure resources when the network infrastructure is owned by another MNO or non telco player (federation at the MTP level).
Operating Scenario	MNO/MVNO
Primary actors	MNO, MVNO, end user
Secondary actors	3rd party resource provider
Preconditions	• ownership of a NFV infrastructure by the MNO • connectivity with a radio access and transport network
General Description	The vEPC can be instantiated as a virtualized Control plane only or as a complete virtualized Control and User planes core network. The vEPC is supposed to provide the same implementation and performances of a real EPC that is deployed on a real infrastructure. The use of a vEPC should be totally transparent and should not impact services end to end latency.
General Requirements	• Maintaining the complete consistency with legacy networks. • Behave transparently as a non-cloudified implementation of EPC. • Full compliance with the 3GPP standards. • Latency <1s for the signaling in the control plane. • Capability to adapt the QoS allocation and throughput at the user plane according to the user application flow type (minimum value of throughput depends on the service type).

UC M.02	**Cloud data for URLLC**
Goal in context	In the context of vEPC in a slice operation, direct access with low delay to distributed cloud services available at the edge of the network.

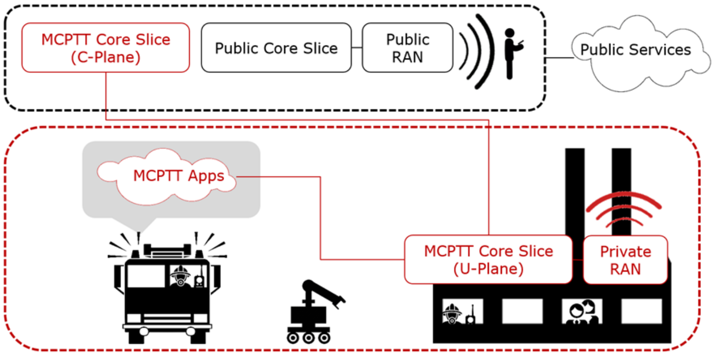
	
Cluster	Enhanced Mobile Broadband, Massive IoT
Addressed Needs	• Need for efficient MEC-like infrastructures at the edge networks to host appliances like video analytics or geo-messaging servers. • Need for local content/video processing resources at the network edges in order to answer to new market needs like vehicular services and smart cities. • Provide users Data as close as possible of the users for URLLC services in order to reduce end to end latency.
Operating Scenario	MNO/MVNO
Primary actors	MNO, MVNO, end user
Secondary actors	3rd party resource provider
Preconditions	• Implement a vEPC. • Implement traffic offload mechanisms in the vEPC to offload the traffic between different data storage infrastructures/cloud.
General Description	This use case is supposed to introduce different levels of data storage depending on service type (better fluidity, speed, reactivity for the UEs) for URLLC. It allows for an MNO or an MVNO to optimize the Core network resources providing local cloud services.
General Requirements	• Administrate and configure a dynamic data cloud service over several distributed data centers • Ability to detect the path on which the traffic data need to be transmitted. • Ability to define and deploy Mini-cloud data services in access/Metro area. • Ability to define dedicated internal slices for inter-cloud communication. • Ability to reroute the user traffic flows towards dedicated slice. • Ability to define the best area (access or metro or regional) for "local cloud" depending on the Service type. • Latency between 1 and 5 ms.

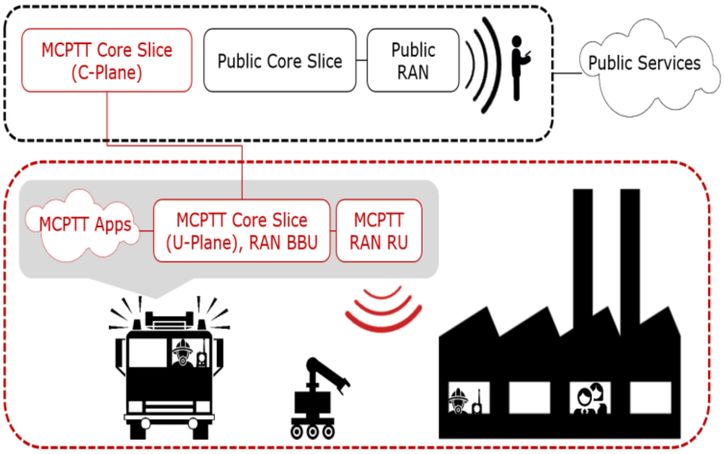
UC M.03	vMonitoring as a Service

Goal in context	Traffic monitoring between VNF instantiated in the 5G network. 
Cluster	Enhanced Mobile Broadband
Addressed Needs	• Need for tools and solutions for data monitoring at different levels of the architecture in order to enforce network policies and help data harnessing and network data analytics. • Need for traffic probing systems able to monitor either the control plane or the data plane traffic that is delivered at any point in the network (i.e. though physical links or virtualized one's), feeding analysis, monitoring and troubleshooting applications.
Operating Scenario	MNO/MVNO operations
Primary actors	MNO, MVNO
Secondary actors	3rd party resource provider
Preconditions	NA
General Description	In order to provide MNO/MVNO with adapted monitoring tools, virtual TAP and virtual probes appliances need to be instantiated dynamically in the MTP, depending on the operator's needs (traffic passive analysis, troubleshooting, operations...)
General Requirements	Administrate and configure a passive traffic monitoring service over several, possibly distributed, data centers: • Ability to detect the virtual bridges on which the traffic mirroring need to be activated. • Ability to define and deploy passive and scalable traffic probes. • Ability to mirror traffic flows between VNF. • Ability to transport the mirrored flows to the ad-hoc virtual Probe.

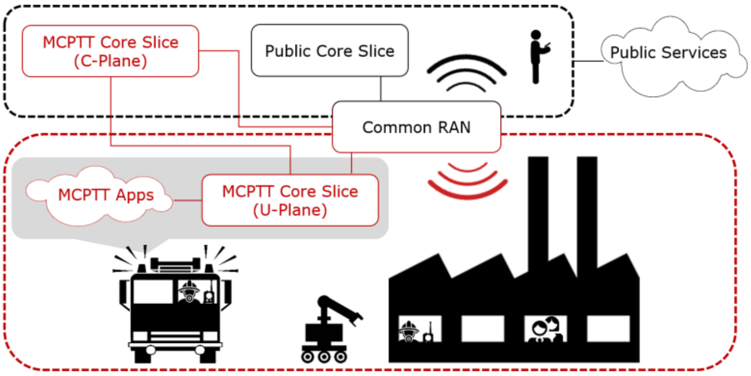
3.5.2 MCPTT MNO use cases

UC M.04	MCPTT network deployment using private RAN
Goal in context	Build a network with MCPTT services in case of an emergency intervention, leveraging on private infrastructure resources.

	
Cluster	Mission Critical Services
Addressed Needs	• Need for horizontal slicing capability at the MNO level to enable SLA commitment to each Mission Critical Service Provider and allow complete isolation between MC and non-MC traffic. • Need for the capability to dynamically instantiate a virtual network to provide communication services locally to an emergency intervention depending on Mission Critical Service Provider consumption demand • Need for an on-demand MCPTT vertical network slice deployment spanning both MCPTT Service Provider and MNO networks. The instantiation of the slice shall be completed within minutes. • Need for means/tools to adjust in real time calls priority and QoS depending on user state, role, location, incident severity, etc. • Need for the capability to federate external resources (brought by MCPTT SP or provided by a private party) with those made available by the MNO to provide the service.
Operating Scenario	Limited area, stationary, short response time deployment (VNF, connectivity to PNF), heterogeneous infrastructure
Primary actors	MCPTT provider, MCPTT user
Secondary actors	MNO, 3rd party resource provider
Preconditions	The private infrastructure provider grants the MC organization to access to its radio and compute resources.
General Description	The MC organization relies on the private infrastructure to build communication services that support the emergency operation. The control plane is leveraging on the MNO network service such as call admission while the user plane service is deployed on local resources and connected to the local points of access (eNB, IoT gateway, WiFi, …)
General Requirements	• Sharing private resources with SLA guaranteed. • Isolation of MC traffic for security. • Prioritization of MC communications in signaling handling, transport layer and processing. • Public and private infrastructures federation to support services. • Resilience.

<table>
<tr><th>UC M.05</th><th>MCPTT network deployment using local dedicated RAN</th></tr>
<tr><td>Goal in context</td><td>Build a network with MCPTT services over on-boarded infrastructure in case of an emergency intervention.

</td></tr>
<tr><td>Cluster</td><td>Mission Critical Services</td></tr>
<tr><td>Addressed Needs</td><td>Need for horizontal slicing capability at the MNO level to enable SLA commitment to each Mission Critical Service Provider and allow complete isolation between MC and non-MC traffic.
Need for the capability to dynamically instantiate a virtual network to provide communication services locally to an emergency intervention depending on Mission Critical Service Provider consumption demand
Need for an on-demand MCPTT vertical network slice deployment spanning both MCPTT Service Provider and MNO networks. The instantiation of the slice shall be completed within minutes.
Need for means/tools to adjust in real time calls priority and QoS depending on user state, role, location, incident severity, etc.
Need for the capability to federate external resources (brought by MCPTT SP or provided by a private party) with those made available by the MNO to provide the service.</td></tr>
<tr><td>Operating Scenario</td><td>Limited area, stationary, short response time deployment, heterogeneous infrastructure</td></tr>
<tr><td>Primary actors</td><td>MCPTT provider, MCPTT user</td></tr>
<tr><td>Secondary actors</td><td>MNO, 3rd party resource provider</td></tr>
<tr><td>Preconditions</td><td>Computation and radio resources are on-board of MC vehicles or transported nearby.</td></tr>
<tr><td>General Description</td><td>MC organization brings its own radio and computation resource at the intervention place. It deploys the RAN and the user plane locally while the control plane is provided as a service by the MNO.</td></tr>
<tr><td>General Requirements</td><td>Sharing private resources with SLA guaranteed.</td></tr>
</table>

	• Isolation of MC traffic for security. • Prioritization of MC communications in signaling handling, transport layer and processing. • Public and MC organization infrastructures federation to support services. • Resilience.

UC M.06	MCPTT network deployment using local dedicated RAN
Goal in context	Build a network with MCPTT services over operator's RAN in case of an emergency intervention. 
Cluster	Mission Critical Services
Addressed Needs	• Need for horizontal slicing capability at the MNO level to enable SLA commitment to each Mission Critical Service Provider and allow complete isolation between MC and non-MC traffic. • Need for the capability to dynamically instantiate a virtual network to provide communication services locally to an emergency intervention depending on Mission Critical Service Provider consumption demand • Need for an on-demand MCPTT vertical network slice deployment spanning both MCPTT Service Provider and MNO networks. The instantiation of the slice shall be completed within minutes. • Need for means/tools to adjust in real time calls priority and QoS depending on user state, role, location, incident severity, etc. • Need for the capability to federate external resources (brought by MCPTT SP or provided by a private party) with those made available by the MNO to provide the service.
Operating Scenario	Limited area, stationary, short response time deployment, prioritization management by MNO
Primary actors	MCPTT provider, MCPTT user
Secondary actors	MNO, 3rd party resource provider
Preconditions	Public radio coverage at the intervention place
General Description	MC organization relies on the MNO infrastructure (radio and core networks) to cover the intervention, but MC user communication data are local to the intervention place.

General Requirements	• Guaranty of SLA. • Isolation of MC traffic for security. • Prioritization of MC communications in signaling handling, transport layer and processing. • Resilience.

4 High-level requirements for Verticals

In this section, the general requirements for each vertical domain are defined. The final goal is to illustrate how 5G, and more specifically 5G-TRANSFORMER, will be able to address significantly different requirements contemporary.

The methodology applied here consists of 3 phases:

1. Listing of requirements qualifying the services.
2. Matching the UCs requirements to the KPIs.
3. Pointing out the different requirements that shall be satisfied contemporary.

The first step consists of listing the requirements qualifying the services. In this stage the assumptions necessary for the realization of each UC shall be listed. For example, in general, it is assumed that in all the UCs the devices use a 5G connection, so a 5G router will be required.

For each requirement, the following fields should be provided:

ID	Requirement	# UC	F/NF
ReqX.XX	e.g. The vehicle shall be connected to a 5G router	XX.XX	F/NF

The meanings of the fields are as follows:

- **ID**: is the identifier of the requirement (written in the form ReqX.XX).
- **Requirement**: a complete sentence explaining the requirement.
- **#UC**: the number of UC (in section 3) which is interest by the requirement.
- **Man**, as the abbreviation of “mandatory”: if the requirement is necessary (Yes) or optional (No).
- **F/NF**: if the requirement is Functional (F) or Non Functional (NF).

NOTE: The Requirement field is written following the approach followed by IETF documents, included next. The key words “must”, “must not”, “required”, “shall”, “shall not”, “should”, “should not”, “recommended”, “may” and “optional” in this document are to be interpreted as described in [21].

1. **MUST** This word, or the terms “**REQUIRED**” or “**SHALL**”, mean that the definition is an absolute requirement of the specification.
2. **MUST NOT** This phrase, or the phrase “**SHALL NOT**”, mean that the definition is an absolute prohibition of the specification.
3. **SHOULD** This word, or the adjective “**RECOMMENDED**”, mean that there may exist valid reasons in particular circumstances to ignore a particular item, but the full implications must be understood and carefully weighted before choosing a different course.
4. **SHOULD NOT** This phrase, or the phrase “**NOT RECOMMENDED**” mean that there may exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
5. **MAY** This word, or the adjective “**OPTIONAL**”, mean that an item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because the vendor feels that it enhances the product

while another vendor may omit the same item. An implementation which does not include a particular option MUST be prepared to interoperate with another implementation which does include the option, though perhaps with reduced functionality. In the same vein, an implementation which does include a particular option MUST be prepared to interoperate with another implementation which does not include the option (except, of course, for the feature the option provides.).

According to [22], and [23], the following definitions are used to provide precise application-specific requirements:

- **End-to-end latency (ms)**

  E2E latency, or one trip time (OTT) latency, refers to the time it takes from when a data packet is sent from the transmitting end to when it is received at the receiving entity, e.g., internet server or another device.

- **Reliability (10^{-x})**

  Refers to the continuity in the time domain of correct service and is associate with a maximum latency requirement. More specifically, reliability accounts for the percentage of packets properly received within the given maximum E2E latency (OTT or RTT depending on the service).

- **User Data rate (Mbit/s)**

  Minimum required bit rate for the application/service to function correctly.

- **Availability (related to coverage)**

  The availability in percentage is defined as the number of places (related to a predefined area unit or pixel size) where the QoE level requested by the end-user is achieved divided by the total coverage area of a single radio cell or multi-cell area (equal to the total number of pixels) times 100.

- **Mobility (km/h)**

  No: static users.

  Low: pedestrians (0-3 km/h).

  Medium: slow moving vehicles (3-50 km/h).

  High: fast moving vehicles, e.g., cars and trains (>50 km/h).

- **Device density (devices/km^2)**

  Maximum number of devices per unit area under which the specified reliability should be achieved.

- **Positioning accuracy (cm)**

  Maximum positioning error tolerated by the application, where a high positioning accuracy means a little error.

- **Confidentiality**

  Preserving authorized restrictions on information access and disclosure, including means for protecting personal privacy and proprietary information.

- Basic: The unauthorized disclosure of information could be expected to have a limited adverse effect on organizational operations, organizational assets, or individuals.
- Moderate: The unauthorized disclosure of information could be expected to have a serious adverse effect on organizational operations, organizational assets, or individuals.
- Elevated: The unauthorized disclosure of information could be expected to have a severe or catastrophic adverse effect on organizational operations, organizational assets, or individuals.

➢ **Integrity**

Guarding against improper information modification or destruction, and includes ensuring information non-repudiation and authenticity.

- Basic: The unauthorized modification or destruction of information could be expected to have a limited adverse effect on organizational operations, organizational assets, or individuals.
- Moderate: The unauthorized modification or destruction of information could be expected to have a serious adverse effect on organizational operations, organizational assets, or individuals.
- Elevated: The unauthorized modification or destruction of information could be expected to have a severe or catastrophic adverse effect on organizational operations, organizational assets, or individuals.

➢ **Availability (related to resilience)**

Ensuring timely and reliable access to and use of information.

- Basic: The disruption of access to or use of information or an information system could be expected to have a limited adverse effect on organizational operations, organizational assets, or individuals.
- Moderate: The disruption of access to or use of information or an information system could be expected to have a serious adverse effect on organizational operations, organizational assets, or individuals.
- Elevated: The disruption of access to or use of information or an information system could be expected to have a severe or catastrophic adverse effect on organizational operations, organizational assets, or individuals.

➢ **Traffic type**

Depending on to the amount of data flowing across a network at a given point of time, the traffic can be:

- Continuous
- Bursty
- Event driven
- Periodic
- All types.

➢ **Communication range(m)**

Maximum distance between source and destination(s) of a radio transmission within which the application should achieve the specified reliability.

- **Infrastructure**
  Limited: no infrastructure available or only macro cell coverage.
  Medium density: Small number of small cells.
  Highly available infrastructure: Big number of small cells available.
- **Energy reduction**
  Reduction of the energy consumption of the overall system. The most common metric that is used to characterize this KPI is the reduction in the consumed Joules per delivered bit.
- **Cost**
  Expenditure of resources, such as time, materials or labor, for the attainment of a certain HW or SW module. OPEX and CAPEX are important components of the overall costs.
- **Service creation time**
  Time required to provision a service, measured since a new service deployment is requested until the overall orchestration system provides a response (a positive response implies the service has been actually provisioned).

According to the above defined requirements, for clustering the use cases, the following KPIs are defined (Table 7):

TABLE 7: TABLE OF DEFINED KPIS FOR HIGH-LEVEL REQUIREMENTS FOR VERTICALS

	Low	Medium	High
End-to-end latency [ms]	1-10	10-50	>50
Reliability [%]	<95	95-99	>99
User data rate [Mbit/s]	<50	50-100	100-1000
Density [devices/km^2]	<1000	1000-10000	≥10000
Mobility [km/h]	<3	3-50	>50
Type of Traffic	Event Driven/Periodic	Bursty/Continuous	All types
Availability (related to coverage)	<95	95-99	>99
Positioning accuracy (cm)	100-1000	30-100	<30
Confidentiality	Basic	Moderate	Elevated
Integrity	Basic	Moderate	Elevated
Availability (related to resilience)	Basic	Moderate	Elevated
Communication range (m)	<300	300-800	>800
Infrastructure	Limited	Medium density	Highly available

Energy reduction	<20%	20-80%	>80%
Cost[4]	TBD in Task 1.3	TBD in Task 1.3	TBD in Task 1.3
Service creation time	<90 seconds	90 minutes	>90 hours

Once defined the KPIs, the methodology consists of matching the UCs requirements illustrated in the previous sections to the KPIs.

UCs clustered to different groups might be in use at the same time. From a network point of view, this implies the necessity to satisfy very different requirements contemporary. To clarify, the following scenario can be envisioned as an example. A father is driving in a urban environment: cooperative navigation application is in use to avoid traffic jams and during the travel he might receive warnings of detection of vulnerable road users. In the meanwhile, his children are watching a film in augmented reality. All these actions are contemporary; this means that 5G is supposed to satisfy the strict-latency issues due to safety application, to process all the traffic information received by the vehicles and to ensure a sufficient amount of band to allow the passengers to watch the film. The ability to support this wide range of services is probably the most important challenge of 5G.

The following section illustrates general requirements for each vertical.

4.1 Automotive

In according to the application scenario, the requirements of automotive domain could be very diverse and challenging. In the following, the most challenging requirements for the automotive use cases are provided (Table 8).

TABLE 8: GENERAL REQUIREMENTS FOR AUTOMOTIVE DOMAIN

ID	Requirement	# UC	F/NF
ReqA.01	All vehicles shall be equipped with 5G router.	A.all	F
ReqA.02	All connected vehicles shall be able to exchange agreed information (those linked to context awareness), regardless the connectivity Provider	A.01, A.02, A.04, A.06, A.07, A.08, A.09, A.10, A.11, A.12, A.13, A.14, A.23, A.24, A.25	F
ReqA.03	All connected vehicles shall be able to exchange agreed information (linked to context awareness), regardless of a different car manufacturer.	A.01, A.02, A.04, A.06, A.07, A.08, A.09, A.10, A.11, A.12, A.13, A.14, A.23, A.24,	F

[4] The cost analysis will be performed in Task 1.3, therefore the results are not yet available.

		A.25	
ReqA.04	All vehicles shall be able to transmit information in roaming.	A.all	F
ReqA.05	Cloud shall be able to receive, process, and send all information to connected vehicles.	A.11 , A.12 , A.13 , A.10 , A.08, A.04 , A.15 , A.16 , A.17 , A.18 , A.19 , A.20 , A.21 , A.22	F
ReqA.06	Infrastructure shall be able to communicate with connected vehicles and provide additional information.	A.02, A.09, A.11, A.12, A.13, A.14, A.07, A.19	F
ReqA.07	On-board system shall be able to monitor, recognize, control and transmit vehicle information.	A.all	F
ReqA.08	Service Provider shall be able to receive information from the vehicle and provide appropriate feedback.	A.19, A.20, A.21, A.22	F
ReqA.09	Wearable devices may be able to monitor and react if previously defined behavior is detected.	A.03	F
ReqA.10	Smart electronic consumer devices shall be able to transmit (stream) all received video information.	A.04, A.10, A.13, A.14, A.15, A.16, A.17, A.18	F
ReqA.11	Drones may be able to cooperate with specified connected vehicle and transmit information.	A.07, A.14, A.24	F
ReqA.12	Navigation system shall be able to transmit information and adapt to it.	A.06, A.08, A09	F
ReqA.13	Vulnerable Road Users shall be able to communicate with connected vehicles.	A.05	F
ReqA.14	End-to-end latency shall be in the range of 10-50 ms.	A.01, A.02, A.04, A.05, A.11, A.12, A.13, A.14, A.23, A.24, A.25	NF
ReqA.15	Reliability shall be more than 99%.	A.01, A.02, A.03, A.04, A.05, A.06, A.07, A.09,	NF

		A.10, A.11, A.12, A.13, A.14, A.23, A.24, A.25	
ReqA.16	User data rate shall be higher than 100 Mb/s.	A.18	NF
ReqA.17	Mobility shall be higher than 50 km/h.	A.all	NF
ReqA.18	Availability (related to coverage) shall be higher than 99%.	A.01, A.02, A.03, A.04, A.05, A.06, A.07, A.08, A.09, A.10, A.11, A.12, A.13, A.14	NF
ReqA.19	Positioning accuracy shall be less than 30 cm.	A.01, A.02, A.04, A.05, A.06, A.07, A.09, A.10, A.11, A.12, A.13, A.14, A.23, A.24, A.25	NF
ReqA.20	Confidentiality shall be elevated.	A.15, A.16, A.17, A.18, A.19, A.20, A.21, A.22	NF
ReqA.21	Integrity shall be elevated.	A.01, A.02, A.03, A.04, A.05, A.06, A.07, A.08, A.10, A.11, A.12, A.13, A.14, A.19, A.20, A.21, A.23, A.24, A.25	NF
ReqA.22	Availability (related to resilience) shall be elevated.	A.01, A.02, A.03, A.04, A.05, A.07, A.11, A.12, A.13, A.14, A.15, A.20, A.22, A.23, A.24, A.25	NF
ReqA.23	In urban scenarios, the system shall operate in	A.01, A.02,	NF

	density higher than 10000/km^2.	A.03, A.04, A.05, A.06, A.07, A.08, A.09, A.10, A.11, A.12, A.13, A.14, A.15, A.16, A.17, A.18, A.19, A.20, A.21, A.22, A.24	
ReqA.24	Traffic shall be continuous.	A.14, A.16, A.18	NF
ReqA.25	Traffic shall be bursty.	A.01, A.02, A.03, A.04, A.05, A.06, A.07, A.08, A.09, A.10, A.11, A.12, A.13, A.14, A.15, A.19, A.20, A.21, A.22, A.23, A.24, A.25	NF
ReqA.26	Traffic shall be event driven.	A.01, A.02, A.03, A.05, A.06, A.07, A.08, A.09, A.11, A.12, A.13, A.14, A.15, A.18, A.19, A.20, A.21, A.22, A.23, A.24, A.25	NF
ReqA.27	Traffic shall be periodic.	A.01, A.02, A.03, A.05, A.06, A.07, A.08, A.09, A.10, A.13, A.14, A.24, A.25	NF
ReqA.28	Traffic shall be all types.	A.01, A.02, A.03, A.04, A.05, A.06,	NF

		A.07, A.08, A.09, A.10, A.11, A.12, A.13, A.14, A.15, A.16, A.17, A.18, A.19, A.20, A.21, A.22, A.23, A.24, A.25	
ReqA.29	Communication range shall be higher than 800 m.	A.06, A.08, A.09, A.10, A.11, A.12, A.15, A.16, A.17, A.18, A.19, A.20, A.21, A.22, A.23,	NF
ReqA.30	Infrastructure shall be highly available.	A.02, A.04, A.06, A.08, A.09, A.13, A.14, A.15, A.16, A.17, A.18, A.19, A.20, A.21, A.22	NF
ReqA.31	Service creation time shall be low.	A.all	NF

The following Table 9 lists the requirements of each automotive use case domain, according to the KPIs introduced in the previous section.

TABLE 9: MATCHING THE UC REQUIREMENTS FOR AUTOMOTIVE DOMAIN TO THE KPIS

	Safety	Mobility	e-Road	Entertainment	Digitalized Vehicles	Automated Driving
End-to-end latency	Medium	Medium	Low	High	Medium	Low
Reliability	High	High	High	Medium	Medium	High
User data rate	Medium	Medium	High	High	Medium	High
Density	Depends on the considered scenario					
Mobility	High					
Type of Traffic	High	High	High	High	High	High

Availability (related to coverage)	High	High	High	Medium	Medium	High
Positioning accuracy	High	High	High	Low	Low	High
Confidentiality	High	High	High	High	High	High
Integrity	High	High	High	Low	High	High
Availability (related to resilience)	High	Low	High	Medium	Medium	High
Communication range	High	Medium	Medium	Low	Low	High
Infrastructure	Medium	High	Low	High	High	Low
Energy reduction	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Service creation time	Low	Low	Low	Low	Low	Low

As introduced in the previous section, several UCs may be in use contemporary. For example, safety applications shall be always running and they shall have the priority with respect to entertainment applications (that maybe are working only when some passengers are on the vehicle). 5G should be able to guarantee a service able to satisfy all these different requirements. In ch automotive domain are shown.

Table 10, the UCs (grouped in clusters) that can potentially be present contemporary in each automotive domain are shown.

TABLE 10: MAPPING THE AUTOMOTIVE UCS THAT CAN POTENTIALLY BE IN USE CONTEMPORARY

	Safety	Mobility	E-Road	Entertainment	Digitalized Vehicles	Automated Driving
Urban	X	X	X	X	X	X
Rural	X	-	-	X	X	X
Highway	X	X	X	X	X	X
Transversal	-	X	-	-	X	-

4.2 Entertainment

In the following table, we list the main requirements for the entertainment domain considering the application scenarios described in section 2.2.

TABLE 11: GENERAL REQUIREMENTS FOR ENTERTAINMENT DOMAIN

ID	Requirement	# UC	F/NF
ReqE.01	The mobile infrastructure provider, network provider and IT integrator shall be able to equip the venue/stadium with 5G solutions.	UC.E01,UC.E02 UC.E03, UC.E04	F
ReqE.02	The fan's user devices (smartphones, tablets, wearables) shall be 5G compatible.	UC.E01,UC.E02 UC.E03, UC.E04	F
ReqE.03	The wireless connectivity provided by the network provider shall be available in any condition with redundancy connection and, in case of failure, shall be guaranteed.	UC.E01,UC.E02 UC.E03, UC.E04	F
ReqE.04	Smart content delivery techniques in the venue/stadium should be supported by the IT provider: - Enable efficient delivery of content from a content caching application. - Support configurations of content caching applications in the network.	UC.E01,UC.E02 UC.E03, UC.E04	F
ReqE.05	Flexible broadcast/multicast should be supported by the IT provider: - Support broadcast/multicast over a limited area (stadium / venue). - Be able to support broadcast/multicast of UHD streaming video.	UC.E01,UC.E02 UC.E03, UC.E04	F
ReqE.06	End-to-end latency shall be in the range of 1-10 ms.	UC.E01,UC.E02 UC.E03, UC.E04	NF
ReqE.07	Reliability shall be more than 99%.	UC.E01,UC.E02 UC.E03, UC.E04	NF
ReqE.08	User data rate shall be higher than 100 Mb/s.	UC.E01,UC.E02 UC.E03, UC.E04	NF
ReqE.09	Mobility may be in the range of 3-50 km/h.	UC.E01,UC.E02 UC.E03, UC.E04	NF
ReqE.10	Availability (related to coverage) shall be higher than 99%.	UC.E01,UC.E02 UC.E03, UC.E04	NF
ReqE.11	Positioning accuracy shall be less than 30 cm.	UC.E01,UC.E02 UC.E03,	NF

		UC.E04	
ReqE.12	Confidentiality shall be elevated.	UC.E01,UC. E02	NF
ReqE.13	Integrity shall be elevated.	UC.E03, UC.E04	NF
ReqE.14	Availability (related to resilience) shall be moderate.	UC.E01,UC. E02	NF
ReqE.15	Device density shall be higher than 10.000/km^2.	UC.E01,UC. E02 UC.E03, UC.E04	NF
ReqE.16	Traffic shall be all types.	UC.E01,UC. E02 UC.E03, UC.E04	NF
ReqE.17	The communication range shall be in the range of 300-800m.	UC.E01,UC. E02 UC.E03, UC.E04	NF
ReqE.18	Infrastructure shall be highly available.	UC.E01,UC. E02 UC.E03, UC.E04	NF
ReqE.19	Energy reduction in the fan's user device shall be less than 20%. - Support mechanisms to improve battery life. - Optimize the battery consumption.	UC.E01,UC. E02 UC.E03, UC.E04	NF
ReqE.20	Service creation time shall be less than 90 seconds.	UC.E01,UC. E02 UC.E03, UC.E04	NF

The following Table 12 list the requirements of each entertainment domain use case, in according to the KPIs introduced in the previous section.

TABLE 12: MATCHING THE UC REQUIREMENTS FOR ENTERTAINMENT DOMAIN TO THE KPIS

	On-site live event experience	Ultra-high-quality media	Immersive and integrated media	User generated content
End-to-end latency	Low	Low	Low	Low
Reliability	High	High	High	High
User data rate	High	High	High	High
Density	High	High	High	High
Mobility	Low	Medium	Medium	Low
Type of Traffic	High	High	High	High
Availability (related to coverage)	High	High	High	High
Localization accuracy	High	High	High	High
Confidentiality	High	High	High	High
Integrity	High	High	High	High

Availability (related to resilience)	Medium	Medium	Medium	Medium
Communication range	Medium	Medium	Medium	Medium
Infrastructure	High	Medium	Medium	High
Energy reduction	Low	Low	Low	Low
Service creation time	Low	Low	Low	Low

All UCs may be in use contemporary (as shown in Table 13). For instance, in an open venue like a golf course high bandwidth shall be required in high density areas (fan zone) to watch the far holes game in high-quality, at the same time coverage shall be guaranteed along the whole course and real-time services (immersive experiences) shall be required by fans, what means low latency requirements.

TABLE 13: MAPPING THE ENTERTAINMENT UCS THAT CAN POTENTIALLY BE IN USE CONTEMPORARY

	On-site live event experience	Ultra-high-quality media	Immersive and integrated media	User generated content
Closed venue	X	X	X	X
Open venue	X	X	X	X

4.3 eHealth

The following Table 14 presents a list of the main requirements extracted from the eHealth use cases.

TABLE 14: GENERAL REQUIREMENTS FOR EHEALTH DOMAIN

ID	Requirement	# UC	F/NF
ReqH.01	All communication networks shall be available to seamlessly connect all actors by means of the eHealth Connectivity Abstraction. (Ubiquitous network connectivity).	H.01 and H.02	F
ReqH.02	All kind of devices (static/mobile, wired/wireless, etc.) shall be able to connect to the communications network. (Support heterogeneous devices).	H.01 and H.02	F
ReqH.03	Different eHealth services should require different quality of service provided by the network: delay, bandwidth, etc. and even different degree of reliability.	H.all	F
ReqH.04	The underlying network and how it works should be transparent to the eHealth services. It is advisable to deploy self-configurable services, reducing the human intervention.	H.01 and H.02	F

ReqH.05	The context of the user should be available to improve the analysis of the health information provided by the patient.	H.01 and H.02	F
ReqH.06	The system shall protect the information exchanged and avoid any unauthorized access to the EHR.	H.all	F
ReqH.07	End-to-end latency shall be in the range of 1-10 ms.	H.01 and H.03	NF
ReqH.08	Reliability shall be more than 99%.	H.01 and H.03	NF
ReqH.09	User data rate shall be higher than 100 Mb/s.	H.01 (paramedic comm.)	NF
ReqH.10	Mobility shall be higher than 50 km/h.	H.01	NF
ReqH.11	Availability (related to coverage) shall be higher than 99%.	H.01	NF
ReqH.12	Positioning accuracy shall be in the range of 30-100 cm.	H.01	NF
ReqH.13	Confidentiality shall be elevated.	H.01 and H.02	NF
ReqH.14	Integrity shall be elevated.	H.01 and H.02	NF
ReqH.15	Availability (related to resilience) shall be elevated.	H.01 and H.03	NF
ReqH.16	Density may be in the range of 1000-10000/km^2.	H.02	NF
ReqH.17	Traffic shall be bursty.	H.01 and H.02	NF
ReqH.18	Traffic shall be event driven.	All	NF
ReqH.19	Traffic shall be periodic.	H.03	NF
ReqH.20	Traffic shall be all types.	All	NF
ReqH.21	Communication range shall be higher than 800 m.	H.01	NF
ReqH.22	Infrastructure shall be highly available.	H.01	NF
ReqH.23	Energy reduction shall be less than 20%.	H.01	NF
ReqH.24	Service creation time shall be less than 90 seconds.	H.01	NF

The following Table 15 lists the requirements of each eHealth domain scenario, according to the KPIs introduced in the introduction of this section.

TABLE 15: MATCHING THE UC REQUIREMENTS FOR EHEALTH DOMAIN TO THE KPIS

	Heart attack emergency	Environmental Information	Remote Surgery
End-to-end latency	Low	High	Low
Reliability	High	Low	High
User data rate	Medium	Low	High
Density	Low	Medium	Low
Mobility	High	Low	Low
Type of Traffic	High	Low	High
Availability (related to coverage)	High	Medium	Low
Positioning accuracy	Medium	Medium	Low
Confidentiality	High	High	High
Integrity	High	High	High
Availability (related to resilience)	High	Medium	High
Communication range	High	Medium	Low
Infrastructure	High	Low	Low
Energy reduction	Low	Low	Low
Service creation time	High	Low	Medium

Use case H.01 (heart attack emergency) is a particular use case in terms of network requirements, because requirements change depending on the state of the patient. During the normal operation, the smart shirt of the user transmits information towards the server, which is located in the cloud analyzing the received information. The requirements of this communication are medium. After a heart attack is detected by the server, and when the system confirms this issue, the network slice shall be reconfigured to improve the performance due to the high requirements of this emergency service. In parallel, the user equipment will start requesting help by using device-to-device communication, which has different requirements.

As summary, the following table shows the different use cases presented for eHealth and their mapping to the two domains described in this scenario:

TABLE 16: MAPPING THE EHEALTH UCS THAT CAN POTENTIALLY BE IN USE CONTEMPORARY

	Heart attack emergency	Enviromental information	Remote surgery
Static	X	-	X
Mobile	X	X	-

4.4 e-Industry

In the following Table 17 the main requirements for the e-industry domain have been listed taking into account the application scenarios described in section 2.4.

TABLE 17: GENERAL REQUIREMENTS FOR E-INDUSTRY DOMAIN

ID	Requirement	# UC	F/NF
ReqI.01	The industrial environment shall be equipped with 5G solutions.	I02, I03, I04, I05, I06	F
ReqI.02	High availability of the wireless connectivity in any condition with redundancy connection in case of failure shall be guaranteed.	I01, I02, I03, I04, I04	F
ReqI.03	Control in cloud shall be provided.	I02, I03, I04, I05, I06	F
ReqI.04	All connected devices shall be able to exchange information with the remote control.	I02, I03, I04, I05, I06	F
ReqI.05	Secure processing in cloud shall be provided.	I02, I03, I04, I05, I06	F
ReqI.06	The current safety level shall be kept when moving control in cloud (handling of robot stop in case of emergency).	I02, I03, I04, I05, I06	F
ReqI.07	Devices shall be equipped with additional external connected sensors (e.g., IMU) to improve the RT monitoring and detect anomalies earlier.	I01, I04, I05, I06	F
ReqI.08	End-to-end Latency shall be in the range of 1-10 ms.	I02, I05, I04 (for protection traffic only)	NF
ReqI.09	Reliability shall be more than 99%.	I02, I03, I04 (for	NF

		protection and control traffic only), I04, I05	
Reql.10	User data rate may be in the range of 100-1000 Mbps.	I02, I03	NF
Reql.11	Density shall be more than 10000/Km^2.	I01, I02, I03	NF
Reql.12	Node mobility may be in the range of 3-50 km/h.	I01, I02, I03	NF
Reql.13	Traffic shall be Event Driven/Periodic.	I02, I03	NF
Reql.14	Traffic shall be Bursty/Continuous.	I01	NF
Reql.15	Availability (related to coverage) shall be more than 99%.	I02, I03, I04, I05, I06	NF
Reql.16	Positioning accuracy shall be less than 30 cm.	I01, I02, I03, I04, I05, I06	NF
Reql.17	Confidentiality shall be elevated.	All	NF
Reql.18	Integrity shall be elevated.	All	NF
Reql.19	Availability (related to resilience) shall be elevated.	All	NF
Reql.20	The communication range shall be in the range of 300-800m.	I02, I03	NF
Reql.21	Infrastructure shall be medium density.	I01, I02, I03, I04, I05, I06	NF
Reql.22	Energy reduction may be in the range of 20-80%.	I01, I02, I03, I04, I05, I06	NF
Reql.23	Service creation time may be 90 minutes.	I01, I02, I03, I04, I05, I06	NF

The following table lists the requirements of each e-Industry domain scenario, in according to the KPIs introduced in the previous section.

TABLE 18: MATCHING THE UC REQUIREMENTS FOR E-INDUSTRY DOMAIN TO THE KPIS

	Monitoring	Cloud Robotics	Automated Logistics	EU: Generation	EU: Transmission	EU: Distribution
End-to-end latency	High	Low	High	High (Low for protection traffic)	High (Low for protection traffic)	High (Low for protection traffic)
Reliability	Low	High	High	High	High	High
User data rate	Low	High	High	Low	Low	Low
Density	High	High	Low	Medium	Medium	Medium
Node Mobility	Medium	Medium	Medium	Low	Low	Low
Type of Traffic	Medium	Low	Low	Low	Low	Low
Availability (related to coverage)	Low	High	High	High	High	High
Localization accuracy	Low	High	High	High	High	High
Confidentiality	High	High	High	High	High	High
Integrity	High	High	High	High	High	High
Availability (related to resilience)	High	High	High	High	High	High
Communication range	Low	Medium	Medium	Low	Low	Low
Infrastructure	Medium	Medium	Medium	Medium	Medium	Medium
Energy reduction	Medium	Medium	Medium	Low	Low	Low
Service creation time	Medium	Medium	Medium	High	High	High

As introduced in the previous section, several use cases can be presented in different scenarios. For example, in an automated factory both monitoring application and Cloud Robotics solutions can be in use. In such case, all the different requirements should be satisfied.

In the following table, the UCs that can potentially be present contemporary in each scenario are shown.

TABLE 19: MAPPING THE E-INDUSTRY UCS THAT CAN POTENTIALLY BE IN USE CONTEMPORARY

	Monitoring	Cloud Robotics	Automated logistics	Electricity Generation	Electricity transmission	Electricity distribution
Indoor	X	X	-	-	-	-
Outdoor	X	-	X	X	X	X

4.5 MNO/MVNO

The requirements of the MNO/MVNO domain could be very diverse as per essence they should allow to sustain any envisioned service provided within 5G networks. In the following Table 20, the most challenging requirements related mainly to the use cases identified in section 3 are captured.

TABLE 20: GENERAL REQUIREMENTS FOR MNO/MVNO DOMAIN

ID	Requirement	# UC	F/NF
ReqM.01	The 5G-TRANSFORMER system shall support the on demand deployment of a transparent implementation of virtual Mobile Core networks entities over slicing.	M.01	F
ReqM.02	Control and User plane separation and virtualization shall be supported for virtual core network entities.	M.01 M.02	F
ReqM.03	The 5G-TRANSFORMER system shall allow to dynamically set-up a traffic monitoring service in any given 5G network slice.	M.03	F
ReqM.04	The monitoring service shall be configured and modified automatically depending on the communication service consumer's demand.	M.03	F
ReqM.05	The orchestration system shall be able to determine the localization of the traffic links that need to be monitored, whatever the location (distributed data centers, edge, ran…) and the nature (physical or virtual appliances) of the considered networking functions.	M.03	F
ReqM.06	It shall be possible to monitor the traffic on any given virtual link in between virtual network functions that can be located in the same or different cloud platform (distributed or centralized data centers, MEC, etc.).	M.03	F
ReqM.07	It shall be possible to monitor the traffic delivered over physical links in between physical network functions.	M.03	F
ReqM.08	The traffic monitoring service shall be dynamically scaled.	M.03	F

ReqM.09	The traffic monitoring service activation shall not impact network services performance.	M.03	F
ReqM.10	The traffic monitoring service shall adapt to changes in VNF configuration changes like e.g., VNF scaling, moving.	M.03	F
ReqM.11	Provision of on-site radio coverage: the MCPTT service provider shall be able to discover and select the available points of access that can be allocated to the local deployment of network access.	M.04 M.05	F
ReqM.12	For MCPTT service, the infrastructure owned by the MCPTT SP or by a private party shall expose operations of discovery, selection and allocation of its resources.	M.04 M.05 M.06	F
ReqM.13	On-site resource managers (core and access) shall provide monitoring information enabling the MCPTT SP to verify the SLA of its running services.	M.04 M.05 M.06	F
ReqM.14	End-to-end latency of the network service deployed over a slice instance shall be in the range of 1-10 ms.	M.01 M.02 M.04 M.05 M.06	NF
ReqM.15	Reliability shall be more than 99%.	M.01 M.02 M.03 M.04 M.05 M.06	NF
ReqM.16	User Data Rate shall be higher than 100 Mb/s.	M.01 M.02 M.03 M.04 M.05 M.06	NF
ReqM.17	Supported density shall be higher than 10.000 devices/km^2.	M.01 M.02	NF
ReqM.18	Supported density shall be of a maximum of 1000	M.04	NF

	devices/km^2.	M.05 M.06	
ReqM.19	Low to high speed mobility of up to 300 km/h shall be supported.	M.01 M.02	NF
ReqM.20	Pedestrian mobility shall be supported, of about 3 km/h.	M.04 M.05 M.06	NF
ReqM.21	All types of traffic shall be delivered.	M.01 M.02 M.03 M.04 M.05 M.06	NF
ReqM.22	Availability (related to coverage) shall be more than 99%.	M.01 M.02 M.03 M.04 M.05 M.06	NF
ReqM.23	Positioning accuracy shall be in the range of 100-1000 cm.	M.01 M.02 M.04 M.05 M.06	NF
ReqM.24	Confidentiality shall be moderate.	M.01 M.02	NF
ReqM.25	Confidentiality shall be elevated.	M.04 M.05 M.06	NF
ReqM.26	Confidentiality shall be basic.	M.03	NF
ReqM.27	Integrity shall be moderate.	M.01M.02 M.03	NF

ReqM.28	Integrity shall be elevated.	M.04 M.05 M.06	NF
ReqM.29	Availability (related to resilience) shall be elevated.	M.01 M.04 M.05 M.06	NF
ReqM.30	Availability (related to resilience) shall be moderate.	M.02 M.03	NF
ReqM.31	High communication range of more than 800m shall be possible.	M.01 M.02	NF
ReqM.32	Communication range shall be less than 300 m.	M.04 M.05 M.06	NF
ReqM.33	Infrastructure of standard macro cell coverage shall be provided at the minimum.	M.01 M.02	NF
ReqM.34	Small cell infrastructure shall be provided.	M.04 M.05 M.06	NF
ReqM.35	Energy reduction shall be less than 20%.	M.01 M.02 M.04 M.05 M.06	NF
ReqM.36	Service creation time shall be less than 90 s.	M.01 M.02 M.03 M.04 M.05 M.06	NF

The following Table 21 lists the requirements of each MNO/MVNO domain scenario, in according to the KPIs introduced beginning of the section.

TABLE 21: MATCHING THE UC REQUIREMENTS FOR MNO/MVNO DOMAIN TO THE KPIS

	vEPCaaS	URLLC	vMonitoring	MCPTT
End-to-end latency	Low	Low	NA	Low
Reliability	High	High	High	High
User data rate	All	All	All	All
Density	High	Low	NA	Low
Mobility	High	Low	NA	Low
Type of Traffic	High	High	High	High
Availability (related to coverage)	High	High	High	High
Positioning accuracy	Low	Low	NA	Low
Confidentiality	Medium	High	Low	High
Integrity	Medium	Medium	Medium	High
Availability (related to resilience)	High	Medium	Medium	High
Communication range	High	High	NA	Low
Infrastructure	Limited	Limited	NA	Medium
Energy reduction	Low	Low	NA	Low
Service creation time	Medium	Medium	Low	Medium

The different UCs from the MNO/MVNO domain can potentially be present contemporary as shown in the following Table 22.

TABLE 22: MAPPING THE MNO/MVNO UCS THAT CAN POTENTIALLY BE IN USE CONTEMPORARY

	vEPCaaS	URLLC	vMonitoring	MCPTT
Standard Network Operation	X	X	X	-
Emergency	X	X	X	X

5 Vertical applications for 5G-TRANSFORMER

This chapter reports the detailed description of the use cases that are candidates for being validated via Proof of Concepts in the final demonstrators.

It will be taken as input for T1.2 and T1.3 and the rest of technical WPs, enabling the definition of a suitable solution, coping with the intended vertical markets. In particular D1.2 will present a more advanced analysis of defined use cases and their technical requirements on the system design as well as the description of the high-level architecture of 5G-TRANSFORMER.

Moreover, this first analysis of what needs to be demonstrated through use cases specific for each vertical domain will be used in T5.1 for the design and configuration of the vertical testbeds. D5.1 will provide indeed a description of how the vertical use cases will be deployed for the demonstration and validation.

For each vertical domain, a selection of use cases is done considering the potential benefits given by the 5G infrastructure provided by the project.

Each selected/operative use case is analyzed providing the following information:

- A general overview of the use case
- A detailed use Case Description containing:
  - Use Case Id: the unique Id for referencing the use case (i.e. ICA).
  - Use Case Name: the title of the use case.
  - Goal: the final purpose of the use case.
  - Triggering Event: the event that cause the starting of the use case.
  - Brief Description: a brief description of the use case.
  - Actors: the list of involved actors.
  - Preconditions: the list of conditions that shall verified before the starting of the use case.
  - Post Condition: the list of conditions that shall verified before at the end of the use case.
  - UC Flow: the list of steps that occur during the use case execution.
- An UML UC diagram illustrating the involved actors and the related functions.
- A high-level Sequence Diagram showing the message exchanged between the main expected modules.
- A logical high-level architecture showing the main modules and their interaction.
- The list of detailed requirements for application (F/NF with restrictions to KPI where applicable).

5.1 Automotive: Cooperative Urban Cross Traffic

The automotive application described in the following paragraphs has been selected because they are considered particularly challenging for the project and of immediate interest to CRF / FCA.

5.1.1 Use Case description

This use case foresees the implementation of an Intersection Collision Avoidance service that thanks to a communication among vehicles and external entity is able to calculate in real time the probability of collision and the speed profile and acts consequently. The demonstrator shall verify that the application will be running and effective also if at the same time a video streaming service is running on board.

The two typical test cases illustrated below are used for validating the ICA application based on ADAS solution.

The two test cases involve both two vehicles that are encountering at the same junction:

- In the first case both vehicles coming from the two crossing ways are going straight from their direction (see Figure 31 (a)).

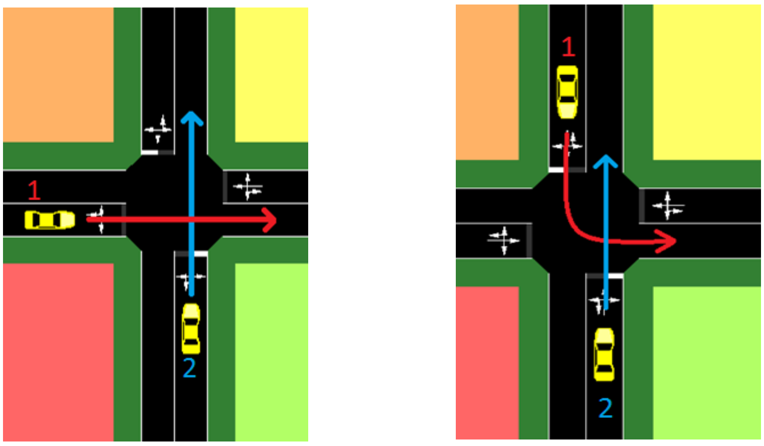


FIGURE 31: ICA TEST CASES SCENARIOS (A) & (B)

- In the latter, the host vehicle is going left on the intersection while the remote vehicle is going straight (see Figure 31 (b)).

Both test cases should be applied for demonstrating the adequate coverage of the ICA solution enabled by 5G-TRANSFORMER.

TABLE 23: DETAILED UC DESCRIPTION FOR AUTOMOTIVE

ICA	Intersection Collision Avoidance with active video streaming service
Goal	Avoid possible collision crossing intersection
Triggering Event	host and remote vehicles are approaching an intersection
Brief Description	The purpose of the intersection collision avoidance system is to alert drivers about the existence of unexpected or unseen vehicles or other eventual obstacles and eventually activate the emergency braking system. The communication infrastructure facilitates a real-time exchange of data between the involved entities. In producing an effective product, the system should provide a reliable real-time warning system that is not only capable of warning the driver, but also gives the driver time to react, as well. The quality of service should not be degraded despite the parallel use of high bandwidth services.
Actors	Driver, (Host & Remote) Vehicles, ICA Module, Context Awareness Service.
Preconditions	the host vehicle is connected and ICA is available, connectivity is available, a high-quality streaming service requiring very high-bandwidth is running on board.

Postconditions	Host Vehicle crosses the intersection avoiding possible collision.
Flow	• Driver of host vehicle activates ICA and set Intervention level and modality (warning or intervention) to apply; • Host Vehicle approaches an intersection; • Host vehicle receive message from context awareness and send its detailed information; • Context awareness allocate the best MTP available resources on the basis of context; • Context awareness receive and send registered vehicle data to and from known neighbor vehicles; • ICA analyses all received info and calculate the collision risk; • On the basis of the collision risk ICA sent a warning to the driver and eventually activates the automatic emergency brake. In alternative, the driver activates the brake by itself; • If the (emergency) brake is being to be activated a multicast warning message is sent to closer vehicles; • Host Vehicle exits from the intersection.

5.1.2 UC Diagram

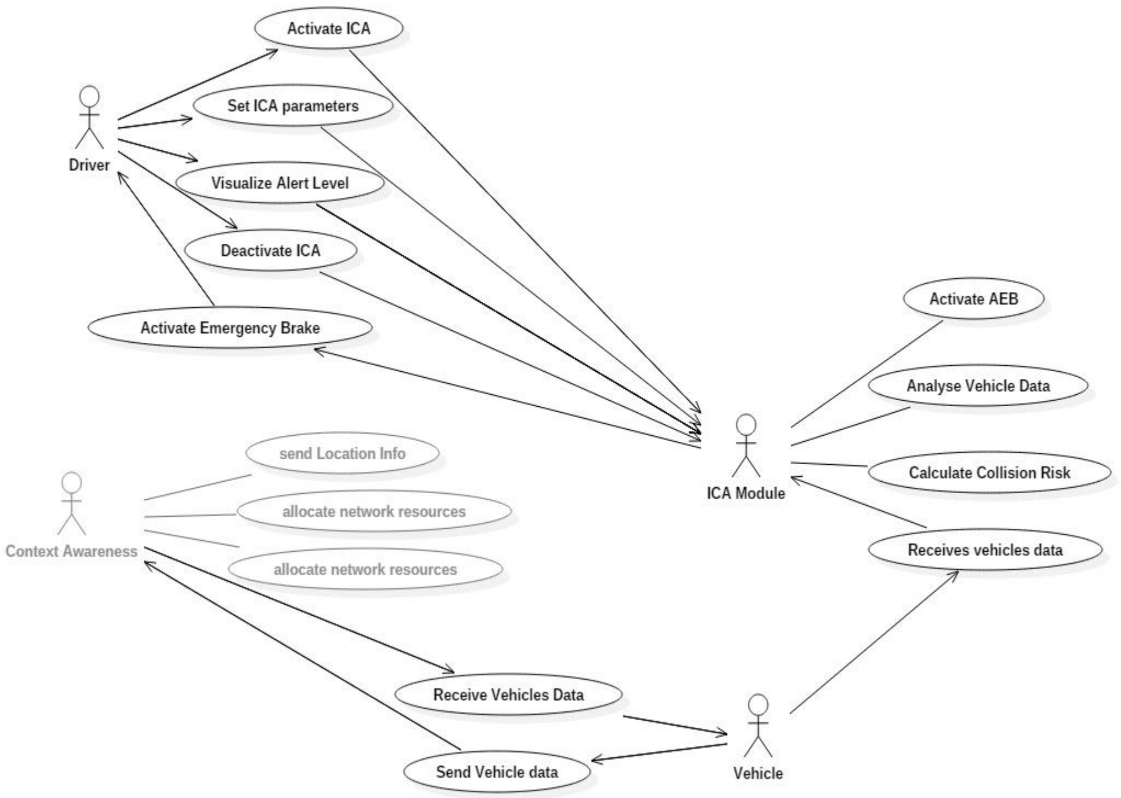


FIGURE 32: ICA UC DIAGRAM

5.1.3 Sequence diagram

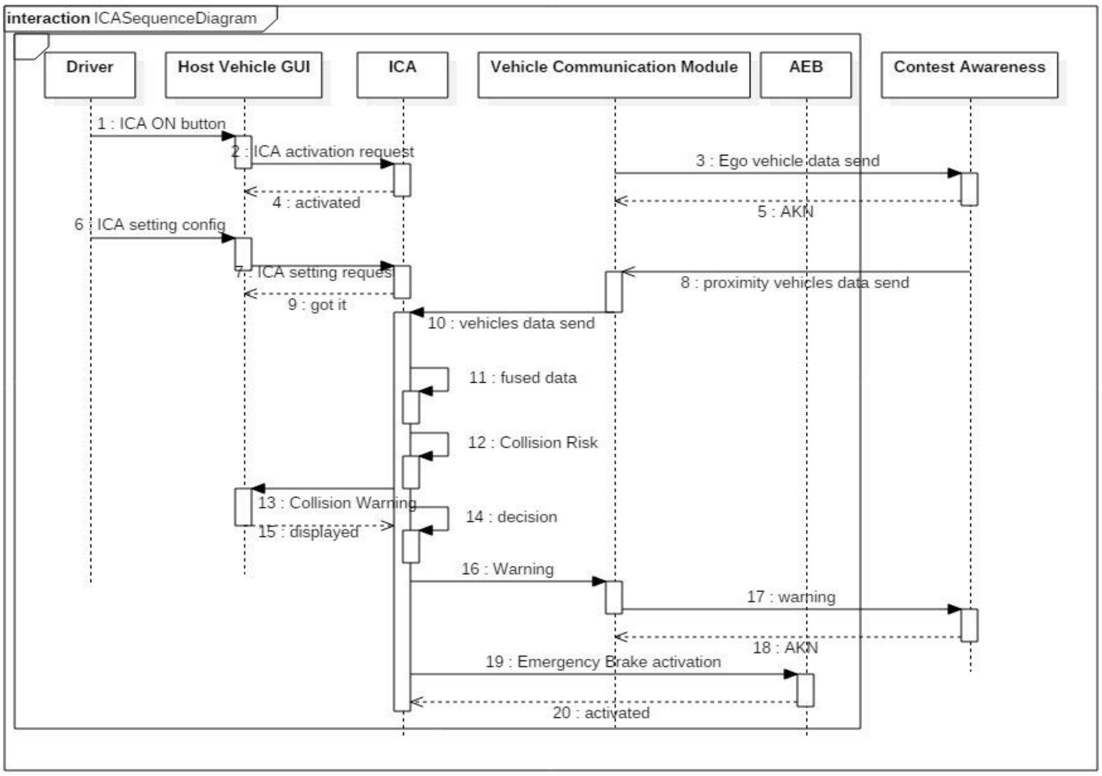


FIGURE 33: ICA SEQUENCE DIAGRAM

5.1.4 Logical Architecture

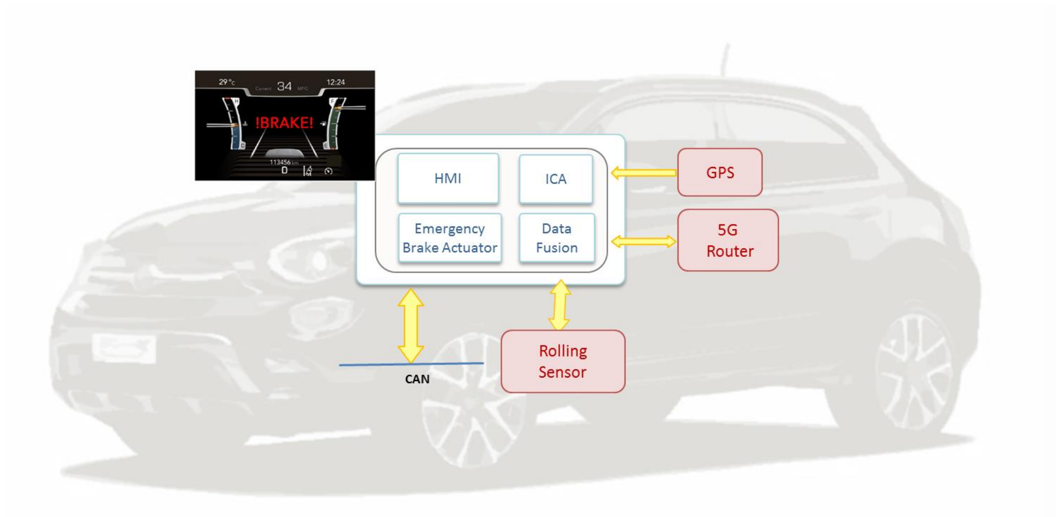


FIGURE 34: VEHICLE EQUIPMENT

5.1.5 Detailed Requirements

The Most Relevant KPI for the UC are the following:

- High Reliability & availability (99%).
- Ultra-Low Latency (<20 ms).
- High Security.

- High Priority.
- Enhanced data rate.

UC Detailed Requirements are described in the following Table 24:

TABLE 24: DETAILED UC REQUIREMENTS FOR AUTOMOTIVE

ID	Requirement	# UC	F/NF
ReqA.101	Intersection shall be equipped with 5G.	ICA	F
ReqA.102	ICA Application shall apply the most suitable strategy for collision avoidance keeping into account the speed range of the involved vehicles.	ICA	F
ReqA.103	The QoS of ICA application shall be ensured despite other services as a high-quality streaming service requiring very high-bandwidth video streaming service is active.	ICA	F
ReqA.104	ICA application shall work regardless the OEM of the involved vehicles.	ICA	F
ReqA.105	ICA application shall work regardless the Telco Operator serving the involved connected vehicles.	ICA	F
ReqA.106	ICA application shall be able to fuse and analyse all data received calculating a collision risk.	ICA	F
ReqA.107	If the collision risk is very high the ICA shall activate AEB.	ICA	F
ReqA.108	The driver shall be able to activate/deactivate the ICA application.	ICA	F
ReqA.109	The driver shall be able to set the ICA parameters (Intervention level and modality (warning or intervention) to apply for the provision of the ICA results.	ICA	F
ReqA.110	The driver shall be alerted when a collision risk is detected.	ICA	F
ReqA.111	If the (emergency) brake is being to be activated a multicast warning message shall be sent to closer vehicles.	ICA	F
ReqA.112	End-to-End Latency shall be in the range of 1-20 ms.	ICA	NF
ReqA.113	Security level shall be elevated.	ICA	NF

For completeness, the list of the general automotive requirements of section 4.1 that applies to the ICA use case is also reported below adding the ICA Id in the # UC field:

ID	Requirement	# UC	F/NF
ReqA.01	All vehicles shall be equipped with 5G router.	A.all, ICA	F
ReqA.02	All connected vehicles shall be able to exchange agreed information (those linked to context awareness), regardless the connectivity Provider.	A.01, A.02, A.04, A.06, A.07, A.08,	F

		A.09, A.10, A.11, A.12, A.13, A.14, A.23, A.24, A.25, ICA	
ReqA.03	All connected vehicles shall be able to exchange agreed information (linked to context awareness), regardless of a different car manufacturer.	A.01, A.02, A.04, A.06, A.07, A.08, A.09, A.10, A.11, A.12, A.13, A.14, A.23, A.24, A.25, ICA	F
ReqA.04	All vehicles shall be able to transmit information in roaming.	A.all, ICA	F
ReqA.06	Infrastructure shall be able to communicate with connected vehicles and provide additional information.	A.02, A.09, A.11, A.12, A.13, A.14, A.07, A.19, ICA	F
ReqA.15	Reliability shall be more than 99%.	A.01, A.02, A.03, A.04, A.05, A.06, A.07, A.09, A.10, A.11, A.12, A.13, A.14, A.23, A.24, A.25, ICA	NF
ReqA.16	User data rate shall be higher than 100 Mb/s.	A.18, ICA	NF
ReqA.17	Mobility shall be higher than 50 km/h.	A.all, ICA	NF
ReqA.18	Availability (related to coverage) shall be higher than 99%.	A.01, A.02, A.03, A.04, A.05, A.06, A.07, A.08, A.09, A.10, A.11, A.12, A.13, A.14, ICA	NF
ReqA.19	Positioning accuracy shall be less than 30 cm.	A.01, A.02, A.04, A.05, A.06, A.07, A.09, A.10, A.11, A.12,	NF

		A.13, A.14, A.23, A.24, A.25, ICA	
ReqA.21	Integrity shall be elevated.	A.01, A.02, A.03, A.04, A.05, A.06, A.07, A.08, A.10, A.11, A.12, A.13, A.14, A.19, A.20, A.21, A.23, A.24, A.25, ICA	NF
ReqA.22	Availability (related to resilience) shall be elevated.	A.01, A.02, A.03, A.04, A.05, A.07, A.11, A.12, A.13, A.14, A.15, A.20, A.22, A.23, A.24, A.25, ICA	NF
ReqA.22	In urban scenarios, the system shall operate in density higher than 10000/km^2.	A.01, A.02, A.03, A.04, A.05, A.06, A.07, A.08, A.09, A.10, A.11, A.12, A.13, A.14, A.15, A.16, A.17, A.18, A.19, A.20, A.21, A.22, A.24, ICA	NF
ReqA.24	Traffic shall be bursty.	A.01, A.02, A.03, A.04, A.05, A.06, A.07, A.08, A.09, A.10, A.11, A.12, A.13, A.14, A.15, A.19, A.20, A.21, A.22, A.23, A.24, A.25, ICA	NF

ReqA.25	Traffic shall be event driven.	A.01, A.02, A.03, A.05, A.06, A.07, A.08, A.09, A.11, A.12, A.13, A.14, A.15, A.18, A.19, A.20, A.21, A.22, A.23, A.24, A.25, ICA	NF
ReqA.26	Traffic shall be periodic.	A.01, A.02, A.03, A.05, A.06, A.07, A.08, A.09, A.10, A.13, A.14, A.24, A.25, ICA	NF
ReqA.27	Traffic shall be all types.	A.01, A.02, A.03, A.04, A.05, A.06, A.07, A.08, A.09, A.10, A.11, A.12, A.13, A.14, A.15, A.16, A.17, A.18, A.19, A.20, A.21, A.22, A.23, A.24, A.25, ICA	NF
ReqA.29	Infrastructure shall be highly available.	A.02, A.04, A.06, A.08, A.09, A.13, A.14, A.15, A.16, A.17, A.18, A.19, A.20, A.21, A.22, ICA	NF

5.2 Entertainment: Onsite fan experience (Spectator App)

An integrated App will offer on spectator fingertips all required services during an event. It will provide a deep understanding of fan profile, settings as well as physical and in-app behavior provide a powerful view of context. This enables contextual triggers driving delivery of app features, content and experiences to the right spectator at the right time and place to ensure it is valuable and relevant.

Such relevancy creates a differentiated experience and drives higher engagement. Contextual triggers help influence spectator behavior.

5.2.1 Use Case description

This use case foresees the implementation of a mobile device application ("Spectator App") that will enrich the fan experience into a Sport venue, so the fan can:

- Access to all statistics and forecasts.
- Facts & Figures, Bios, Insights, etc.
- Watch live views from another position.
- Automatic push notifications.
- Replay best & most amazing moments.
- Immersive experiences using AR.
- Buy, move, consume.

The Spectator App will allow the fans to follow competition progress in real time, from their mobile devices, as well as interact with other additional services into the venue. Some of the features the app will provide to the fan are:

- Mobile app used as event/game Guide with Live and Historical results integrated with Video.
- Video in sync with live results and multi-language commentary.
- Follow your player/team with automatic notifications and personalized highlights.
- Virtualized venue/stadium, following at any moment all players' location, ball positions, etc.
- Leader board, scorecard and all stats integrated with live video and mini-clips shots.
- Key insights and infographics from competition and historical data patterns.
- Highlights from key actions and best moments from your favourite player/team.
- Augmented reality of the green overlaying green map, ball trajectory and player information.
- Post event information and key highlights for engagement after the event.
- Share key moments with friends win Social media.
- Event news and information relative to the players.
- Guidance within the venue with a virtual map.

FIGURE 35: SPECTATOR APP

The integrated App shall offer on spectator fingertips all required services before, during and after the event:

- User Authentication integration.
- Purchase tickets from the existing Ticketing provider, with the digitalization to access using mobile.
- Advertising from the event Advertising Providers.
- Integration with Food & Beverage and eCommerce to buy and pick up at selected points.
- Integration with Payment platforms to pay with mobiles inside the venue.
- eVolunteer to support issues and questions of Fan before, during and after tournament.
- LinkRay integration to display key information and historical moments at specific locations.
- Venue and Tournament information including weather forecast during tournament.

TABLE 25: DETAILED UC DESCRIPTION FOR ENTERTAINMENT

OLE	On-site live event experience
Goal	To provide a better fan experience to users attending (on-site) to an event, via multimedia services integrated in an app (Spectator App).
Triggering Event	Fan enrolls and launches the Spectator App
Brief Description	The Spectator App will allow the fans to follow competition progress in real time, from their mobile devices, as well as interact with other additional services into the venue.
Actors	Fan, Spectator App, Service Providers (content, ticketing, scoring, food&drink…)
Preconditions	Fan must have installed the Spectator App.
Postconditions	Fan has enjoyed an enriched event experience using his mobile device.
Flow	• Fan enables his 5G device (smartphone/tablet); • Fan install the Spectator App in his user's device (if not done in advance); • Fan registers to the allowed services into the Spectator App (if not done in advance);

	• Fan authenticates himself into the Spectator App; • Fan can consume the services and contents integrated into the App: o View extended info about the event (statistics, bio-players, recorded content…) o Select live content from different cameras and views. o View replays of any action over the event/game. o Buy tickets from the Ticketing Provider. o Watch Ads from the Advertising Providers (Event Sponsors). o Pre-order and buy food and beverages. o Contact eVolunteers for questions and issues.

5.2.2 UC Diagram

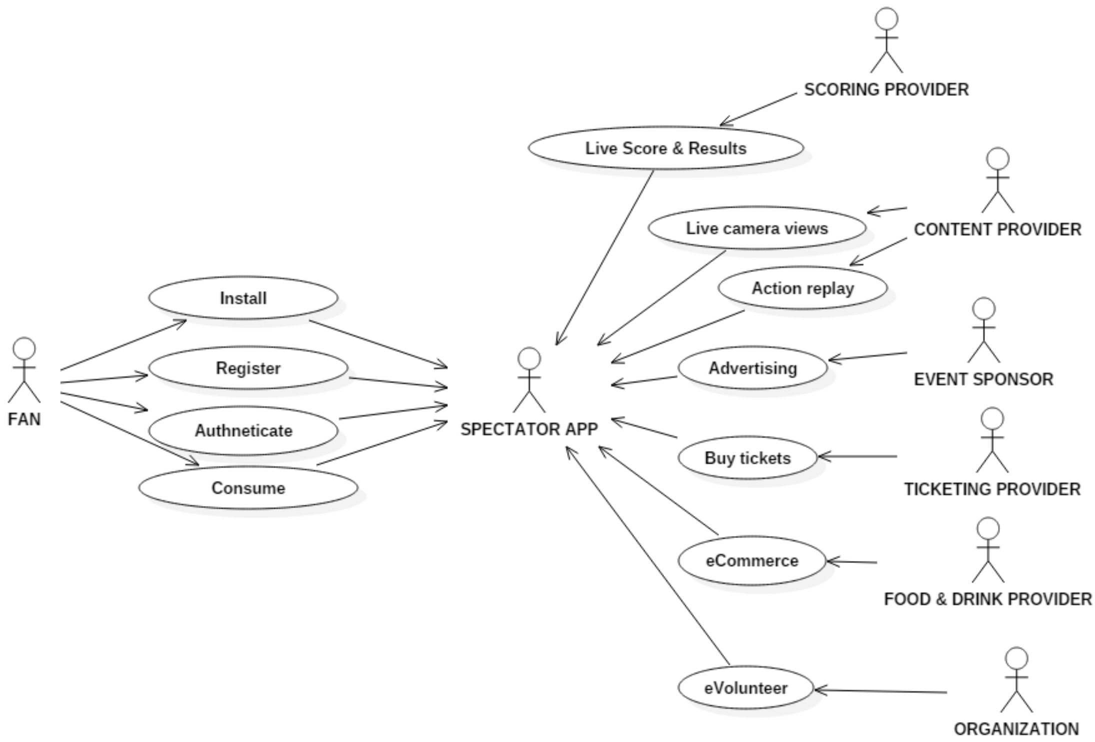


FIGURE 36: UC DIAGRAM OF "ON-SITE LIVE EVENT EXPERIENCE"

5.2.3 Sequence Diagram

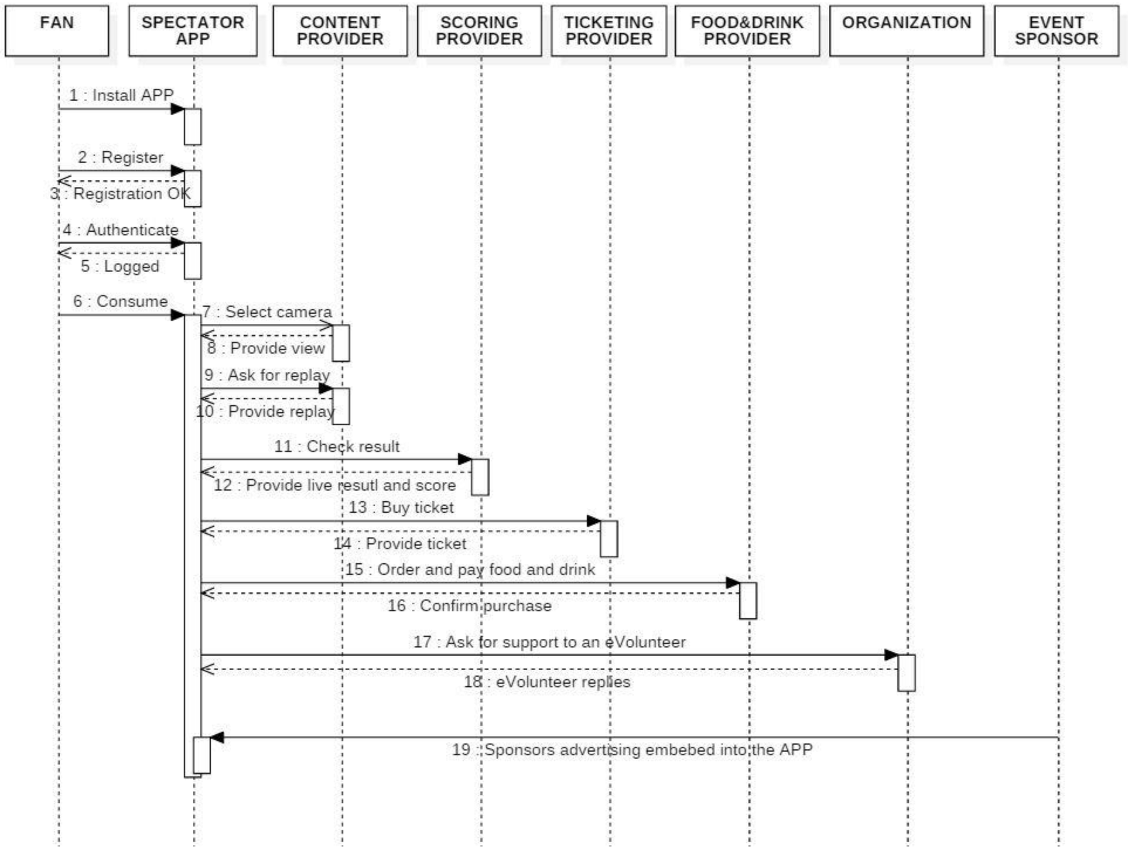


FIGURE 37: SEQUENCE DIAGRAM OF "ON-SITE LIVE EVENT EXPERIENCE"

5.2.4 Logical architecture

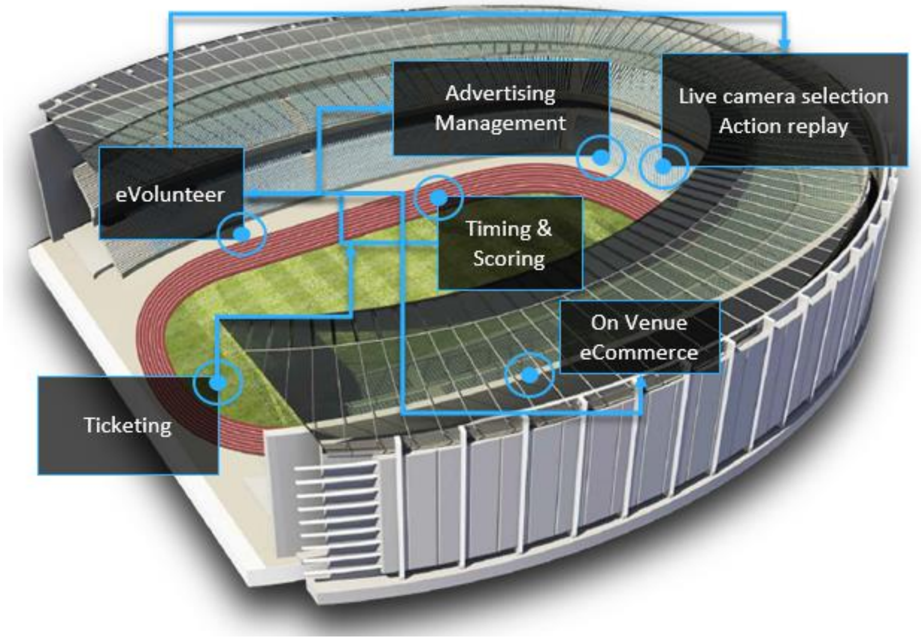


FIGURE 38: LOGICAL ARCHITECTURE FOR "ON-SITE LIVE EVENT EXPERIENCE" UC

5.2.5 Detailed Requirements

The Most Relevant KPI for the UC are the following:

- High User Data Rate.
- High Reliability.
- Low Latency.
- High Density.

There are no new requirements beyond those already reported in section 0. All general entertainment requirements already reported in Table 11 applies to the OLE use case as shown in the Table 26 below where the table is reported specifying the OLE Id in the # UC field.

TABLE 26: DETAILED UC REQUIREMENTS FOR ENTERTAINMENT

ID	Requirement	# UC	F/NF
ReqE.01	The mobile infrastructure provider, network provider and IT integrator shall be able to equip the venue/stadium with 5G solutions.	UC.E01,UC. E02, UC.E03, UC.E04, OLE	F
ReqE.02	The fan's user devices (smartphones, tablets, wearables) shall be 5G compatible.	UC.E01,UC. E02 UC.E03, UC.E04, OLE	F
ReqE.03	The wireless connectivity provided by the network provider shall be available in any condition with redundancy connection and, in case of failure, shall be guaranteed.	UC.E01,UC. E02, UC.E03, UC.E04, OLE	F
ReqE.04	Smart content delivery techniques in the venue/stadium should be supported by the IT provider: - Enable efficient delivery of content from a content caching application. - Support configurations of content caching applications in the network.	UC.E01,UC. E02, UC.E03, UC.E04, OLE	F
ReqE.05	Flexible broadcast/multicast should be supported by the IT provider: - Support broadcast/multicast over a limited area (stadium / venue). - Be able to support broadcast/multicast of UHD streaming video.	UC.E01,UC. E02 UC.E03, UC.E04, OLE	F
ReqE.06	End-to-end latency shall be in the range of 1-10 ms.	UC.E01,UC. E02, UC.E03, UC.E04, OLE	NF
ReqE.07	Reliability shall be more than 99%.	UC.E01,UC. E02 UC.E03, UC.E04, OLE	NF
ReqE.08	User data rate shall be higher than 100 Mb/s.	UC.E01,UC. E02 UC.E03, UC.E04, OLE	NF
ReqE.09	Mobility may be in the range of 3-50 km/h.	UC.E01,UC. E02 UC.E03,	NF

		UC.E04, OLE	
ReqE.10	Availability (related to coverage) shall be higher than 99%.	UC.E01,UC.E02 UC.E03, UC.E04, OLE	NF
ReqE.11	Positioning accuracy shall be less than 30 cm.	UC.E01,UC.E02 UC.E03, UC.E04, OLE	NF
ReqE.12	Confidentiality shall be elevated.	UC.E01,UC.E02	NF
ReqE.13	Integrity shall be elevated.	UC.E03, UC.E04, OLE	NF
ReqE.14	Availability (related to resilience) shall be moderate.	UC.E01,UC.E02, OLE	NF
ReqE.15	Device density shall be higher than 10.000/km^2.	UC.E01,UC.E02 UC.E03, UC.E04, OLE	NF
ReqE.16	Traffic shall be all types.	UC.E01,UC.E02, OLE UC.E03, UC.E04	NF
ReqE.17	The communication range shall be in the range of 300-800m.	UC.E01,UC.E02 UC.E03, UC.E04, OLE	NF
ReqE.18	Infrastructure shall be highly available.	UC.E01,UC.E02 UC.E03, UC.E04, OLE	NF
ReqE.19	Energy reduction in the fan's user device shall be less than 20%. - Support mechanisms to improve battery life. - Optimize the battery consumption.	UC.E01,UC.E02 UC.E03, UC.E04, OLE	NF
ReqE.20	Cost TBD.	UC.E01,UC.E02 UC.E03, UC.E04, OLE	NF
ReqE.21	Service creation time shall be less than 90 seconds.	UC.E01,UC.E02 UC.E03, UC.E04, OLE	NF

5.3 eHealth: Heart Attack Emergency

The following use case allows the testing of different elements defined in 5G-TRANSFORMER, particularly the integration with MEC.

5.3.1 Use Case Description

This use case presents a scenario where a patient has on a smart wearable which can monitor precise cardiac, respiratory, sleep and activity data. This information is transmitted in raw to the cloud by using a 5G radio access. On the cloud, the information is processed and analyzed, and after an issue is detected, an alarm is generated towards the user. If the user cancels the alarm, no further action is taken, but in other case, an emergency event is executed.

Thanks to MEC, the cloud server is transferred near the patient, so to reduce the latency communication with the wearable. At the same time, this server contacts the emergency services, providing updated processed information, location of the user and the EHR after contacting the corresponding server.

Device-to-device communication is used by the patient’s devices in order to contact any paramedic near his/her location. If any paramedic is in the neighbor, it will receive the same information as the emergency services.

One or several network slices are instantiated to run all necessary services: video from paramedics to doctors at the hospital/home, voice among all paramedics, data generated by the wearable, etc.

TABLE 27: DETAILED UC DESCRIPTION FOR EHEALTH

HAE	Heart-Attack Emergency
Goal	Fast response and treatment after a heart-attack outside the hospital.
Triggering Event	an alarm is detected by an analytic entity.
Brief Description	Cardiac patients will wear special underwear vests or smartwatches (wearable), with sensors and 5G network cards providing connectivity with other devices. With the first symptoms of a heart attack, the user equipment sends an alarm to the eHealth service (eServer) using any of the available connections (device-to-device communication, 5G cells, etc.). After this initial message, the user equipment and the eServer have to exchange information like the location of the user (which can be provided by the 5G network if this service is available), heart rate, position of the patient (horizontal/vertical), etc. The eServer may contact the patient by sending a message to his/her mobile phone to detect false alarms. If the user does not answer back the request or confirms the alarm, the provided information is then processed at the eServer. Then, the eServer contacts the proper ambulance station, based on where they are located, the equipment they are carrying, etc., no matter if they are in service or not. This staff selection may result in the mobilization of several equipment: doctors, ambulances, police, etc. The eHealth service should establish an ad-hoc communications network for all these public services, sending the proper commands to all of them, coordinating all the process. When the first members of the staff arrive where the patient is located, they have to start with the first aid maneuvers, but also broadcasting information about the state of the patient is key. In this case, transmitting video may be helpful for other members of the medical staff to understand the situation. They also receive the patient's clinic history in their tablet, which is a valuable information to select the following steps.
Actors	patient, wearable, eServer, paramedic and doctor.
Preconditions	The patient wears an eHealth wearable and this wearable can connect to an eHealth server.

Post conditions	After a heart-attack, the patient is found in a very short period by a paramedic and he/she can start the first aid maneuvers assisted by a remote doctor.

Flow	• Patient wears the eHealth wearable.
	• The wearable connects with the eHealth server (eServer).
	• The wearable sends patient information in raw to the eServer.
	• The eServer process all the information received.
	• If the eServer detects an issue, it sends an alarm towards the wearable.
	• The wearable shows the alarm to the patient.
	    o If the patient cancels the alarm, then the eServer cancels this event.
	    o If the patient does not cancel the alarm, or if she confirms the alarm, then both the wearable and the eServer start the emergency protocol.
	▪ At the eServer side:
	    o The eServer contacts the vertical slicer (VS) to instantiate a network slice to handle all forthcoming communications among all actors involved in this scenario, to satisfy the aforementioned requirements.
	    o The eServer contacts the nearest ambulance station (only those stations with the required equipment are selected).
	    o The eServer transmits the electronic health records (EHR) of the patient to the ambulance station, so a group of paramedics receives this information.
	    o The ambulance departs to the patient localization.
	▪ At the wearable side:
	    o It starts searching for nearby paramedics (distance depends on the available technology, around 100 meters if WiFi is used) using device-to-device (D2D) technology.
	    o If a paramedic is found, a connection is established between the wearable and the paramedic.
	    o The paramedic requests the user identification.
	    o The wearable sends the (encrypted) user identification to the eServer.
	    o The paramedic sends this information to the eServer, which in turns transmits the EHR to the paramedic.
	▪ When a paramedic (in an ambulance, or a paramedic near the patient) arrives to the patient location, it may establish a video call with a doctor in a hospital to request assistance.

5.3.2 UC Diagram

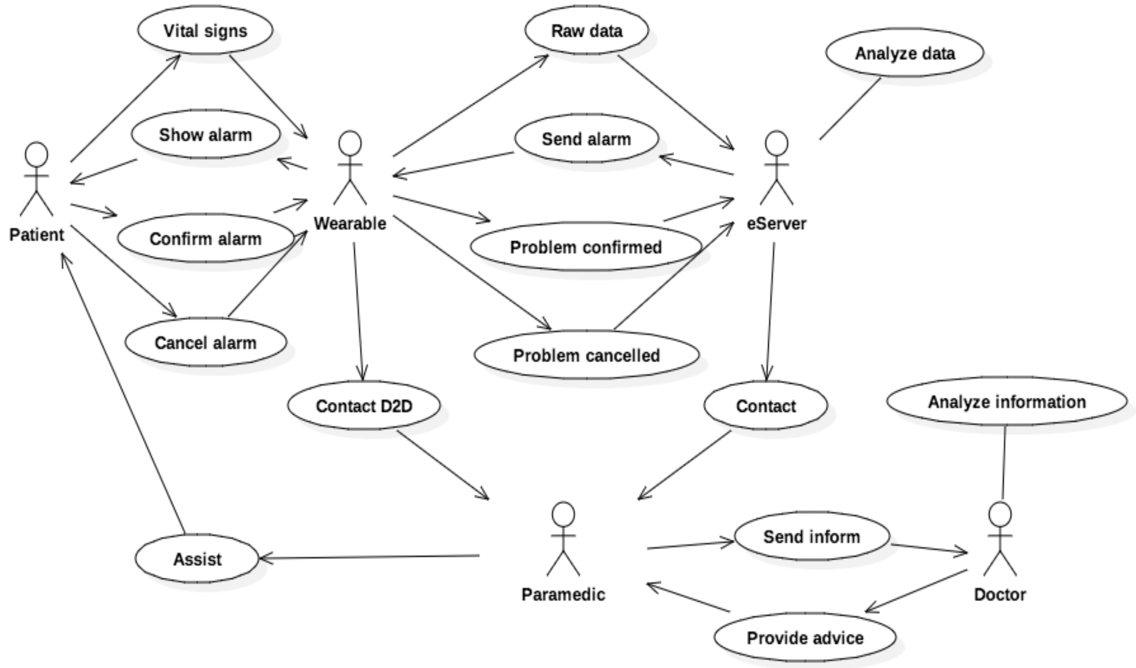


FIGURE 39: UC DIAGRAM FOR "HEART ATTACK EMERGENCY"

5.3.3 Sequence Diagram

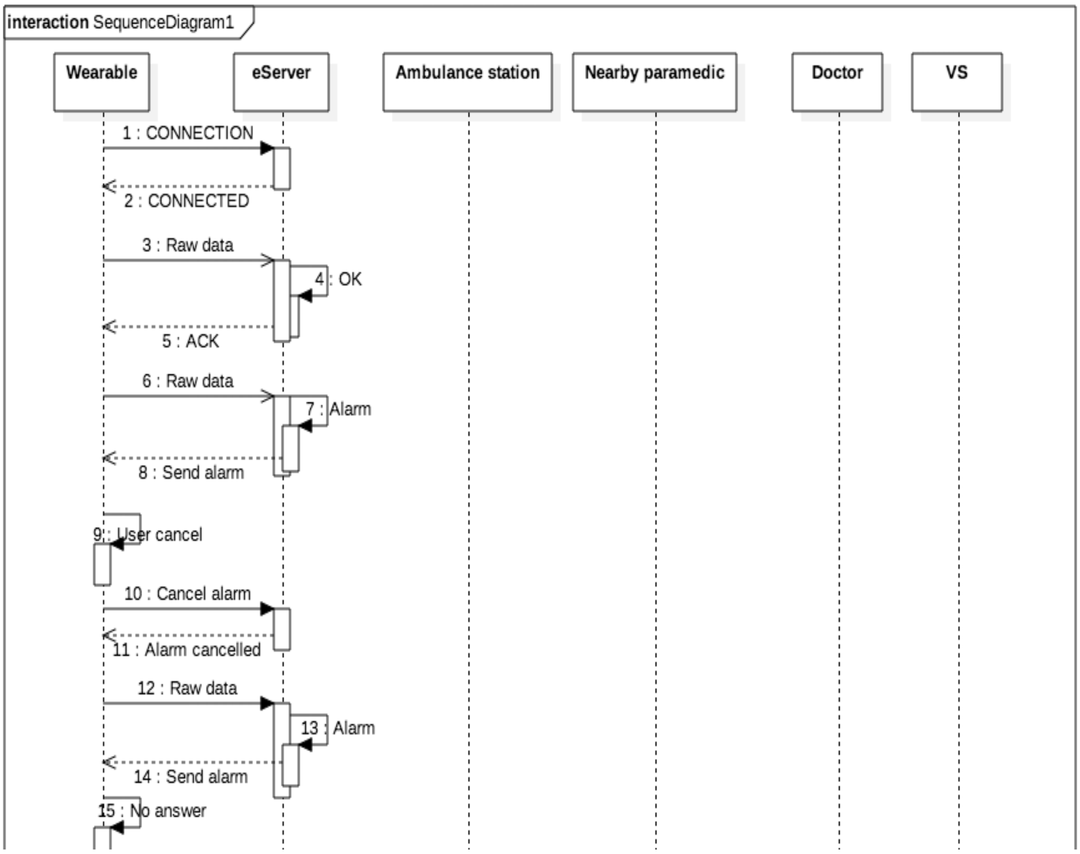


FIGURE 40: SEQUENCE DIAGRAM FOR "HEART ATTACK EMERGENCY" (PART1)

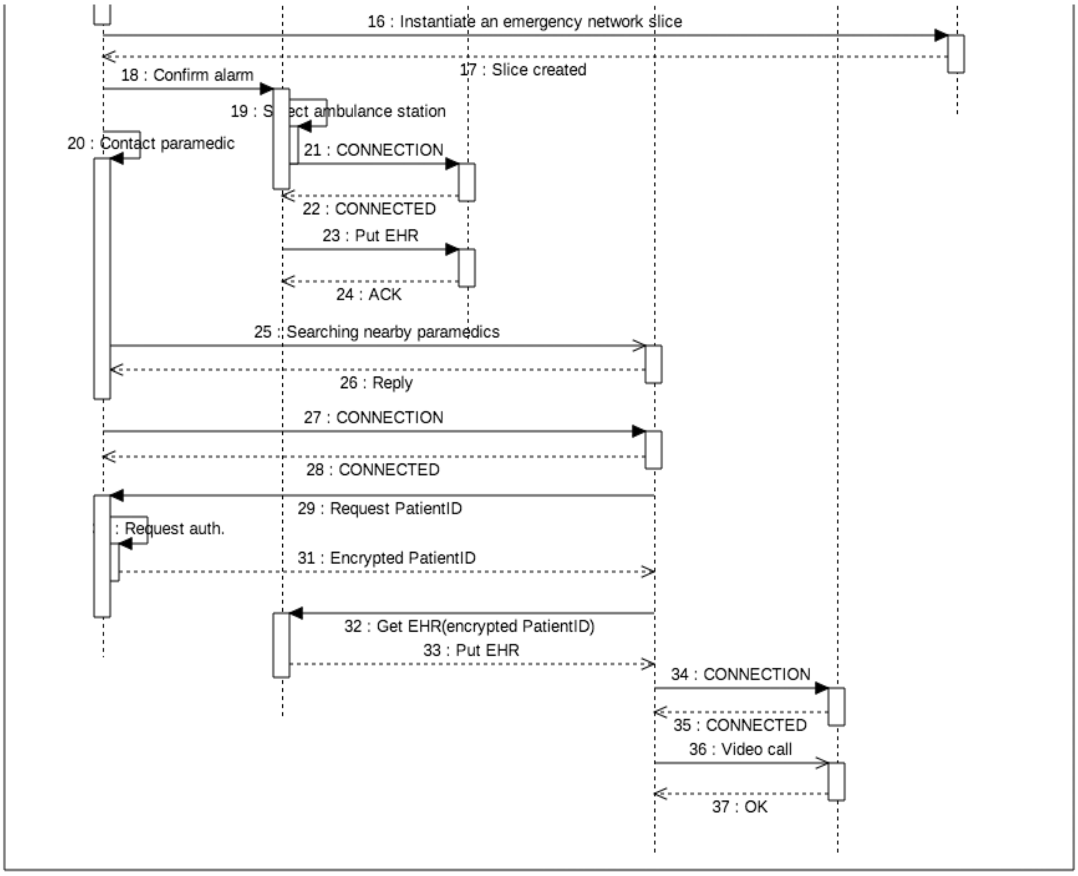


FIGURE 41: SEQUENCE DIAGRAM FOR "HEART ATTACK EMERGENCY" (PART2)

5.3.4 Logical Architecture

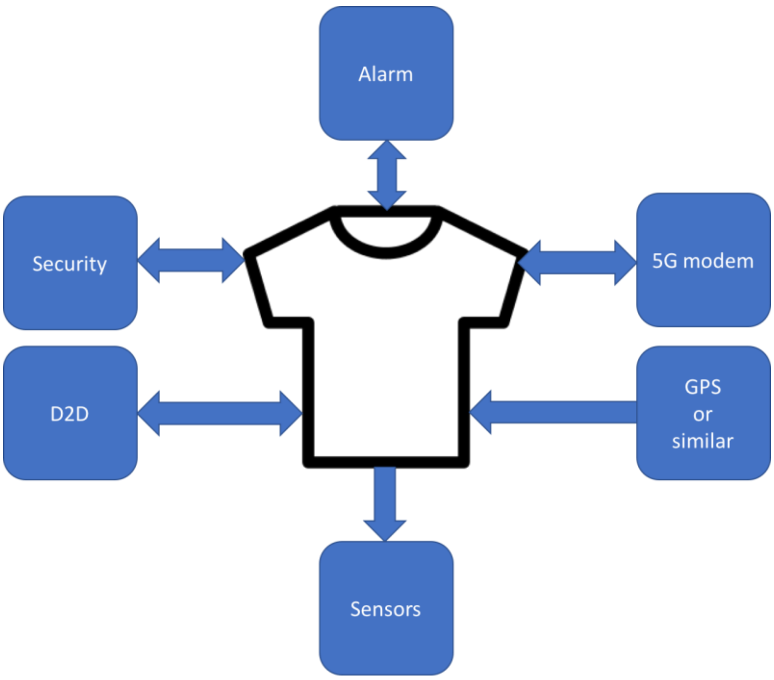


FIGURE 42: PATIENT WEARABLE EQUIPMENT FOR "HEART ATTACK EMERGENCY"

5.3.5 Detailed Requirements

The most relevant KPIs for the UC are the following:

- Low end-to-end latency.
- High reliability.
- High security.
- Elevated confidentiality and integrity.

UC Detailed Requirements are described in the following Table 28:

TABLE 28: DETAILED UC REQUIREMENTS FOR EHEALTH

ID	Requirement	# UC	F/NF
ReqH.101	Wearable must be equipped with 5G modem and/or D2D communication device.	HAE	F
ReqH.102	Wearable must include a security block to guarantee confidentiality and integrity.	HAE	F
ReqH.103	Wearable must include sensors to generate raw data.	HAE	F
ReqH.104	eServer shall process incoming raw data in real time (less than one second).	HAE	F
ReqH.105	Paramedics shall be able to receive patient's her.	HAE	F
ReqH.106	End-to-end latency shall be in the range of 1-10 ms.	HAE	NF
ReqH.107	Reliability shall be more than 99%.	HAE	NF
ReqH.108	User data rate shall be higher than 100 Mb/s.	HAE	NF
ReqH.109	Mobility shall be higher than 50 km/h.	HAE	NF
ReqH.110	Availability shall be higher than 99%.	HAE	NF
ReqH.111	Positioning accuracy shall be in the range of 30-100 cm.	HAE	NF
ReqH.112	Confidentiality shall be elevated.	HAE	NF
ReqH.113	Integrity shall be elevated.	HAE	NF
ReqH.114	Availability (related to resilience) shall be elevated.	HAE	NF
ReqH.115	Traffic shall be bursty.	HAE	NF
ReqH.116	Traffic shall be event driven.	HAE	NF
ReqH.117	Traffic shall be all types.	HAE	NF
ReqH.118	Communication range shall be higher than 800 m.	HAE	NF
ReqH.119	Infrastructure shall be highly available	HAE	NF

5.4 e-Industry: Cloud Robotics for Industrial automation

This UC shows how lean production in manufacturing can be achieved by combining robotics with cloud and mobile communication. Moving the control of the production processes and of the robots functionalities in cloud allows providing high automation of the factory plant, a minimized infrastructure and optimized processes.

5.4.1 Use Case Description

This use case presents the implementation of a Cloud Robotics service for factory automation where robots and production processes are remotely monitored and controlled in cloud, exploiting wireless connectivity (LTE/5G) to minimize infrastructure, optimize processes, and implement lean manufacturing.

The objective of the demonstrator is to verify the interaction and coordination of multiple (fixed and mobile) robots controlled by remote distributed services.

In the presented scenario, robotic arms are put in place to load and unload goods from the mobile robots. An automated warehouse is simulated by a rotating platform, and two automated doors are placed along the navigation tracks to show a flexible and optimized shuttling of materials between work cells in a plant.

TABLE 29: DETAILED UC DESCRIPTION FOR E-INDUSTRY

CR	Cloud Robotics for industrial automation
Goal	Enable more efficient manufacturing and lean production
Triggering Event	a facility manager asking for a CR service
Brief Description	We are considering an industrial scenario where robots have the tasks of picking up goods at the warehouse and transporting them to a work cell. Control functionality, both of production processes and of robots, are virtualized and moved into the cloud, to utilize its massive computing power. This requires the development of an innovative system architecture, which allows the communication among robots and cloud, via a wireless network infrastructure.
Actors	facility manager, fixed robots interacting with AGVs; virtual control (e.g., primary PLC for the control of the whole production line; work cell PLC; robot controller)
Preconditions	Wireless connectivity available in the warehouse, possibility to control electromagnetic noise.
Postconditions	Remotely controlled sensors and mobile and fixed robots interacting in a warehouse environment.
Flow	• A facility manager activates the CR service. • The MTP allocates the Storage, Computing and Networking resources to provide control and network functionalities (e.g., vEPC, virtual control including Primary vPLC, Work Cell vPLC, Robot controller). • A facility manager sends a request for a task. • The server asks to the mobile robot (e.g., AGV) to move to a destination and exchange data with mobile robot for navigation control. • The mobile robot moves to the destination. • The server asks the fixed Robots (e.g., robotic arm) to perform a task and exchange data for movement control. • The robotic arm performs a task (e.g., picking and placement of goods).

5.4.2 UC Diagram

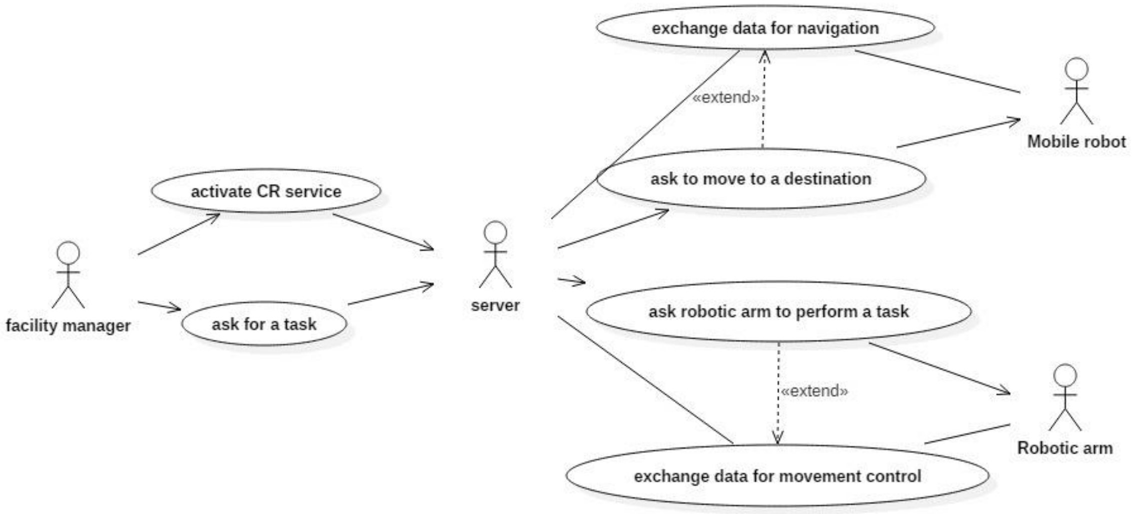


FIGURE 43: UC DIAGRAM FOR CR

5.4.3 Sequence Diagram

Here we report the sequence diagram of the CR use case supposing that the service is already up and the resources allocated.

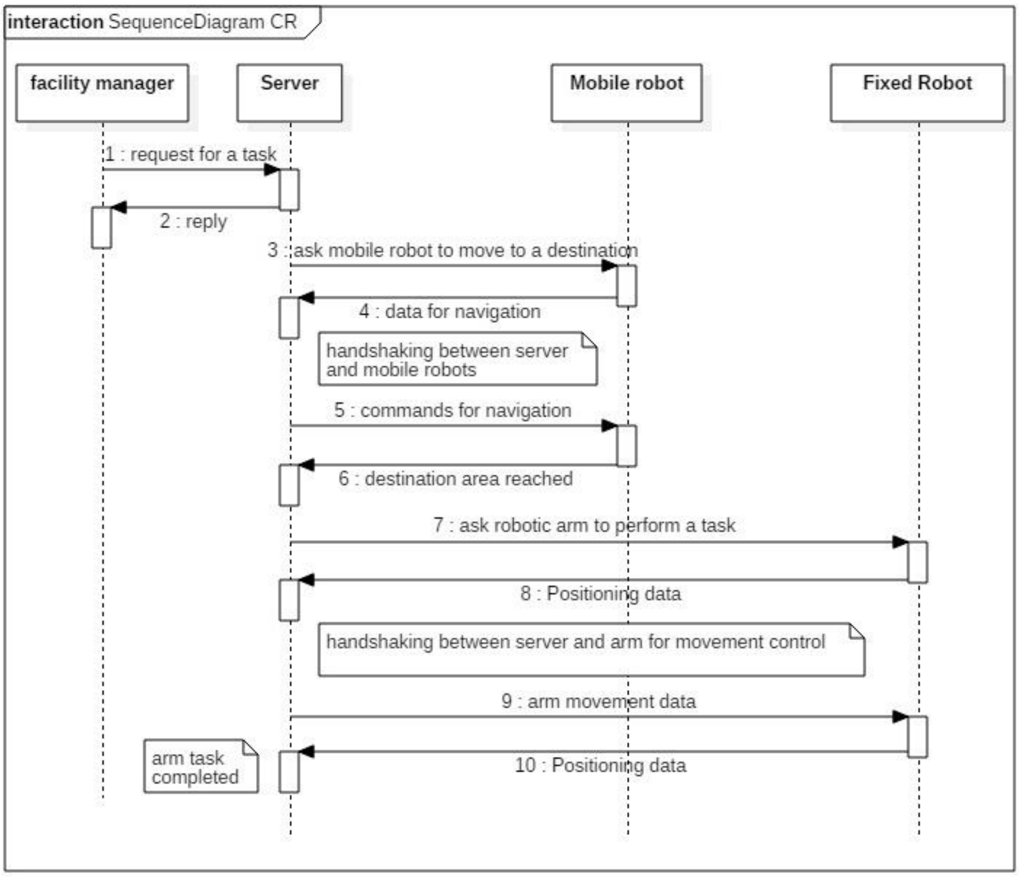


FIGURE 44: SEQUENCE DIAGRAM FOR CR

5.4.4 Logical Architecture

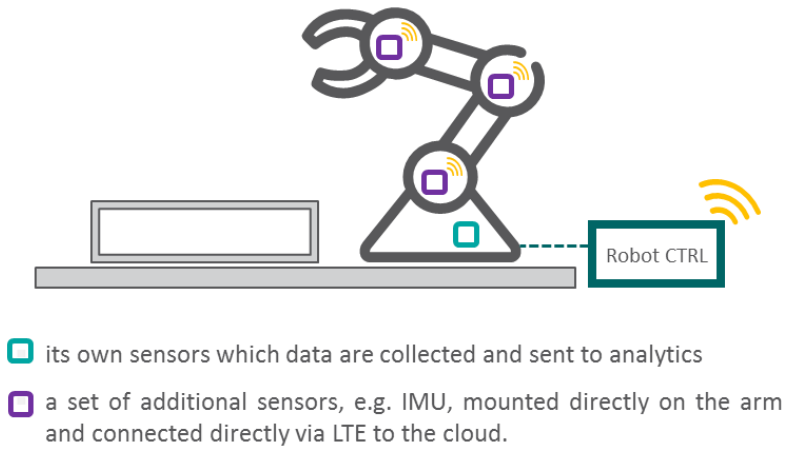


FIGURE 45: EQUIPMENT FOR CR

5.4.5 Detailed Requirements

The Most Relevant KPI for the UC are the following:

- Ultra-Low Latency (this requirement depends on the functions moved in the cloud).
- Enhanced data rate.
- High Reliability & availability (99.999%).
- High Security.

UC Detailed Requirements are described in the following Table 30:

TABLE 30: DETAILED UC REQUIREMENTS FOR E-INDUSTRY

ID	Requirement	# UC	F/NF
ReqI.101	Latency between the primary PLC and work cell PLC shall be less than 30 ms.	CR	NF
ReqI.102	Latency between work cell PLC and robotic devices shall be less than 30 ms.	CR	NF
ReqI.103	If all the robot control functionalities are virtualized latency between control and robot shall be less than 5 ms.	CR	NF
ReqI.104	Latency between control and AGV should be around 100 ms.	CR	NF
ReqI.105	Bandwidth should be from 1 Mbps to 10 Mbps CBR for each robot (depending on its configuration and what functions are in cloud).	CR	NF
ReqI.106	Bandwidth shall be up to 15 Mpbs for real time video from high definition cameras.	CR	NF
ReqI.107	Availability shall be 99.999%.	CR	NF
ReqI.108	Node mobility for AGV may be 6km/h.	CR	NF

Moreover, for further information, the list of the general e-industry requirements that applies to the CR use case and already presented in section 4.4 is reported specifying the CR Id in the # UC field.

ID	Requirement	# UC	F/NF
ReqI.01	The industrial environment shall be equipped with 5G solutions.	CR, I03, I04, I05, I06	F
ReqI.02	High availability of the wireless connectivity in any condition with redundancy connection in case of failure shall be guaranteed.	I01, CR, I03, I04, I04	F
ReqI.03	Control in cloud shall be provided.	CR, I03, I04, I05, I06	F
ReqI.04	All connected devices shall be able to exchange information with the remote control.	CR, I03, I04, I05, I06	F
ReqI.05	Secure processing in cloud shall be provided.	CR, I03, I04, I05, I06	F
ReqI.06	The current safety level shall be Kept when moving control in cloud (handling of robot stop in case of emergency).	CR, I03, I04, I05, I06	F
ReqI.08	End-to-end Latency shall be in the range of 1-10 ms.	CR, I05, I04 (for protection traffic only)	NF
ReqI.09	Reliability shall be more than 99%.	CR, I03, I04 (for protection and control traffic only), I04, I05	NF
ReqI.10	User data rate may be in the range of 100-1000 Mbps.	CR, I03	NF
ReqI.11	Density shall be more than 10000/Km^2.	I01, CR, I03	NF
ReqI.12	Node mobility may be in the range of 3-50 km/h.	I01, CR, I03	NF
ReqI.13	Traffic shall be Event Driven/Periodic	CR, I03	NF

ReqI.15	Availability (related to coverage) shall be more than 99%.	CR, I03, I04, I05, I06	NF
ReqI.16	Positioning accuracy shall be less than 30 cm.	I01, CR, I03, I04, I05, I06	NF
ReqI.17	Confidentiality shall be elevated.	I01, CR, I03, I04, I05, I06	NF
ReqI.18	Integrity shall be elevated.	I01, CR, I03, I04, I05, I06	NF
ReqI.19	Availability (related to resilience) shall be elevated.	I01, CR, I03, I04, I05, I06	NF
ReqI.20	The communication range shall be in the range of 300-800m.	CR, I03	NF
ReqI.21	Infrastructure shall be medium density.	I01, CR, I03, I04, I05, I06	NF
ReqI.22	Energy reduction may be in the range of 20-80%.	I01, CR, I03, I04, I05, I06	NF
ReqI.23	Service creation time may be 90 minutes.	I01, CR, I03, I04, I05, I06	NF

5.5 MNO/MVNO: 5G Network as a Service

The use case proposed in the following paragraphs has been defined to be representative of the “as a Service” deployment and use of multiple slices for different needs of MNO/MVNO players on a given administrative domain. The required flexibility in terms of simultaneous deployment and operations of networks with different needs is particularly challenging for the project.

5.5.1 Use Case Description

This use case foresees the implementation of a 5G Network as a Service for an MNO/MVNO through the combination of two usages described in section 4 for the MNO/MVNO domain:

- The deployment of a dedicated vEPC core network for managing local multi-access technologies in a very dense environment.
- The provision of mission critical services leveraging on the local infrastructure.

The demonstrator of this use case shall verify the functional operations.

TABLE 31: DETAILED UC DESCRIPTION FOR MNO/MVNO

5GNaaS	5G network as a Service
Goal	Operate a 5G multi-access sliced network with different needs from MNO/MVNO, MCPTT.
Triggering Event	Apparition of a very dense environment.
Brief Description	The purpose is to meet 5G requirements in terms of MNO/MVNO environment deployment and flexibility. At the initial stage, a basic macro-cell of an MNO network provides the 5G connectivity. We also assume that an IoT network slice (LPWAN coverage) is set up to provide sensors data collection services. At a given time, a very high demand from mobile devices for network resources (connectivity, bandwidth, processing, etc.) is detected (e.g. could be the happening of a special event in a given area like a stadium and its vicinity). Then, additional multi-access RAN infrastructure resources (small cells, Wi-Fi access points) are activated to provide connectivity not only to the operator's network but also to the local DC infrastructure (MEC based services). The MNO/MVNO instantiates and configures a dedicated network slice to extend the connectivity infrastructure through additional resources like small cells and WiFi APs. The configured network slice is deployed over a vEPC that is tailored with entities, QoS, data rates and computing resources adapted to the scenario usage. For instance, the Data Plane leverages on local resources where specific traffic VNFs are instantiated while the vEPC Control Plane VNFs are instantiated in the operator's cloud environment. End users are provided with local access to the network like if they would be served by the macro-network of the MNO/MVNO, with unified authentication over 4G/5G and Wi-Fi RAN. Additionally, their data can also be stored in the local DC. Besides, another slice is configured by the MNO for MCPTT critical services, based on the sharing of the local infrastructure resources and possibly also on additional infrastructure resources brought by the MCPTT service provider itself. Each network service is provided with its specific QoS and security requirements. Virtualized monitoring tools are used to verify that the service KPIs are met and help troubleshooting the virtualized infrastructure when necessary.
Actors	MNO/MVNO, MCPTT provider, end-users
Preconditions	• resources are available locally in the very dense area (eNodeBs, Wi-Fi APs, local DC…) but not activated • A centralized operator's cloud should be available to host control VNFs • Connectivity between on-site (radio resources, local DC) resources and cloud (centralized DC) resources • IoT LWPAN network and Macro cell RAN are already set up and operational.
Postconditions	Demonstrate the hosting and isolation of the different vertical services (MNO/MVNO, MCPTT and IoT). The provided infrastructure and connectivity may also be used to instantiate both the services and slices from other verticals.
Flow	• The MNO/MVNO requests the instantiation of a specific

	5G network with local access to the infrastructure, in a split vEPC mode (CUPS like or NG CN like); • The network slice is set up and the vEPC network service is instantiated, connected to local small cells and Wi-Fi access points. The User Plane VNF and PNF are configured in the local area infrastructure; the Control Plane is virtualized in the operator's core cloud. The end to end slice provides the network service with the required flexibility to access to local and central infrastructure and services; • End-users are provided with multi-access connectivity (4G/5G/Wi-Fi) with a uniform QoE, including unified authentication; • Direct access to local cloud allows end users to share and store their data locally with low delay and high bandwidth; • A MCPTT Provider needs to deploy its own service, bringing its own assets to offer group calls. It configures a network service deployment with high expectations in terms of availability to guarantee the support of critical services. • The MCPTT service is provided with another slice with a dedicated vEPC, controlling MNO shared RAN resources and private resources. • Monitoring tools allow verifying KPI conformance for the different network services. Virtualized traffic mirroring and probing functions can be automatically configured for troubleshooting operations.

5.5.2 Use Case Diagram

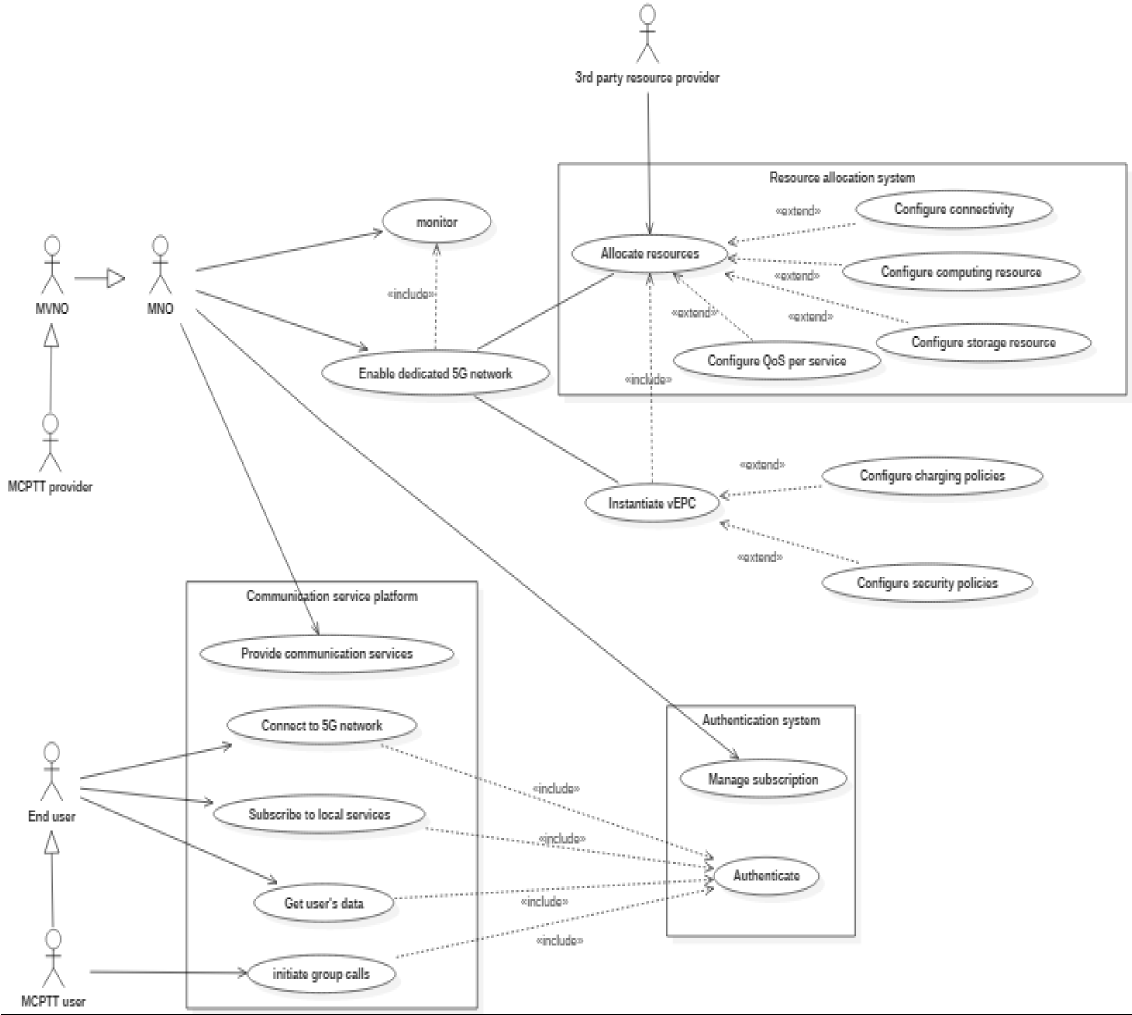


FIGURE 46: UC DIAGRAM FOR MNO/MVNO

5.5.3 Sequence Diagram

In this deliverable and at this stage of the project, it is difficult to produce accurate sequence diagram for the MNO/MVNO use case scenario. As mentioned in section 2 and 3, the MNO/MVNO domain is not like other verticals as the offered service is a Network service not a Vertical service. With regards to this propriety of MNO/MVNO use case, any functionality that needs to be demonstrated in a Use case implies necessarily the direct involvement of the network slicing architecture entities. Considering that the design of the 5G-TRANSFORMER high-level architecture is still ongoing at this stage of the project and that any functional and technical choices on the architecture would directly influence the execution of the MNO/MVNO use case scenario, we decided to keep such detailed use case information at the implementation phase in the deliverables of WP5, after the finalization of D1.2 and the design of the high-level architecture.

5.5.4 Logical Architecture

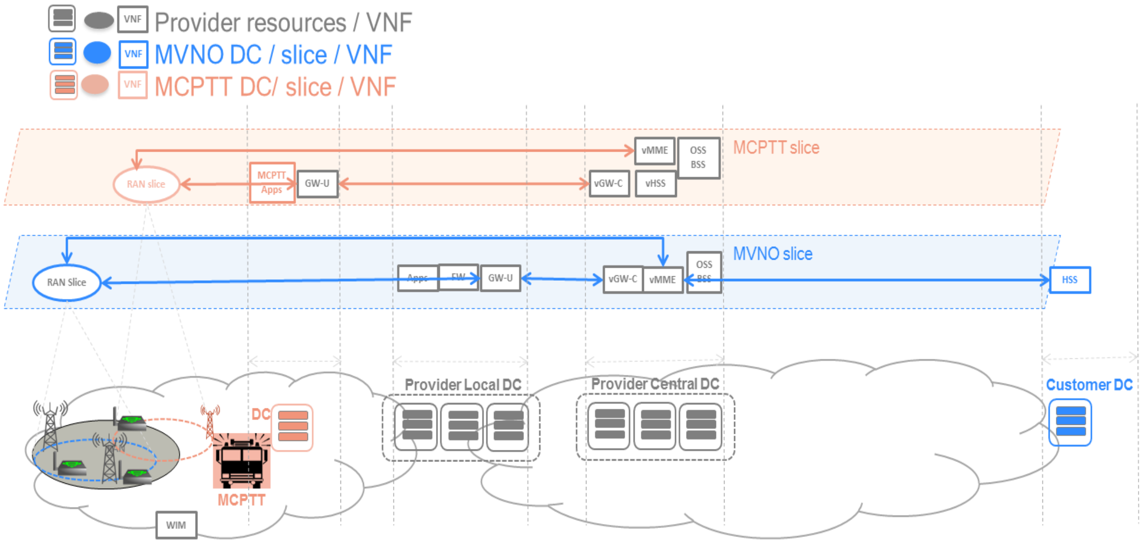


FIGURE 47: LOGICAL ARCHITECTURE FOR 5GNAAS UC

5.5.5 Detailed Requirements

The Most Relevant KPI for the UC are the following:

- Low End-to-end latency.
- High Reliability.
- High User data rate.
- High Density.
- Low Mobility.
- High Type of Traffic.
- High Availability.
- High Confidentiality.
- High Integrity.
- High Availability (related to resilience).
- Medium Infrastructure.

The list of the general requirements that applies to the MNO/MVNO use case and already presented in section 4.5 is reported specifying the use case Id in the # UC field.

TABLE 32: DETAILED UC REQUIREMENTS FOR MNO/MVNO

ID	Requirement	# UC	F/NF
ReqM.01	The 5G-TRANSFORMER system shall support on demand deployment of a transparent implementation of virtual Mobile Core networks entities over slicing.	M.01, 5GNaaS	F
ReqM.02	Control and User plane separation and virtualization shall be supported for virtual core network entities.	M.01 M.02 5GNaaS	F

ReqM.03	The 5G-TRANSFORMER system shall allow to dynamically set-up a traffic monitoring service in any given 5G network slice.	M.03 5GNaaS	F
ReqM.11	Provision of on-site radio coverage: the MCPTT service provider shall be able to discover and select the available points of access that can be allocated to the local deployment of network access.	M.04 5GNaaS	ReqM.11
ReqM.13	On-site resource managers (core and access) shall provide monitoring information enabling the MCPTT SP to verify the SLA of its running services.	M.04 5GNaaS	ReqM.13
ReqM.14	End-to-end latency of the network service deployed over a slice instance shall be in the range of 1-10 ms.	M.01 5GNaaS	ReqM.14
ReqM.15	Reliability shall be more than 99%.	M.01 5GNaaS	ReqM.15
ReqM.16	User Data Rate shall be higher than 100 Mb/s.	M.01 M.02 M.03 M.04 M.05 M.06 5GNaaS	NF
ReqM.17	Supported density shall be higher than 10.000 devices/km^2.	M.01 M.02 5GNaaS	NF
ReqM.20	Pedestrian mobility shall be supported, of about 3 km/h.	M.04 M.05 M.06 5GNaaS	NF
ReqM.21	All types of traffic shall be delivered.	M.01 M.02 M.03 M.04 M.05	NF

		M.06 5GNaaS	
ReqM.22	Availability (related to coverage) shall be more than 99%.	M.01 M.02 M.03 M.04 M.05 M.06 5GNaaS	NF
ReqM.33	Infrastructure of standard macro cell coverage shall be provided at the minimum.	M.01 M.02 5GNaaS	NF
ReqM.34	Small cell infrastructure shall be provided.	M.04 M.05 M.06 5GNaaS	NF

6 Analysis of KPIs

6.1 5G-PPP KPIs and 5G-TRANSFORMER

The EU Commission and the 5G Infrastructure PPP signed the PPP Contractual Arrangement [24] on December 2013 which, among other aspects, describes the high-level KPIs of the PPP for the period starting in 2014 and finalizing in 2020. Phase-2 projects are expected to go leverage on Phase-1 projects' outcomes and advance a step forward towards achieving those KPIs.

In the following, we present the 5G-PPP KPIs that are relevant to the 5G-TRANSFORMER project and provide a first qualitative assessment of the relevance of each of these KPIs in relation to the planned contributions in the project. We present them divided in performance, societal, and business related KPIs (note that 5G-PPP KPIs that are not addressed by 5G-TRANSFORMER are not included in the analysis that follows).

6.1.1 Performance KPIs

TABLE 33: 5G-PPP PERFORMANCE KPIS

KPI		Relevance (High/Medium/Low)	Details on planned contribution towards achieving the KPI
P1	Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010.	High	The design of 5G-TRANSFORMER is based on the utilization of high-capacity transport technologies, leveraging 5G-Crosshaul output, and their integrated cooperation through a common control plane, which reduces capacity overprovisioning and resource waste. Higher data rates and capacity will be achieved by a more flexible, cost-efficient centralization of base station functions, leading to C-RAN-like setting.
P2	Saving up to 90% of energy per service provided.	High	A chief objective of 5G-TRANSFORMER is to support the agile reconfiguration of the network to maximize hardware resource and reduce resource waste. To do this, an SDN/NFV-based control and management approach is followed, simplifying the management of the 5G-Crosshaul data plane and

			increasing its flexibility. Reduction of energy consumption will also be explored via exploiting dynamic (energy-aware) reconfiguration of computing resources and smart placement of VNFs.
P3	Reducing the average service creation time cycle from 90 hours to 90 minutes.	High	5G-TRANSFORMER is a service-oriented platform enabling the deployment of applications through the use of open APIs by third parties, including MVNOs and vertical sectors. The use of the 5G-Crosshaul unified backhaul/fronthaul data plane and SDN/NFV-based control plane approach facilitates the quick re-configurability of the network. Thus 5G-TRANSFORMER will not only increase the opportunities to create new services and applications but also, minimize the effort to deploy and reconfigure services.
P4	Creating a secure, reliable and dependable Internet with a “zero perceived” downtime for services provision.	Low	5G-TRANSFORMER mechanisms will look at non-functional requirements such as reliability and security. In particular, end-to-end security will be addressed by re-using as much as possible existing security mechanisms.
P5	Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people.	Medium	The 5G-TRANSFORMER management platform integrates high-capacity, low-latency and flexible backhaul/fronthaul 5G-Crosshaul data plane design, along with state-of-the-art technologies where appropriate, to increase the capillarity of the network.

6.1.2 Societal KPIs

TABLE 34: 5G-PPP SOCIETAL KPIS

KPI		Relevance (High/Medium/Low)	Details on planned contribution towards achieving the KPI
S3	European availability of a competitive industrial offer for 5G systems and technologies.	High	The new ecosystem created by 5G-TRANSFORMER will certainly promote smart and sustainable growth and strengthening Europe's role as global actor through innovative solutions validated by industrial partners brought to the market and new qualified man power trained by the academia and research centers.
S5	Establishment and availability of 5G skills development curricula (in partnership with the EIT).	Medium	The project will research and experiment on software network technologies. This will enhance partners' skills in this area.

6.1.3 Business-related KPIs

TABLE 35: 5G-PPP BUSINESS-RELATED KPIS

KPI		Relevance (High/Medium/Low)	Details on planned contribution towards achieving the KPI
B1	Leverage effect of EU research and innovation funding in terms of private investment in R&D for 5G systems in the order of 5 to 10 times.	Medium	5G-TRANSFORMER consortium is composed of multiple vendors, SMEs and operators. This shows the relevance of the addressed topics for private companies.
B2	Target SME participation under this initiative commensurate with an allocation of 20% of the total public funding.	High	The SMES participating in the project are very much committed and aims at putting into their products the mechanisms developed in the project. The project recognizes the importance of SMEs in the economic development of Europe, hence it allocates 20.9% of its budget to SMEs.
B3	Reach a global market	Medium	The technologies developed in

	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.		5G-TRANSFORMER are expected to strength the position of European companies in the upcoming 5G Mobile Network market, both in Europe and Worldwide, for the whole value chain (Verticals, Providers, Manufacturers and Complementary Industries). 5G-TRANSFORMER features members that are amongst the leading Mobile Network Operators (MNOs) and manufacturers in Europe. The two MNOs participating in 5G-TRANSFORMER, namely Orange and Telefonica, have business interests in 11 countries in Europe (e.g., France, UK, Germany, Spain, Poland, etc.), plus more than other 30 countries across different geographical areas (mainly in Africa and America), accounting for about 22% of the EU market share (84M Orange, 84M Telefonica). The 5G-TRANSFORMER manufacturers, namely, TEI, NOK-N, NEC, and IDCC are leading providers of mobile network equipment and solutions for Telecom Operators in Europe and Worldwide. Their portfolios cover most aspects of Mobile Broadband deployment, including LTE Radio Access Networks, Transport Networks, Evolved Packet Core equipment, MEC solutions, and SDN software products, acting as world-wide leaders in all those areas. These manufacturers envision a direct impact of 5G-TRANSFORMER on their products. The SMEs add novel complementary technologies to 5G-

			TRANSFORMER such as NFV and Cloud orchestration (MIRANTIS), Unified Gateway (BCOM), SDN control (NXW). Finally, 5G-TRANSFORMER includes vertical industries of distinct sectors, CRF, ATOS and SAMUR, which will validate developed solutions through relevant use-cases demanding very different requirements.

6.2 5G-TRANSFORMER high-level (project) KPIs

In order to be able to provide quantifiable contributions from the 5G-TRANSFORMER project towards the achievement of the 5G-PPP KPIs described in the previous section, we have defined and quantize a set of high-level KPIs (introduced in section 4). We refer to those as high-level/project/5G-TRANSFORMER KPIs. We summarize next, for the benefit of the reader, these project KPIs in Table 36.

TABLE 36: LIST OF 5G-TRANSFORMER KPIS

KPI	Acronym	Description
End-to-end latency	LAT	E2E latency, or one trip time (OTT) latency, refers to the time it takes from when a data packet is sent from the transmitting end to when it is received at the receiving entity, e.g., internet server or another device.
Reliability	REL	Refers to the continuity in the time domain of correct service and is associate with a maximum latency requirement. More specifically, reliability accounts for the percentage of packets properly received within the given maximum E2E latency (OTT or RTT depending on the service).
User data rate	UDR	Minimum required bit rate for the application to function correctly.
Availability (related to coverage)	A-COV	The availability in percentage is defined as the number of places (related to a predefined area unit or pixel size) where the QoE level requested by the end-user is achieved divided by the total coverage area of a single radio cell or multi-cell area (equal to the total number of pixels) times 100.
Mobility	MOB	No: static users Low: pedestrians (0-3 km/h) Medium: slow moving vehicles (3-50 km/h) High: fast moving vehicles, e.g. cars and trains (>50

		km/h)
Device density	DEN	Maximum number of devices per unit area under which the specified reliability should be achieved.
Positioning accuracy	POS	Maximum positioning error tolerated by the application, where a high positioning accuracy means a little error.
Confidentiality	CON	Preserving authorized restrictions on information access and disclosure, including means for protecting personal privacy and proprietary information.
Integrity	INT	Guarding against improper information modification or destruction, and includes ensuring information non-repudiation and authenticity.
Availability (related to resilience)	A-RES	Ensuring timely and reliable access to and use of information.
Traffic type	TRA	Depending on to the amount of data moving across a network at a given point of time, traffic can be: • Continuous. • Bursty. • Event driven. • Periodic. • All types.
Communication range	RAN	Maximum distance between source and destination(s) of a radio transmission within which the application should achieve the specified reliability.
Infrastructure	INF	• Limited: no infrastructure available or only macro cell coverage. • Medium density: Small number of small cells. • Highly available infrastructure: Big number of small cells available.
Energy reduction	NRG	Reduction of the energy consumption of the overall system. The most common metric that is used to characterize this KPI is the reduction in the consumed Joules per delivered bit.
Cost	CST	Expenditure of resources, such as time, materials or labour, for the attainment of a certain HW or SW module. OPEX and CAPEX are important components of the overall costs.
Service creation time	SER	Time required to provision a service, measured since a new service deployment is requested until the overall orchestration system provides a response (a positive response implies the service has been actually provisioned).

From the definitions and descriptions summarized in the table above, a relation between the 5G-TRANSFORMER KPIs and those from the 5G-PPP can be established[5], which is summarized below in Table 37:

TABLE 37: RELEVANCE OF 5G-TRANSFORMER KPIS INTO THE KPIS PUT FORTH BY THE 5G-PPP

		5G-PPP KPIs					
		P1	P2	P3	P4	P5	S3
5G-TRANSFORMER KPIs	LAT						X
	REL				X		
	UDR	X					
	A-COV					X	X
	MOB					X	
	DEN					X	
	POS					X	
	CON				X		
	INT				X		
	A-RES				X		
	TRA	X					
	RAN					X	
	INF					X	
	NRG		X				
	CST		X	X			
	SER			X			

[5] Note that we exclude S5 and B1-B3 from this analysis (as they are horizontal ones).

7 Conclusion

5G-TRANSFORMER aims at designing and implementing a whole end-to-end architecture capable of delivering slicing as a Service to different vertical industries. The goal is to design, provide and validate a proof of concept demonstrating the efficiency of the combination of network slicing with virtualization and end-to-end transport technologies in offering a fine grained and tailored services for a variety of vertical domains with various needs and requirements.

In order to reach such objectives, a first step in 5G-TRANSFORMER project organization is the definition and analysis of the different vertical domains and the extraction of the high-level requirements for each vertical use case that will be implemented and demonstrated later on in the project. This is carried out through this D1.1 deliverable as part of Task 1.1 of the project. Five vertical domains are selected and investigated in order to understand the different types of requirements and KPIs of future 5G system: the Automotive domain, the Entertainment domain, the eHealth domain, the e-Industry domain and lastly the Mobile (Virtual) Network Operator's one. The organization of the document followed a methodology that was discussed and agreed by all the partners of the project and that is gathered through the different sections. It helps to understand ecosystem, vertical industries, relevant use cases and high-level requirements. A detailed description of the use cases that are candidates for being validated via Proof of Concepts in the final demonstrators is also provided: the cooperative urban cross traffic application; an entertainment application for onsite fan experience during an event; a heart attack emergency scenario; cloud robotics for industrial automation; 5G network as a Service automated deployment and operation. Lastly, our analysis includes a first qualitative assessment of the relevance of high-level 5G-PPP high-level in relation to the planned contributions in the project.

This document will be considered as a first reference for all the other documents of the project and tasks, from the architecture design to the analysis of what needs to be demonstrated through use cases specific for each vertical domain. Firstly, the detailed requirements analysis of use cases will be taken into consideration when designing the high-level architecture of the project in T1.2 through the study and refinement of network slicing concept; the definition of functional elements; and the design of service function chains lifecycle and orchestration in multi-domain and federated environments. A first baseline architecture (D1.2) will be designed and fed into WP2/3/4 for their respective technology developments on the Mobile compute and Transport Platform, the Vertical Slicer and the Service Orchestrator building blocks. Iterative refinements of this architecture will be considered in parallel to technology development progress in order to come up with its final design and validation at the end of the project. The analysis of the market and business implications will be also conducted in T1.3 for the different stakeholders, namely infrastructure providers, network operators and vertical industries. Lastly, a strong effort will be devoted in WP5 to implementing and demonstrating the main project elements and use cases, integrating the novel technology components and validating experimentally that system and vertical requirements are fulfilled.

8 References

[1] NGMN Alliance, “Description of network slicing concept,” NGMN 5G P, vol. 1, 2016.

[2] Y. C. Hu, M. Patel, D. Sabella, N. Sprecher, and V. Young, “Mobile edge computing: A key technology towards 5g,” ETSI White Paper, vol. 11, 2015.

[3] 3GPP TR 28.801, “Study on management and orchestration of network slicing for next generation network (Release 15)”, V1.2.0, May 2017.

[4] Description of Network Slicing Concept by NGMN Alliance, NGMN 5G P1 Requirements & Architecture Work Stream End-to-End Architecture, version 1.0, January 2016.

[5] NGMN Alliance, “Description of Network Slicing Concept”, v.1.0.8, September 2016.

[6] ETSI GS NFV MAN 001, “Management and Orchestration”, v1.1.1, December 2014.

[7] NGMN Alliance, NGMN 5G White Paper, Feb. 2015.

[8] “5G: Serving Vertical Industries”

[9] Traffic Safety Facts, Rural/Urban Comparison - July 2015

[10] “Roadway and environment Urban/rural comparison”

[11] 3GPP TR 36.885, “Study on LTE-based V2X Services (Release 14)”, V14.0.0, June 2016.

[12] “Maternia, M., S. Eddine El Ayoubi, M. Fallgren, P. Spapis, Y. Qi, D. Martín-Sacristán, Óscar Carrasco, M. Fresia, M. Payaró, y M. Schubert. «5G PPP use cases and performance evaluation models». 5G PPP 1 (2016).”

[13] Lea Skorin-Kapov and Maja Matijasevic, “Analysis of QoS Requirements for e-Health Services and Mapping to Evolved Packet System QoS Classes,” International Journal of Telemedicine and Applications, vol. 2010, Article ID 628086, 18 pages, 2010. doi:10.1155/2010/628086

[14] ETSI. “Analysis of user service models, technologies and applications supporting eHealth”, ETSI TR 102 764 v1.1.1 (2009-02). http://www.etsi.org/deliver/etsi_tr/102700_102799/102764/01.01.01_60/tr_102764v010101p.pdf [available online: September 2017]

[15] China Mobile, Softbank, Huawei, CloudMinds, Skymind, “GTI 5G and Cloud Robotics White Paper”, 21st June 2017.

[16] “Deterministic Networking Use Cases” Internet Engineering Task Force (IETF) Internet-Draft. Version 12. April 2017

[17] International standard IEC 61400-25 (Communications for monitoring and control of wind power plants, TC 88)

[18] Ahmed, M. and R. Kim, "Communication network architectures for smart-wind power farms." Energies, p. 3900-3921, June 2014.

[19] Sperotto, A., Sadre, R., Vliet, F., and A. Pras, "A First Look into SCADA Network Traffic", IP Operations and Management, p. 518-521, June 2009.

[20] 3GPP TS 23.214 Architecture enhancements for control and user plane separation of EPC nodes.

[21] RFC 2119, "Key words for use in RFCs to Indicate Requirement Levels".

[22] "5G PPP use cases and performance evaluation modelling_v1.0" - April 2016.

[23] NIST "Information Security" - October 2006.

[24] EU Commission and 5G-PPP contract. Available at: https://5g-ppp.eu/contract/. The technical annex is also available at: https://5g-ppp.eu/wpcontent/uploads/2014/02/Advanced-5G-Network-Infrastructure-PPP-inH2020_Final_November-2013.pdf

9 Annex A. Additional details regarding Vertical Domains

9.1 e-Industry

9.1.1 Electrical Utilities: Generation scenario

Traffic characteristics relevant for the network planning and dimensioning process in a wind turbine scenario are listed below (Table 38). The values in this section are based mainly on the relevant references [18] and [19]. Each logical node (Table 5) is a part of the metering network and produces analogue measurements and status information which must comply with their respective data rate constraints.

TABLE 38: TRAFFIC CHARACTERISTICS

Subsystem	Sensor count	Analog Sample Count	Data Rate (bytes/sec)	Status Sample Count	Data rate (bytes/sec)
WROT	14	9	642	5	10
WTRM	18	10	2828	8	16
WGEN	14	12	73764	2	4
WCNV	14	12	74060	2	4
WTRF	12	5	73740	2	4
WNAC	12	9	112	3	6
WYAW	7	8	220	4	8
WTOW	4	1	8	3	6
WMET	7	7	228	-	-