5G CITY

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D2.1: 5GCity System Requirements and Use Cases

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WP2 - 5GCity Architecture, Requirements and Use Cases

D2.1: 5GCity System Requirements and Use Cases

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Editor name: Stefan Guerra (Comune di LUCCA)

List of Contributors

Participant	Short Name	Contributor
Municipality of Lucca	LUCCA	Mauro Di Bugno, Luca Falsiroli, Sfefan Guerra
Italtel	ITL	Antonino Albanese, Viscardo Costa
Fundacio I2CAT	I2CAT	Sergi Figuerola, Shuaib Siddiqui, August Betzler
INCITES	INC	Theodoros Rokkas, Ioannis Neokosmidis
RAI	RAI	Luca Vignaroli
Retevision (Cellnex Telecom)	RTV	David Pujals
Comunicare Digitale	CoDi	Andrea Michelozzi
Mog Technologies	MOG	Pedro Santos
Nextworks s.r.l.	NXW	Nicola Ciulli, Paolo Cruschelli
WindTre	WindTre	Maria Rita Spada, Andrea Viola
BTV	BTV	Jordi Colom
Ubiwhere	UBI	Pedro Diogo
Virtual Open Systems	VOSYS	Michele Paolino, Daniel Raho
Accelleran	XLRN	Simon Pryor, Antonio Garcia

List of Reviewers

Participant	Short Name	Contributor
Italtel	ITL	Antonino Albanese
Retevision (Cellnex Telecom)	CLNX	David Pujals, Luis Moreno
Nextworks	NXW	Paolo Cruschelli
WindTre	WindTre	Maria Rita Spada
Italtel	ITL	Viscardo Costa
Accelleran	XLRN	Simon Pryor, Antonio Garcia

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Executive Summary

This deliverable describes the 5GCity Use Cases with their system requirements as the main outcome of task T2.1 which has the following objectives

- defines the Use Case scenarios
- provides descriptions of the Use Cases selected and the high-level specifications for the city-wide pilot demonstrators
- defines the end-user requirements
- defines a deployment strategy.

In addition, this deliverable collects preliminary aspects of the architecture, system requirements, and KPIs and also identifies in the context of 5G City all involved stakeholders/actors with their interests

1. Introduction

5GCity main goal is to turn a city into a distributed, third party, and multi-tenant edge infrastructure, extending the cloud model all the way to the edge while enabling dynamic, fast and interoperable provisioning of 5G-based services. The 5GCity platform will embody a hierarchical architecture embedding network, compute and storage resources distributed across Small Cells and deployed at various technical spaces throughout the city: in lampposts, urban furniture, street cabinets, and traditional data centers.

The 5GCity platform will be used by 5G service providers to offload capacity to the Neutral Host, by municipalities to host Smart City services and by additional third-party services, such as media or automotive verticals in order to offer innovative services to their customers.

Another objective is to maximise the return on investment for the whole digital market chain (users, application, cloud providers, i.e., the municipalities themselves, telecom providers, and infrastructure providers). To this end, 5GCity will build and deploy a common, multi-tenant, open platform that extends the (centralized) cloud model to the extreme edge of the network. The project will manage a demonstration in three Smart Cities (Barcelona, Bristol and Lucca), and thus advance the state of the art to solve the main open research challenges in a 5G-based edge virtualization domain, including the Neutral Host perspective in dense deployment environments such as cities.

This document is outlined as follows:

Section 1 presents the basic terminology, the approach applied for the analysis of the Use Cases and the 5GCity conceptual architecture.

Section 2 presents the Use classification and scenarios by groups categorizing the project Use Cases as well as the actors and roles descriptions.

Section 3 presents the Use Cases selected for the field demos over Barcelona, Bristol and Lucca infrastructures.

Section 4 groups and summarizes all the necessary requirements, as well as maps the proposed 5G KPIs to the context of the 5GCity platform.

In **Section 5,** we conclude our remarks.

1.1. Terminology

The key terms related to our analysis are explained below:

- **Use Case**: a specific application paradigm.
  A Use Case describes how the proposed technology can be used to satisfy specific needs.

- **Scenario**: a wide application area, where the proposed technology can be valuable.
  A scenario describes the environment in which a set of Use Cases can be defined. It describes the complete functionality of the system and may include multiple Use Cases.

- **Stakeholder**: a party, which is involved and affected by a specific scenario or Use Case.
  A stakeholder can take multiple roles.

- **Role**: a set of specific activities within a specific scenario or Use Case.
  A role could be played by different stakeholders.

- **End-User**: the ultimate consumers of the services created in the telecommunication ecosystem.

- "**KPIs**": Key Performance Indicators are used to evaluate factors that are crucial to the success of the system under consideration.

- "**Requirements**": These are categorized as "functional" and as "non-functional". A requirement pertains to the technical aspects that the corresponding system must fulfil.

- "**Evaluation**": An attribute usually representing some property subject to change. Examples for potential parameters of a small cell network can be, for example: Coverage increase and increase in functionality offered to the user.

- "**Metric**": A quantitative measure of the degree to which a system, component, or process, possesses a given attribute.

1.2. Approach for Use Cases analysis

The real strength of the 5GCity project in terms of real-world impact lies in the envisioned deployment of its 5G-based edge platform in three Smart Cities: Barcelona, Lucca and Bristol. To this aim, 5GCity has already identified relevant Use Cases for the cities, to be detailed in the next sections of this document.

The employed methodology for the Use Case analysis aims to detail each Use Case, using them as a comprehensive source of requirements for the 5GCity architecture. The analysis begins with the collection of meaningful scenarios and the identification of actors' role, by collecting functional and non-functional system requirements, the involved stakeholders' interests and relationships, since the different industries are well represented within the consortia (cities, media companies and telecom companies).

For each one of the Use Cases we will elaborate a possible deployment strategy in the three cities (Barcelona, Lucca and Bristol) and will analyse the expected impact.

For each Use Case, we are going to consider the following aspects:

- Overall description of the Use Case
- Actors involved
- Deployment topology
- Evaluation
- Requirements
- Expected impact

The final step of the methodology is the extraction of high-level technical requirements based on the outcomes of the Use Cases' analysis. The extracted requirements are unified and grouped in order to proceed with the definition of the 5GCity architecture.

This kind of information will be also used for further discussions and classifications of Use Cases, KPIs, requirements and metrics that will be derived in the future, coming from testbed simulations and field trials.

1.3. 5GCity Conceptual Architecture

The 5GCity architecture will integrate the Cloud and Edge concepts through a three-tier architecture, consisting of Data Centers (DCs), 5GCity Multi Access Edge Computing (MEC) nodes (i.e., street cabinets), and 5GCity Small Cells (i.e., street gateways).

The three-tier architecture reflects three different geographical areas where the physical resources are deployed, identified with:

- a centralized area (which typically corresponds to a DC, where massive computing resource are deployed),
- an edge area corresponding to street cabinets (where limited computing resources are available due to physical constraints),
- an edge area where wireless devices (Small Cells or Wi-Fi powered) are deployed.

This concept of resource grouping in different geographical areas is well described in Figure 1.

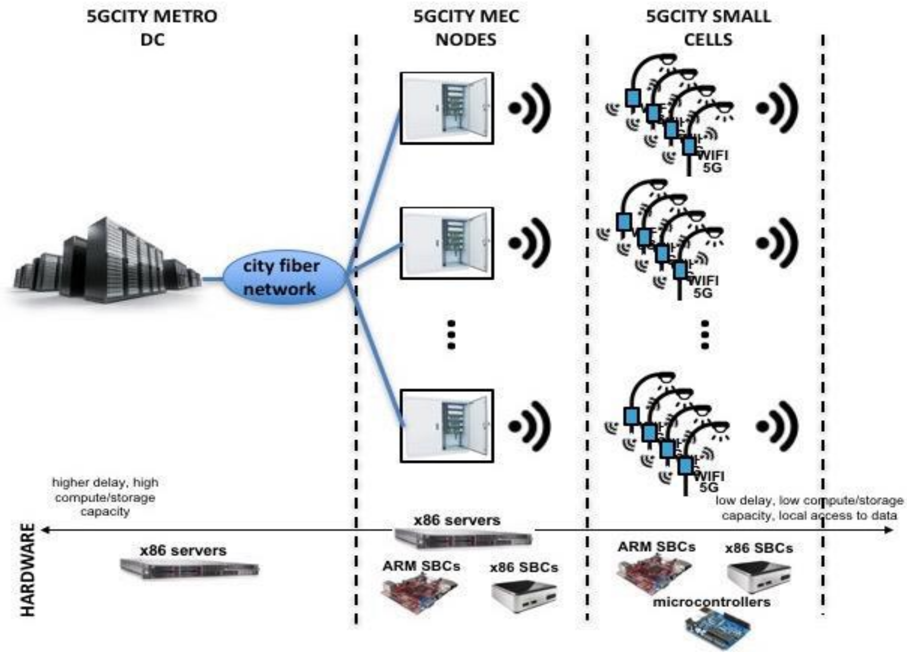

Figure 1. 5GCity Architecture and physical resources

From the functional point of view, 5GCity architecture can be described as a set of functional blocks grouped in four functional areas.

The overall 5GCity functional architecture is presented in Figure 2 and described in the remaining part of this section.

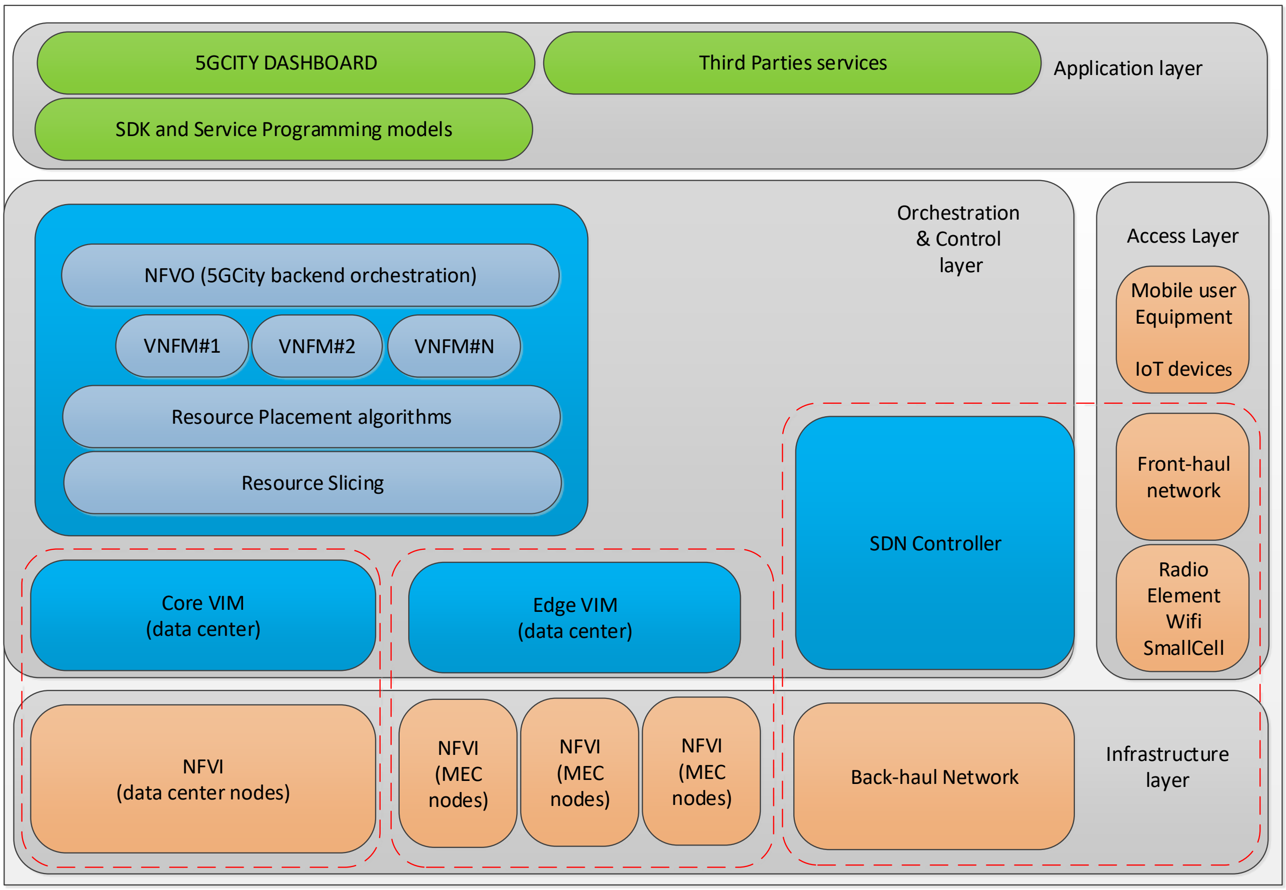

Figure 2. 5GCity high-level architecture concept

Application layer consists in a specific set of functions/tools of the proposed 5GCity architecture available for the operators of the infrastructure, their customers, subcontractors and any third-party actors. The sets of tools can be identified as:

- *5GCity dashboard* is the entry point to the system and provides capability to deploy end-to-end services upon the city physical infrastructure. The dashboard will hold different views to enable multi-tenancy by allowing different roles and capabilities for each user or tenant (e.g. super user, tenant administrator, external user)
- *Third party services* will consist in a set of tools and interfaces for the interaction between third party users representing a separate administrative domain, which holds interests in interacting with the city infrastructure.
- *SDK (Software Development Kit) and service programming models* consists in a set of tools for the creation, validation and test of specific items (i.e. VNF and network services packages) available to be deployed by Dashboard users upon 5GCity physical infrastructure. These tools are typically used in a DevOps framework.

Orchestration & Control layer represent the core functionality of the architecture by providing the capability to (i) manage a non-homogeneous set of physical resources (i.e. computing, storage, wired network and wireless network), (ii) abstract physical resources (iii) operate a horizontal slicing thus providing inherent (iv) cast end-to end services tailored to a multitenant framework. The orchestration and control layer are described in the ETSI [1] and MEC [2] references architectures.

The following functionalities are identified:

- **NFVO (Network Functions Virtualization Orchestrator)** is a functional block with two main responsibilities: (i) the orchestration of NFVI resources across multiple VIMs, fulfilling the Resource Orchestration (RO) functions and (ii) lifecycle management of Network Services (NS), fulfilling the Network Service orchestration functions
- **VNFM (Virtualized Network Function Manager)** is a functional block with the main responsibility for the VNF's lifecycle management including operations such as (i) Instantiate VNF (create a VNF using the VNF on-boarding artefacts), (ii) Scale VNF (increase or reduce the capacity of the VNF) (iii) Update and/or Upgrade VNF (support VNF software and/or configuration changes of various complexity) (iv) Terminate VNF (release VNF-associated NFVI resources and return it to NFVI resource pool). In 5G-City architecture more than one specific VNFM function could potentially deployed to satisfy specific functional requirements requested by VNF lifecycle management. A final decision on this matter does not pertain to the actual deliverable.
- **Resource Placement algorithms** are responsible for the placement of the virtual resources (VNF) over different physical resources domain. This is typically done by algorithms, tailored to the specific services intended for deployment, which take in input data from the edge network (geographical position, available resources in terms of vCPU, vRAM, vDISK) and calculates the best placement option. The output of this algorithm is an input to VIM layer, which effectively runs the deployment over the operated infrastructure.
- **VIM (Virtualized Infrastructure Manager)** is responsible for controlling and managing the NFVI compute, storage and network resources, usually within an operator's infrastructure domain. A VIM can be specialized in handling a certain type of NFVI resource (e.g. compute-only, storage-only, networking-only), or can be capable of handling multiple types of NFVI resources (e.g. in NFVI-Nodes). In the 5GCity Architecture two different types of VIM will be used:
    - Core VIM (which operates homogeneous physical resources located in the city data center).
    - Edge VIM (which operates a non–homogenous, wide area, resource constrained set of physical resources located in street cabinets across the City).
- **SDN controller** is responsible to provide intuitive programmatic interfaces along the lines of the network interfaces and thus can be best categorised as an abstraction layer below the VIM for a given NFVI-PoP. Each NFVI-PoP or administrative domain may include a network controller (e.g. SDN controller) responsible for providing the programmable network interfaces that enable the establishment of connectivity within the domain. In 5GCity architecture, the SDN Controller oversees the configuration of the back-haul and front-haul network. For this, the SDN Controller interacts with the Access Layer for the front-haul network and the Infrastructure Layer for the back-haul network.

The Infrastructure layer is composed by functional blocks for physical resources management across the city infrastructure.

- **Core NFVI (data center)** is responsible for the management of virtualized and non-virtualized resources, supporting full and partially virtualized network functions. Virtualized resources *in-scope* are those that can be associated with virtualization containers, and have been catalogued and offered for consumption through abstracted services, for example:
    - Compute, including machines (e.g. hosts or bare metal), and virtual machines, as resources that comprise both CPU and memory.
    - Storage, including volumes of storage at either block or file-system level.
    - Network, including: networks, subnets, ports, addresses, links and forwarding rules, for the purpose of ensuring intra- and inter-VNF connectivity.
- **Back-haul network** is the portion of network, which provides connectivity from MEC nodes to the DCs resources.

- **Edge NFVI** (MEC nodes) are non-homogeneous pools of resources located away from centralized DCs, with limited capabilities due to constrained resources in terms of power, computing, connectivity.

Access layer is composed by all physical resources providing connectivity in the 5GCity infrastructure (e.g., end-user devices and IoT sensors). The components of the access layer are categorized in:

- **Radio element (for Small Cells and/or Wi-Fi),** which corresponds to the hardware equipment producing the LTE/5G radio channels. 5GCity, following the evolution of radio access network towards a perfect integration with 5G topics, foresees a Wi-Fi and LTE/5G as main radio access technologies.
- **Front-haul network** is the portion of network, which connects the cell site unit (RRH or RU) of the base station to its digital unit (BBU) residing centrally in a DC or local cabinet.
- **End-user devices** correspond to the devices, which generate traffic or request a set of services from 5GCity architecture and can be divided in two main categories based on their requirements and resource demands, (i) Mobile Phones (End-User Mobile equipment) and (ii) IoT sensors (Video Cameras).

2. 5GCity Use Cases Scenarios

2.1. 5G Use Cases classification

The 5G architecture is expected to accommodate a wide range of Use Cases with advanced requirements, especially in terms of latency, resilience, coverage, and bandwidth. Thus, a major challenge is to provide end-to-end network and cloud infrastructure slices over the same physical infrastructure in order to fulfil vertical-specific requirements as well as mobile broadband services in parallel.

The current network and ICT solutions are based on a relatively static and closed architecture; on the other hand, for the 5G solutions, decoupling the two levels of hardware and software will constitute the technical enabler to offer a new paradigm to operate ICT infrastructures with the degree of flexibility imposed by the 5G requirements. The new solution will also help to move computing and storage resources to the most peripheral areas of the network (Edge Computing) closer to the users by lowering the latency values as required by some digital services, even within the energy industry. The flexibility offered by SDN and NFV will be used to develop virtual frameworks, or "network slice" consisting of a set of virtualized resources that share the same physical infrastructure.

Another element of innovation in the new 5G core network architecture is the separation of user mobility Control Plane (CP) from User Plane (UP). The split between CP and UP increase the flexibility and adaptability of the network by handling the User Plane (payload) more effectively for each transported service by the infrastructure. In this way 5G networks will deliver a step change of ultrafast, low latency (i.e. quicker reaction times), reliable, mobile connectivity, that is able to support ever larger data requirements, as well as wide-ranging of new applications. So, 5G networks will be dynamically tailored to meet the needs of the individuals or services time by giving users all the communications capability they needed.

Another 5G pillar - needed to cope with some Use Cases requesting ultra-bandwidth – is the availability of new multiple bands of spectrum. 5G needs radio spectrum within three key frequency ranges to deliver widespread coverage and support all Use Cases (see Figure 3).

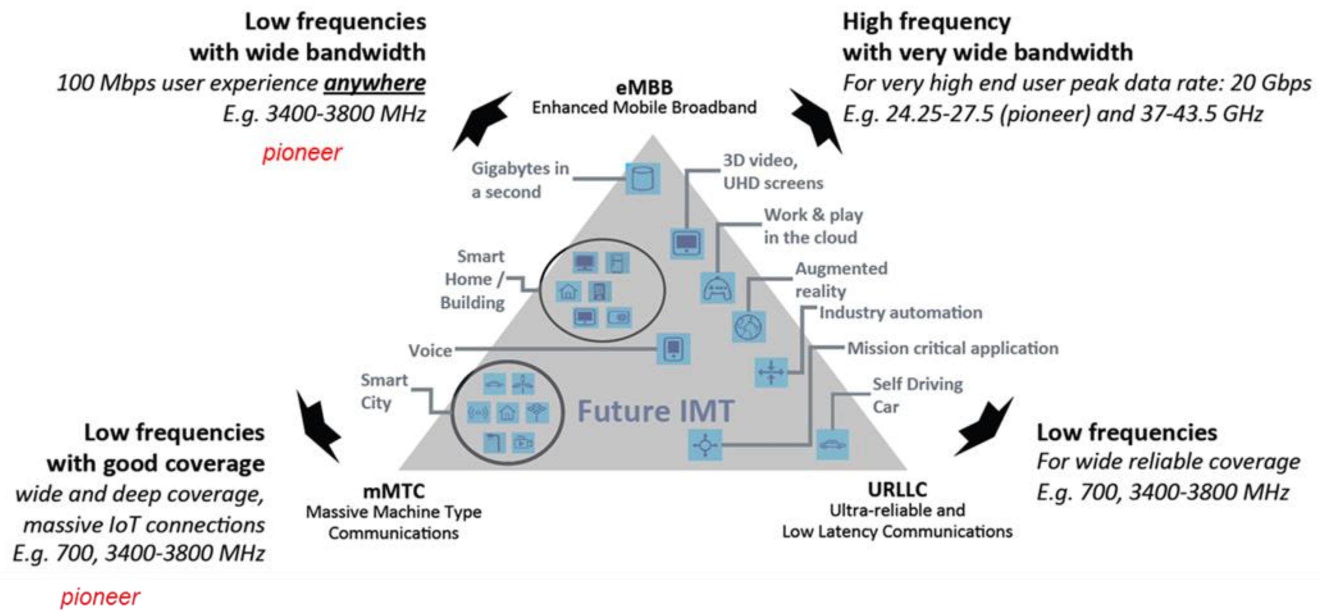

Figure 3. Mapping between 5G Use Cases and radio spectrum

The 5G techno-economic landscape described so far leads to a huge number of Use Cases, which have been described and analysed in the context of several standards bodies, such as 3GPP and ITU-T, industry forums such as NGMN Alliance, projects of phase 1 of the 5G-PPP, and through the interaction with the community of the industry verticals. In the remaining part of this section, we will present the Use Cases classification handled by NGNM Alliance and the 5G-PPP initiative that operates a Use Case classification considering a certain number of drivers. In addition, it will be shown how the 5GCity specific Use Cases map into a wider Use Case framework.

The NGMN Alliance, [6], has put proper focus on the end-user and the mobile to access services. To this scope, the following categories (see Figure 4) have been identified as representative of different possible scenarios. The categories are intended to group Use Cases and scenarios with similar requirements and are described as follows:

- **Broadband Access in Dense Areas:** The focus is service availability in densely populated areas (e.g., multi-storey buildings, dense urban city centers or events), where thousands of people per square kilometre (km^2) live and/or work. Communications are expected to be pervasive and part of everyday life. Augmented reality, multi-user interaction, three-dimensional (3D) services will be among the representative services
- **Broadband Access Everywhere**: The focus is on the capability to ensure ubiquitous access to broadband service, including the more challenging situations in terms of coverage from urban to suburban and rural areas
- **Higher User Mobility**: With focus on a growing demand for mobile services in vehicles, trains and even aircrafts
- **Massive Internet of Things (IoT)**: the typical scenario with massive number of devices (e.g., sensors, actuators and cameras) with a wide range of characteristics and demands
- **Extreme Real-Time Communications**: This family covers Use Cases, which have a strong demand in terms of real-time interaction. These demands are Use Case specific and, for instance, may require one or more attributes such as extremely high throughput, mobility, critical reliability, etc. For example, the autonomous driving Use Case that requires ultra-reliable communication may also require immediate reaction (based on real-time interaction), to prevent road accidents. Others such as remote computing, with stringent latency requirement, may need robust communication links with high availability
- **Lifeline Communication**: with focus on Public safety and emergency services, referring also to authority-to-citizen and citizen-to-authority and authority-to-authority communication in case of emergency prediction and disaster relief
- **Ultra-reliable Communications**: with focus on automotive, health and assisted living applications
- **Broadcast-like Services**: with focus on content and interactive services or acknowledgement information.

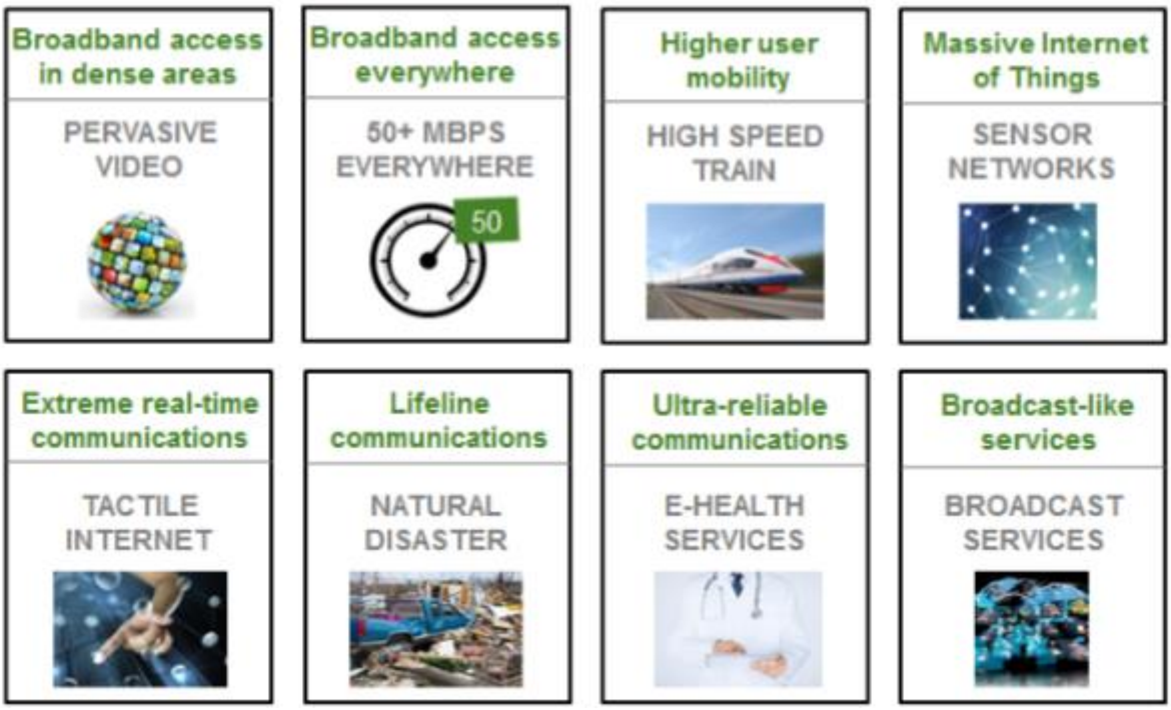

Figure 4. NGMN Use Cases classification

On the other hand 5G-PPP Association [9] uses a different rationale, where the Use Cases are originated by the 5G verticals (factory of the future, energy, healthcare, media and entertainment, automotive and mobility) and the classification is done according to 5G KPIs (device density, mobility, infrastructure, traffic type, user data rate and latency) thus providing the following groups:

- Dense Urban
- Broadband (50+Mbps) everywhere
- Connected vehicles
- Future smart offices
- Low bandwidth IoT
- Tactile internet / automation

The 5GCity Use Cases show that while they are still part of the 5G vision identified so far, some inherent peculiarities are strictly tied to the specific needs and requirements of three representative European smart cities.

The proper mapping of 5GCity Use Cases to NGNM Alliance and the 5G-PPP Association is given in Table 1 and Table 2.

NGNM Use Cases families	5GCity Use Cases
Broadband Access in Dense Areas	UC1, UC2, UC3, UC4, UC6
Broadband Access Everywhere	UC6
Higher User Mobility	UC5
Massive Internet of Things (IoT)	N/A

Extreme Real-Time Communications	N/A
Lifeline Communication	UC1
Ultra-reliable Communications	N/A
Broadcast-like Services	UC3, UC4

Table 1. 5GCity Use Cases with respect to the NGNM Alliance Classification

5G PPP Use Cases families	5GCity Use Cases
Dense Urban	UC1, UC2, UC3, UC4, UC5, UC6
Broadband (50+Mbps) everywhere	UC3, UC4
Connected vehicles	UC6
Future smart offices	N/A
Low bandwidth IoT	UC1
Tactile internet / automation	N/A

Table 2. 5GCity Use Cases with respect to the 5G PPP Association Classification

2.2. 5GCity Scenarios

5GCity architecture paves the way to adapt distributed cloud technologies within 5G dense deployments in city-based environments building its combined edge and network infrastructure. It provides a multi-tenant, cost-effective platform for deploying virtualized heterogeneous services, including the multi-RAT and virtualization technologies for the access network.

5GCity has identified three main scenarios which groups the project Use Cases, namely the **Neutral Host**, **Industry vertical** (Media and Entertainment) and **City services**, as described in Figure 5.

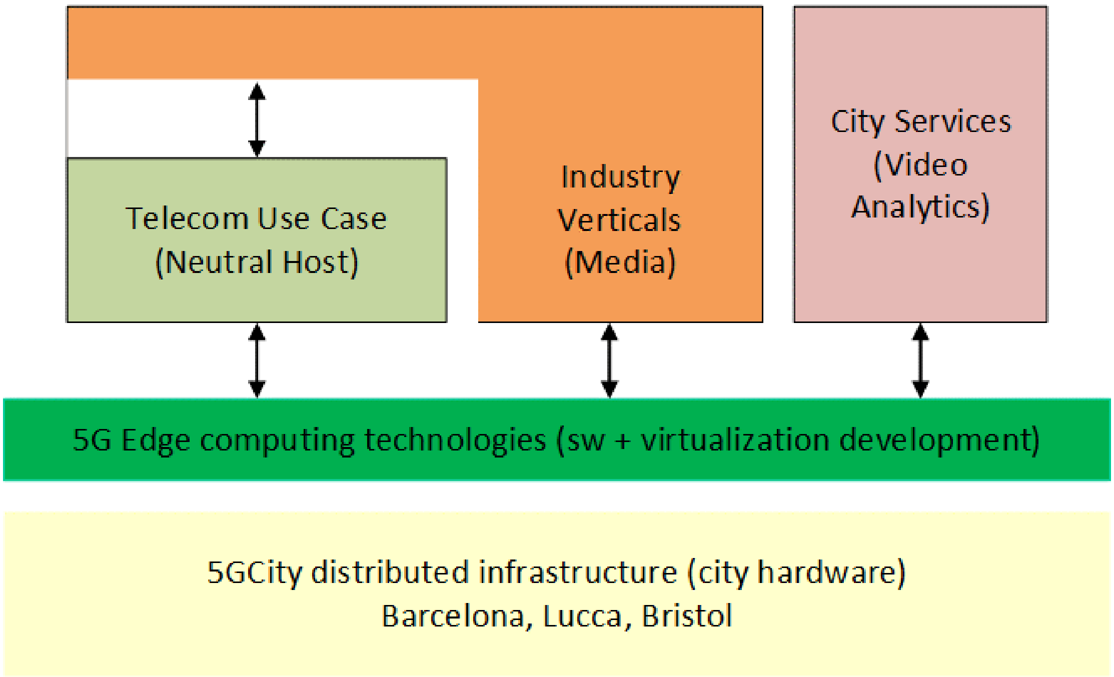

Figure 5. 5G City Use Cases Scenarios

In the first scenario (Telecom Use Case), 5GCity leverages its virtualization platform to enable the cities (or any infrastructure provider) to create dynamic end-to-end slices containing both virtualized edge and network resources and lease it to third-party operators. For example, a mobile operator can become a service provider in cities where it does not have infrastructure, with full management and control capabilities over the slice, further than the typical MVNO Use Case.

Business modelling aspects and techno-economics aspects of the Use Case are fundamental aspects to be investigated.

This scenario is called the “Neutral Host Use Case” and consists of managing the underlying physical infrastructure to offer a set of virtual resources to an operator, who builds, on top, its own services ready for end-user consumption. It will play a key role in the development of 5G networks, especially in "Enhanced Mobile Broadband" or "Ultra Low Latency" cases where the need to increase capacity or reduce latency is greater, and to densify the access network.

In this model, the “Neutral Host”, which is the infrastructure owner, is able to operate a partition of its resources and to arrange them in a set of homogeneous tenants (or slices), and is able to expose them to a service provider which in turn uses these resources to compose the portfolio of its services. In the most typical case, the service provider is represented by TLC retail, OTT, Industries, same Public Administration.

This model combines the vision of a physical network as a container of a set of virtual networks; each of these networks is, in turn, made up of virtual resources realized using a portion of the allocated physical resources and functionalities that the specific "virtualization" or "slice" requires. The specific requirements of each slice can be related to quality policies, security and encryption functions, functions routing, radio resource management capabilities, etc.

The Neutral Host model must therefore be able to include all the features that enable different "slice" of resources to be managed on various levels: from ad hoc functions to network portions and even spectrum, while maintaining low the cost of the network service provided by Competitive Neutral Hosts.

According to the ETSI and 3GPP standards, the 5G network aims to provide broadband services with very stringent reliability and latency requirements, such as in machine-type communications (e.g. tele control, automotive, smart city).

In this scenario, the innovation trends will be to dynamically adjusted resources on demands: infrastructure resources, connectivity and all network functions will be delivered as a service: the "Neutral Host" model will require some partnership-based business models to be explored in the 5GCity project. Operators will tap into the opportunity to enhance the value of third-party services. Partnerships will be established on multiple layers ranging from sharing the infrastructure, to exposing network capabilities as a service end-to-end, and integrating partners' services into the 5G system through a rich and software-oriented capability set.

All the Use Cases will help to investigate many important open issues, in particular correlated to the new "Neutral Host" model: among the expected impacts will be the capability to better understand how to cope with the highly demanding disruptive capabilities of 5G.

The diversity of services and the complexity of the infrastructure will increase: the "Neutral Host" model in 5G is expected to radically cut total cost of ownership of the infrastructure and it could be useful in the reduction of service creation and deployment times.

The second scenario (Industry vertical) is strictly related to different aspects of the media and entertainment industry, which are strictly integrated into 5GCity project, and encompass all the Use Cases pivoting around video acquisition, editing and delivery.

This scenario is called the "Media Use Case"; where three different media Use Cases are taken into account:

- Mobile real-time transmission
- UHD video distribution
- Real-time video acquisition and production in the edge cloud.

The third scenario (**City Services**) is tailored to the specific needs of the city of Lucca, which holds some yearly events that are highly disproportionate to the city size, resulting in many issues including illegal waste dumping. 5GCity exploits the cities' surveillance cameras, deploying a virtualized monitoring service that can process video streams near cameras automatically to identify illegal dumping. This scenario is intended to encompass the Use Case 4 "Unauthorized waste dumping prevention Use Case" and it enables the Video Analytics based applications to be deployed at the city's infrastructure.

2.3. Actors and Roles description

The value creation in the telecommunications market is no longer the case of a closed market limited to a few players: new roles and relationships are evolved and become part of the new ecosystem. Each actor must understand its position in order to increase its value and maximize the potential revenues.

The following section describes the initial insights regarding the value chain analysis to be built upon the main element of 5GCity. The value chain of actors involved in the architecture and Use Cases of 5GCity is depicted in Figure 6.

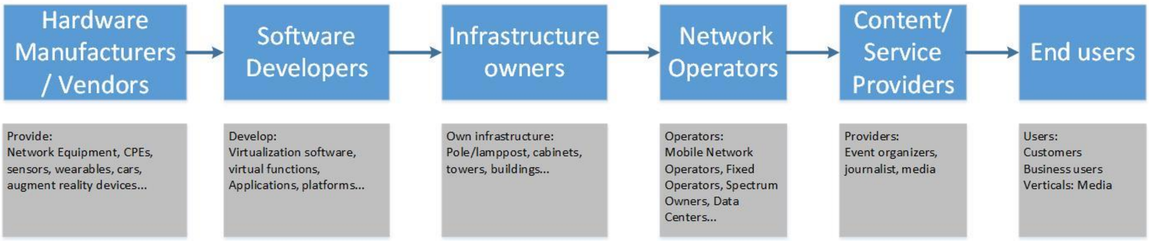

Figure 6. Value chain analysis

The definition of the actors that take part in the value chain analysis is the following:

Hardware (Equipment) manufacturers / vendors

This actor is on the beginning of the value chain and provides all the necessary equipment to all other actors involved in the 5GCity architecture. It includes entities / equipment that either manufactures and/or sells. The equipment can be ICT related like servers, hard disk drives, RAM etc., networking equipment like routers and switches and radio equipment like small cells. In a broader perspective, we can also include vendors that manufacture equipment associated with the city infrastructure such as lampposts, cabinets, cameras, sensors etc. It also includes vendors providing devices for End Users such as mobile phones, tablets and wearable devices that allow the delivery of enhanced 5G services like augmented reality or UHD video.

Software Developers

These entities develop the necessary software as well as the Virtual Network Functions (VNFs) for the delivery / provision of 5G services. The VNFs can be classified as i) those that are necessary for the delivery of the service and ii) the other ones that are complementary and are tailored to fulfil the requirements of users like the media vertical or immersive services. This type of actor also includes entities that create applications that can benefit from the 5GCity architecture, like for example video analytics or augmented reality software.

Infrastructure owners

These entities own the necessary infrastructure that can be used for hosting the computing, storage and networking infrastructure. The available resources include space in street cabinets, lampposts or buildings along with power supply and connectivity facilities. These are necessary to power and interconnect the ICT equipment. Municipalities can be included in this category and are expected to play a significant role since they possess both facilities and ICT infrastructure. Municipalities will act as a Neutral Host providing wholesale access to interested parties (network operators). Thus, such entities will be an important part of 5GCity business model enabling network densification and keeping low costs.

Network Operators (ICT infrastructure providers)

This category includes all types of network operators like mobile and fixed, cloud providers, data centers that owns the physical resources of the network. It also includes entities that own spectrum licenses. This entity will receive wholesale access from Neutral Host in order to provide services to End-Users.

Content/Service Providers

It includes entities that does not own network resources but use virtual resources to create and provide their own services. By taking advantage of the 5GCity architecture and the Neutral Host concept, service providers have a pool of different type of resources that can select and use to develop new and innovative services. The type of services they offer can be connectivity, Internet access, content distribution etc. They can develop their own content or come into agreement with other Content Providers or even End Users. They enter into Service Level Agreements with Network Operators to get access to the physical resources.

End-Users

This term covers all short of users that range from simple users that seek only connectivity services to vertical industries that have more specific and tight requirements. They are the ultimate consumers of the services created in the telecommunication ecosystem. Furthermore, End-Users can become content producers to Service Providers.

The relationships between the different actors involved in the value chain are illustrated in Figure 7 .

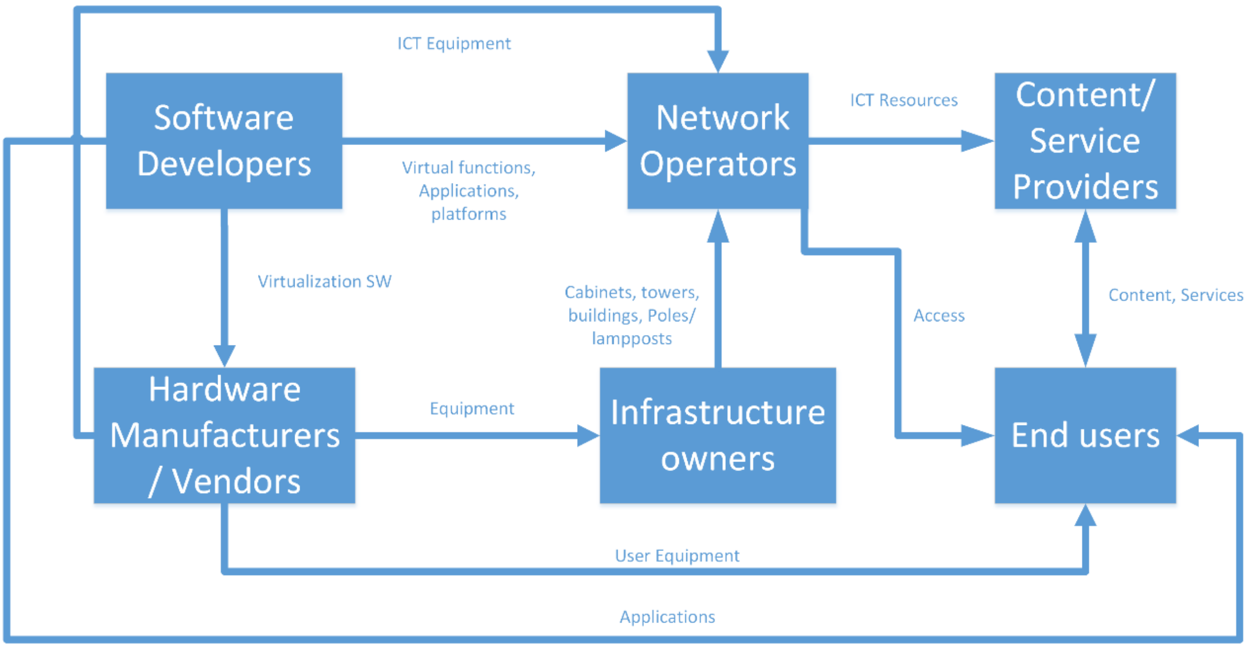

Figure 7. Relationships between actors

The Hardware Manufacturers and Vendors provide all the necessary hardware equipment to other actors. The software developers provide the software required for the hardware to the Hardware Manufacturers and the VNFs along with platforms to the Network Operators, they also develop applications that are oriented towards the End-Users. Infrastructure owners provide access to the resources they own to the Network Operators in order to install the necessary ICT equipment and provide access to the End-Users. The Content/Service Providers can get resources from the Network Operators and provide the content and services to End-Users.

Finally, End-Users consume the resources and services provided by the other actors while at the same time they produce their own content that sell to Content Providers.

3. Use Cases Description

In this section are described the 5GCity Use Cases selected for the field demos over Barcelona, Bristol and Lucca infrastructures.

For each Use Case, we investigate the involved actors, deployment topology, the evaluation process, as well as the main requirements extracted. Six Use Cases have been selected, see Table 3; they are strictly related to the scenarios illustrated in section 2.2.

ID	Use Case Name	City		
		Barcelona	Bristol	Lucca
UC1	Unauthorized Waste Dumping Prevention	NA	NA	Yes
UC2	Neutral Host	Yes	Yes	Yes
UC3	Video Acquisition and Production Community media engagement in live events	Yes	Yes	NA
UC4	UHD Video Distribution Immersive Services	NA	Yes	Yes
UC5	Mobile Backpack Unit for Real-time Transmission	Yes	NA	NA
UC6	Cooperative, Connected and Automated Mobility (CCAM)	Yes	NA	NA

Table 3. 5GCity Use Cases table

3.1. Unauthorized Waste Dumping Prevention

3.1.1. Overall Description

The Use Case is focused on monitoring, by means of video surveillance, of urban areas under the risk of environmental abuse, mainly because of unauthorized dumping of waste materials. The Municipality has already identified areas prone to this risk, and has in place a preliminary set of standard video cameras installed for that purpose. The Municipality would like to exploit the existing structure in a flexible and scalable way, both for the pilot case in 5GCity, and in order to evaluate and increase the level of service for the city, in the frame of 5GCity.

Overall, disposal of waste represents an issue for the Municipality and requires an active cooperation of citizens according to relevant regulations related to waste management. The collection of Municipal waste in the historic center of Lucca and in the surrounding areas is commonly carried out by "door to door" collection, directly at the households. Residents are required to separate different waste fractions and leave them outside their homes in different bins or sacks during specific time windows. In addition to the door-to-door collection system, there are in the city center seven collection bays where authorized residents can dispose waste fractions inside specific containers. The access to the containers requires the full identification through a smart card. However, unauthorized waste disposal in areas not intended for collecting waste or cases of incorrect disposal (waste not allowed or waste to unauthorized device) are frequent.

To tackle this situation, the City of Lucca has launched a law enforcement effort by the Municipal Police. To intensify this activity several video surveillance points have been deployed to address environmental control. In this sense, a specific resolution of the Board of the City has identified 20 areas to be subject of environmental video surveillance that are already partly equipped with specific signboards.

Video recordings are collected through fixed and mobile cameras (also with unmarked cars) and sent to the Municipal Police station. The City aims to extend the video surveillance network to cover all areas identified as relevant for monitoring and to improve efficiency in the use of the data recorded with devices others than the ones currently used, while respecting the principles of data confidentiality and security.

In this Use Case, in the context of 5GCity, the City intends:

- To set up a dedicated 5GCity monitoring point to deploy the required technologies (HD Video Camera), in a specific waste collection island that will be monitored H24. The video stream will be made available to the Municipal Police through Wi-Fi connection for the usual control, and to other authorized municipal offices
- To host a video analytics application - at the specific Municipal Office premises, at the edge (cabinet) - useful to identify the most common scenarios where unauthorized actions are performed, in order to ease the identification of the most interesting frames of the video
- To investigate about the possibility to distribute with 5G capabilities provided by partners the video stream to specific mobile terminals and introduce flexibility in the use of available physical infrastructure
- To deploy the same level of infrastructures in other waste collection islands
- To set up a mobile 5GCity monitoring point to deploy the required technologies (HD Video Mobile Camera), in areas outside the city centre where surveillance is required by the Municipal Police, due to frequent unauthorized dumping of waste. The video stream will be made available to the Municipal Police through Wi-Fi/LTE/5G connection
- To run VNFs hosted at the edge close to the monitored area, considering the trade-off between processing power and available space on the street cabinet
- The use of (real-time/near-real-time) video analytics VNF will allow smarter control procedures, including the possibility to trigger (real-time) alert procedure to the Municipal Officers, which are the closest to the monitored point
- To overcome physical constrains of the historic built environment (e.g. urban canyons, rules concerning conservation of build heritage, hindering excavation and optimal deployment of wireless technologies, distance from MEC to data center)
- To increase flexibility of the virtual infrastructure (e.g. several processing shutdowns, speed up activation of new services at the edge).

In short, at the monitored area the abuse of a certain persons consisting in unauthorized waste dumping outside the available containers (or other related abuses carried out at the monitored area, e.g. unauthorized parking) will be recorded by a dedicated HR video camera and analysed by real-time video application running on VM on a commodity server hosted by a cabinet nearby in order to detect the abuse.

Thereafter real-time alert and possibly relevant video recording sequences should be sent to the Municipal Police Officer closest to the monitored area in order for him/her to reach the place and catch in the act the offender.

3.1.2. Actors Involved

HW vendors

Provide servers for video computing to be hosted at the edge in street cabinets (e.g. Adlink).

SW developers

Provide video analytics applications (e.g. NEC).

Infrastructure owner

City of Lucca

Network Operators

Provides 5G access (i.e. non WiFi) to mobile terminals of the Municipal Officers (video streaming, alerting messages, etc.) - (e.g. WindTre)

Content/Service Provider

NA

End-User

Municipal Officers (e.g. Police, municipal ICT managers).

3.1.3. Deployment topology

A deployment scenario in the City of Lucca concerning unauthorized waste dumping prevention is represented in Figure 8 and Figure 9.

The area lies nearby the ancient city walls inside the historic town. Real time video analytics application will run in MEC server hosted in the cabined close to the monitoring area.

For example, in case any offender leave or throw waste outside the specific waste container the abuse shall be recognized by real-time video analytics and the Municipal Police Officer closest to the area shall be alerted on his/her smart device. Possibly relevant video sequence shall be transmitted to him/her in order to get into action directly and catch the abuser on the act.

Figure 8. Use Case 1 – Location

Figure 9. Use Case 1 – Cameras details

3.1.4. Evaluation

The evaluation will consider the following main criteria:

- The reduction of the ratio between recorded and transmitted video
- The reduction of the time spent by Municipal Officers in the process of verifying video recordings in order to identify waste dumping abuses
- The energy consumption of the devices for video surveillance
- The ratio between the monitored time window and the transmitted video.

In general, it will be relevant to focus on the number of abuses detected shortly after the abuse is performed, where at least an increase of 50% of abuses detected will be targeted, as well as the number of cases where the offender is caught on the act.

In addition, an increase of the number of other type of abuses, as cars illegally parked in the monitored areas will be carefully considered.

3.1.5.Requirements

We can summarize in Table 4 the most important requirements.

Rn	Description
1	Multiple Wi-Fi/4G/5G hotspots distributed in the project area
2	2-10 Mbps per device
4	Download bit rate from 2 to 10 Mbps
5	Near real-time video service, transmitting relevant video sequences to the Municipal Police Officer.
6	Storage service at the edge (MEC)

Table 4. Use Case 1 Requirements

3.1.6. Expected Impact

We expect six positive impacts:

- Lowering costs – the automatic video analytics application can significantly shorten the time dedicated to manually analyse video recording to identify relevant waste disposal abuse scenarios
- Shortening the response time of Municipal Police after the abuse has been performed, to ease the identification of the culprit
- Enhancing the urban environment
- Freeing resources – the need for personnel to manually cover video analysis tasks is reduced and therefore these resources can be redirected to another relevant tasks and activities requiring personnel
- Increasing the quality of experience (QoE) – The usage of high quality video recording will improve the QoE for the involved personnel
- Transferring this approach to other issues where video surveillance is relevant for the city, e.g. crowd control, crime prevention, mobility and car plate identification.

3.2. **Neutral Host**

The deployment of a new mobile infrastructure due to the introduction of 5G technology will create serious impacts in the economy of the telco companies

The development of new communication networks is dependent on the emergence of globally accepted standards to ensure interoperability, economy of scale with affordable cost for system deployment and End-Users. This new high-performance network will be operated via a scalable management framework by enabling fast deployment of novel applications, that includes sensor-based applications, to reduce by at least 20% the network management cost (OPEX) comparing the current metrics.

In addition, will be provided a new lightweight but robust security and authentication metrics suitable for a new era of pervasive multi domain virtualised networks and services.

It is thought that different applications and different services will require different bands of spectrum and different networks. In view of the challenges we face, we must find the types and topologies of the network, the management of the infrastructures, the spectrum management and business models that respond to the needs of citizens, industries and the digital ecosystem in general.

One of the mechanisms that may help to lower the network deployment costs by reducing the number of deployed sites in a same area and also decreasing the number of infrastructure elements is the use of a Neutral Host scenario, this will take advantage of applying ‘slicing’ techniques to the network. In such scenarios, the network will be operated by only one entity and the RF channels will be sliced and offered to the service providers (the companies that offers the service to end customers). In that case, the service providers or tenants will not have the need to deploy their own network and will have the chance to use network slices hired to the Neutral Host operator.

The business model that will succeed will take advantage of these improvements in terms of technology but many things need to be specified in this project in order to have it clear. Technological parameters will define concretely the final business model and the corresponding revenues. For example, on the one hand coverage will be needed for CAPEX cost and on the other hand latency for End-User definition.

Moreover, considering the Neutral Host architecture, in the project we will define how to sell the service, how to impute costs, how to guarantee the quality of service. Now 3G, 4G networks are based on service but do not consider bandwidth used, users, kind of quality, etc.

3.2.1. **Overall Description**

The “Neutral Host” is an intermediate provider between manufacturer or RF equipment provider and Mobile Operators/Service Providers.

Different business models as well as different technical solutions and roles could take place depending on the specific context and on the different actors of the value chain, from Municipalities as owners of the urban space, infrastructure suppliers, participating network operators, service providers, up to the End-Users.

The Neutral Host operator is having many dedicated functions to carry out in order to offer a good service to each of the tenants. These functions need to be operated in the edge of the network to be closer the access point and to be able to assure the right performance as throughput, latency, capacity, etc. The virtualization of the network is a key point to achieve correct system behaviour by making use of VNF and/or SDN techniques.

In this context, the network element operating infrastructure and resources will have to manage several technical and business aspects such as RAN resource reservation, Edge computational resources reservation, providing connectivity to the core service of each tenant, providing isolation, monitoring SLAs for each tenant, etc.

3.2.2. Actors Involved

According to the adopted schema as described in section 2.3, the actors that take part are the following:

Hardware (Equipment) manufacturers / vendors

This actor provides all the necessary equipment to realize the Neutral Host framework. It includes entities that either manufacture and/or sell equipment. In the Neutral Host framework, the following equipment are involved: ICT related like servers, hard disk drives, RAM etc. MEC, networking equipment like routers and switches and radio equipment like small cells, sellers of infrastructure such as pole lamps, cabinets, cameras, sensors, mobile phones, tablets and wearable devices.

In all three cities Accelleran will provide the Small Cell products in different LTE band variants (depending on the spectrum availability in the different cities) such as 2.6GHz FDD (3GPP B7), 2.6GHz TDD (3GPP B38) and the 3.5GHz TDD (3GPP B42 and 3GPP B43) spectrum earmarked for 5G in sub-6GHz bands. Accelleran will also provide the needed centralised Small Cell cluster functions deployed in the city cabinets.

Software Developers

Software developers are involved to provide services based on Virtual Network Functions (VNFs) according to the requirements to deliver services not only for media vertical but also to offer innovative solution based on the new capabilities of 5GCity architecture.

Infrastructure owners

Usually, Municipalities are owners and administrators of urban spaces well positioned to host 5G small-cells, like lampposts, urban furniture, street cabinets and bus shelters. They play as fibre infrastructures provider, as well.

Telco operators are owners and administrators of the access and backbone network; they make possible a fast and effective small-cell deployment, thus sharing costs and increase the overall sustainability of smart city applications and services

Different roles can be envisaged for the telco operators in the smart city platform. These include integration and operation of the overall network infrastructures (owned and from third parties) that are required to manage both static use-cases requiring mostly fixed facilities (e.g. surveillance, waste and air pollution monitoring) as well as rather dynamic ones like mobility management, which rely on an umbrella wireless coverage across the whole city.

In the deployment of such nanocells, urban spaces of Municipalities will play a key role. Such big deployment will require a high density of sites that can only be provided by Municipalities.

Network Operators (ICT infrastructure providers)

This category includes all types of network operators like mobile and fixed, cloud providers, data centers that own the physical resources of the network. It also includes entities that own spectrum licenses. This entity will receive wholesale access from Neutral Host to provide services to end-users.

Thanks to the synergistic work among the Neutral Host framework, vertical operator, local public administrations it is possible to realize a telecommunications network by maximizing the reuse of existing infrastructures, while providing innovative and useful services to End-Users, particularly those expected by the citizens.

The vertical operators (such as TLC operators) plays an important role in this model, providing end-to-end service to the final user in cases where radio coverage and mobility are crucial to ensuring the service with the expected requirements. In particular, it is critical for model development to verify the coexistence of 5G technology and to interplay with the existing 4G network, the portability of services currently available on the LTE network, and the improvements that can be made to other Wi-Fi-based solutions.

Content/Service Providers

It includes entities that use virtual resources to create and provide their own services. Within the project for Barcelona side Retevision (Cellnex Telecom), Barcelona City and i2Cat will be the main involved actors, for the Italian side RAI, CoDi, WindTre and Lucca and for the Bristol side BIO and MOG will also be the main involved partners.

End-Users

In the Neutral Host Use Case as End-Users we will consider a range from simple users that seek only connectivity services to vertical industries that have more specific requirements. We will consider Citizen, Municipal Officers, content producer (End-User included) and content and service providers.

3.2.3. Deployment topology

The “Neutral Host” model is of the fundamental importance where the need is to densify the access network to reduce costs and maximize the use of available resources. In fact, a single hosting operator provides access to network resources in a neutral place or environment by discriminating and maximizing efficiency in the use of scarce resources (e.g. radio frequencies, physical spaces such as cabinets, etc.).

NFV and SDN will be key elements in the 5G deployment. The amount of available solutions based on NFV and SDN allows facilitating the separation of the network layers and the deployment of shared and distributed active and passive infrastructure. Therefore, it can be useful in the 5G networks deployment allowing a more efficient use of the functional network elements and accelerating the availability of services for the End-Users. In addition, the availability of SDN based architecture will be able to facilitate the coexistence and the transition from 4G to 5G.

5G can be *understood* as an umbrella underneath of which there will be a massive number of services with different functional requirements and therefore the solutions in terms of infrastructure will depend on each particular service.

Thanks to concepts like Network Slicing and Network Virtualization, it is very likely that different services and different applications will be implemented on a single common infrastructure over which several qualities of service may run.

Notwithstanding, it is also reasonable to think that a unique network will not be able to respond the needs of all the range of applications that 5G could offer. In some cases of high level of criticism and availability is possible to decide the deployment of independent and dedicated networks, due to the type of services to be run and the level of requirements for operating. An example could be the security and emergency networks.

The fact that the coverage radius of the small cells is much smaller than the traditional base stations will cause a multiplication of the number of sites housing these new stations. In that context, in high density population areas but also in rural and sub-urban areas, the availability of optical fibre (for the connectivity and access), electrification and accommodation of the urban furniture (light posts, traffic signals, roofs, etc.) will become of big relevance, being the latter the passive infrastructures over which most of the Small Cells will be installed. Regarding the access to urban furniture there are two aspects to highlight, on the one hand the impact of the local regulation and on the other hand, the furniture sharing, that is understood to be necessary to rationalize the investment, optimize the deployment (civil works, electrification, etc.) and decrease the visual impact. In terms of connectivity, the lack of access to fibre optic can be covered with short-range radio links or even satellite connection, in exceptional cases where latency is not a critical element.

At technical level, the 5G network capillarity will be achieved by a local connection based on small short-range radio sites. Small Cells will play a relevant role in that sense increasing the capacity and capillarity of the networks. They will be short-range networks as the transmitted power is low and they will work in higher frequency bands.

In terms of forecasting the volume and the impact in the small cells deployment, according to market estimations, in urban areas, for each current macro node (site) they could deploy about 10 small cells. The impact of this deployment in the cities will be relevant and will require some organization and coordination.

Capillarity will also be achieved under the concept of HetNets (heterogeneous networks) where there is a new chance for the devices to connect to the network not only directly through the 5G radio interface, but also by a varied set of already available technologies (Wi-Fi, Bluetooth, LPWA, etc.).

The composition of network slice functionality, User Plane / Control Plane decoupling, and modularity of network functions in VNF allow for greater resilience (if a VNF stops working, a copy of the function can replace it by retrieving it the state of that failed) and execution speed on different platforms with different hardware. Taking advantage of this, the "Neutral Host" model shares the greatest benefits:

- Creating user profiles independent
- Separation of mobility functions from the session management ones
- Agnostic access, that is, the independence of Core Network design from the access network
- Single Reference Point for Access to the Core Network
- Integrated authentication and independent authentication functionality
- Integrated application in the solution
- Complete scalability.

Virtual Network Functions are exposed in this multi-tenant open platform, where telco operators can provide, in addition to network capabilities and connectivity services, additional applications like user profiling for targeted advertisement, and this by virtue of its close relationship with their customers.

It is possible also give a description of two kind of environments where the introduction of the Neutral Host would offer new capabilities: the indoor and outdoor context.

- A typical indoor environment could be represented by a shopping mall, in which the mobile indoor coverage has poor quality, there are many users, and store owners are interested in providing advertising to their possible customers and in user profiles. In this case, the venue owner can act as the Neutral Host, which will build the network infrastructure and the Network Operator can act as service provider for their customers and as enabler of advertisement services for store owners. The Operator will have access to the 5GCity open platform and will use the "Neutral Host" VNF.
- An outdoor scenario could be represented by an on-site live event characterized by: high number of devices generating traffic simultaneously, high bit rate, localized coverage and high reliability. On-site Live Event Experience requires several thousands of devices connected simultaneously in a single stadium or concert hall. It makes this Use Case the most demanding with a data volume density of up to at least 0.75 Tbps for a standard stadium in the 2020s. This very challenging target, which is not reachable with 4G and its evolutions, will require a seamless integration of various innovative technologies including broadcast and millimeter waves. In this scenario, the network operator will act as infrastructure and VNF provider for the multi-tenant open platform.

Regarding the Mobile Network sharing options (Figure 10), the Neutral Host Use Case will test the two main architectures of a neutral operator:

- MOCN – Multiple Operator Core Network
- MORAN - Multiple Operator Radio Access Network.

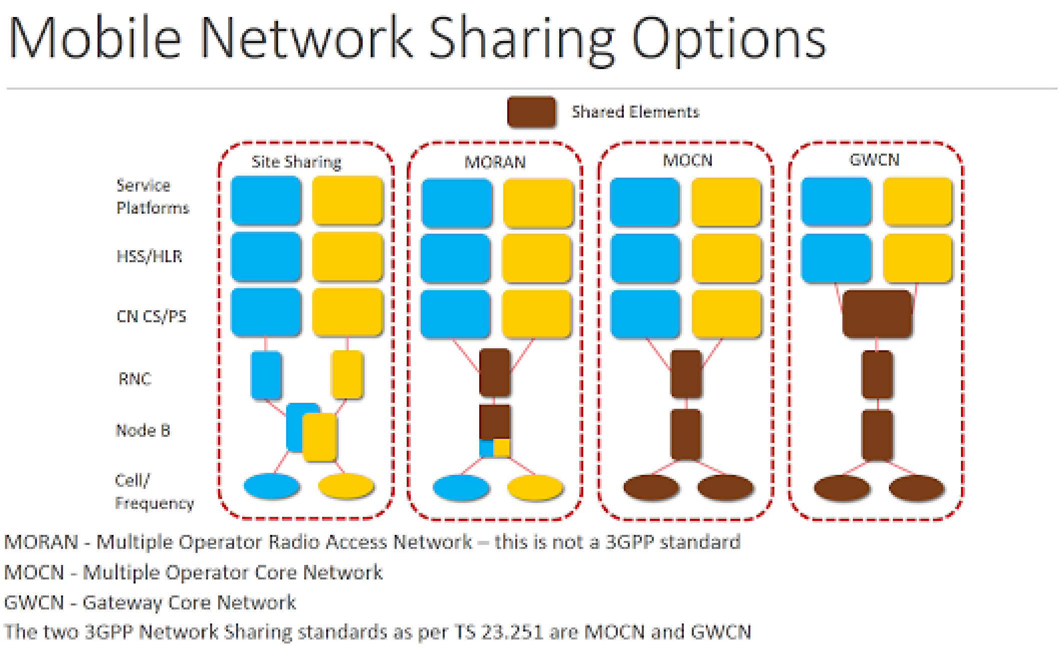

Figure 10. Mobile Network sharing options

In 5GCity, in the case of Barcelona, we intend to test both the MOCN and "virtual" MORAN architecture with some different operators (we expect two or three different at least).

In the MOCN architecture, the Cabinet hosts centralised Small Cell components dedicated to the control of a cluster of physical Small Cells deployed in the city lampposts and other possible urban furniture. In this case the spectrum resources are shared by different participating Mobile Operators.

In the "virtual" MORAN architecture, where each Mobile Operator intends to use their own spectrum, the different physical single carrier Small Cells supporting different bands can be dedicated to a particular Mobile Operator. They are controlled by the centralized Small Cell cluster functions in the cabinet, which offer a "virtual" MORAN view of the physical small cells deployed in the lampposts. The centralized Small Cell cluster control function running in the cabinet has the advantage that it will offer the same functionality and services regardless on whether the physical Small Cells deployed are single or multicarrier capable. At the same time, the centralised Small Cell cluster functions, together with MEC functionality in the cabinet, will enable the support of certain stringent requirements such as ultra-low latency needed for some services.

In Figure 11 you can see a high-level architecture of the Small Cell RAN Cluster functionality located in the city cabinet and controlling the physical Small Cells located on the urban furniture.

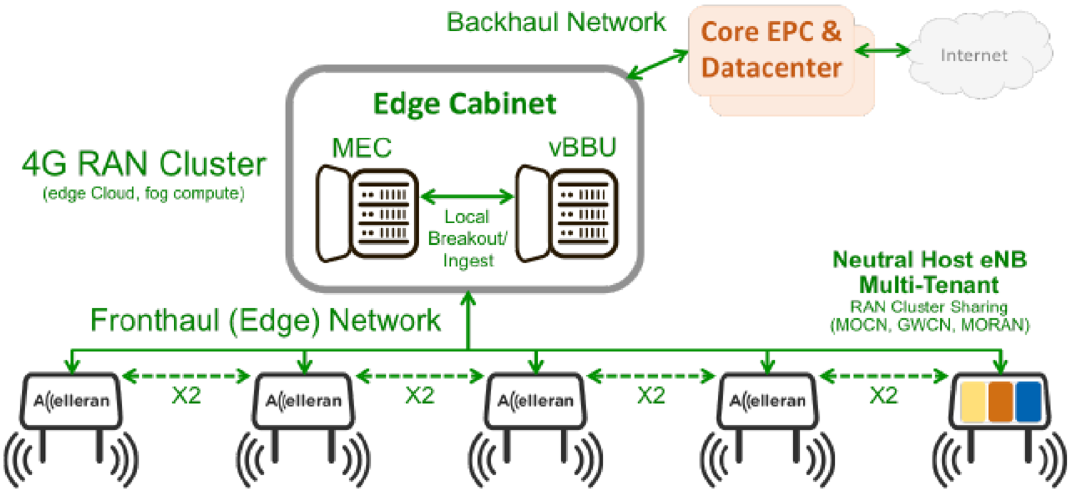

Figure 11. 4G Small Cell RAN cluster

In Figure 12, you can see a set of Small Cell RAN clusters in their respective cabinets controlling the different physical Small Cells deployed in the city lampposts and laying the overall digital city Small Cell connectivity infrastructure.

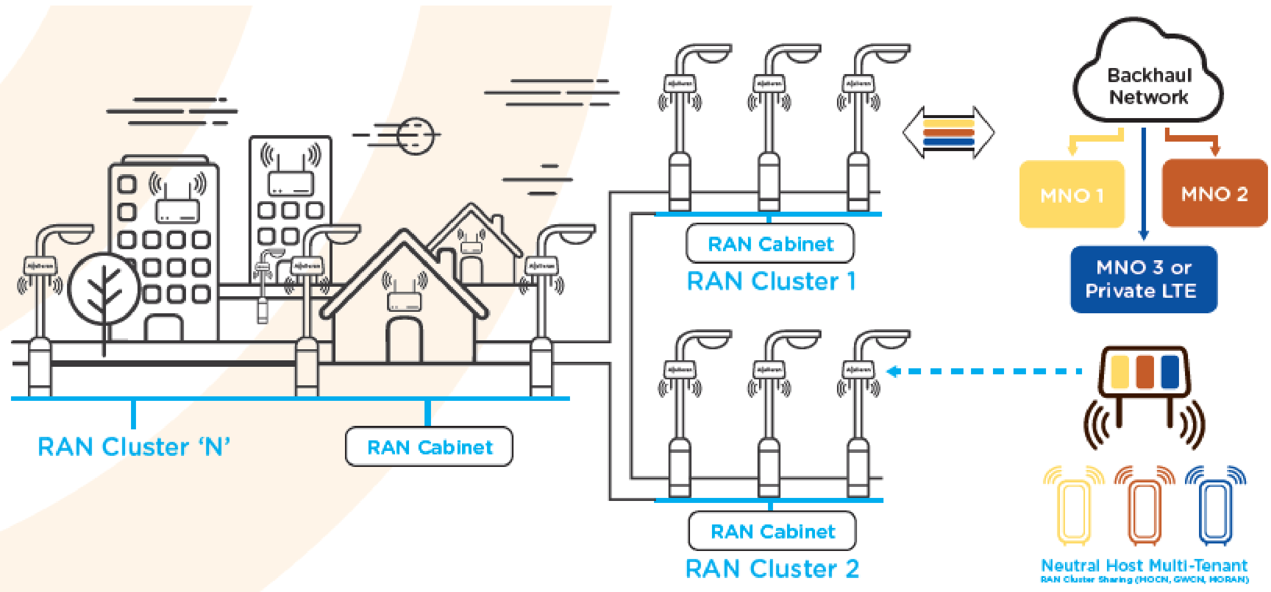

Figure 12. Neutral Host in Smart Cities

In general, as demonstrated in the project urban contexts (Barcelona, Bristol and Lucca), the "Neutral Host" solution, providing the real possibility for virtual operators to be hosted on an infrastructure that belongs to an 'infrastructure provider', expands the chances of entering the mobile services market. It enables also new business models where the same local administrations they may require a dedicated network slice to provide the same services to citizens.

The Neutral Host deployment will be based on the possibility to merge different components:

- An area in which the massive computing resource will be deployed.
- An edge area (should be corresponding to street cabinets) characterised by a limited computing resources available according to the real needs.
- Wireless devices area (Small cells or Wi-Fi powered, or 4G/5G mobile terminals).

With more details, for network, compute and storage components the following element should be available:

- Network components, including: networks, subnets, ports, addresses, links and forwarding rules, for the purpose of ensuring intra- and inter-VNF connectivity; we have also element which provides connectivity from MEC nodes to the datacenters resources. The MEC nodes, non-homogeneous pools of resources located away from centralized datacenters, are characterised by limited capabilities due to constrained resources in terms of power, computing, connectivity and will be located very close the area of the single Use Case
- Compute components including machines (e.g. hosts or bare metal), and virtual machines, as resources that comprise both CPU and memory
- Storage components, including volumes of storage at either block or file-system level.

In this scenario, the network operator will act as infrastructure and VNFs provider for the multi-tenant open platform to deploy the different solution to the End-Users.

Finally, to ensure the success of the deployment, an efficient and intelligent management of infrastructures, especially urban ones, will be necessary.

Cellnex Telecom, as a neutral operator of infrastructures, is in favour of this model of infrastructure management and sharing. We are convinced of the value it could bring to citizens, administrations and all the actors in the value chain in terms of economic rationality in the deployment, optimization of network management and administrative procedures, acceleration of deployment, lower environmental impact and optimization of energy consumption.

In this sense, publicly owned infrastructures will be key in the deployment of 5G networks and, therefore, it will be essential to eliminate access barriers for their use as well as encouraging the sharing, in which the intermediation of specialized managers should be considered.

The measures to facilitate the use of these infrastructures should be considered from a national perspective to be applied by any public or private entity that manages these assets potentially destined to house functional elements of the telecommunications network. The access and necessary activities on public roads for the deployment of small cells should have a fast time of processing and response by public entities.

In addition, rationalization criteria should be established, minimizing the impact on public and shared space, and ensuring its compliance. For this, the neutral operators in the wholesale market can be facilitators of this process, with guarantees and time to market according to the needs of citizens, administrations and the market.

3.2.4. Evaluation

The different pilots will be used to evaluate and increase the level of service for the city, in the frame of 5GCity project.

In particular the Neutral Host Use Case will be the "enabler" of different capabilities, the evaluation will take into account different elements, in the following described.

The following parameters stated by 5G PPP are indicative new network characteristics to be achieved at an operational level:

- Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010
- Saving up to 90% of energy per service provided. The main focus will be in mobile
- Communication networks where the dominating energy consumption comes from the radio access network
- Reducing the average service creation time cycle from 90 hours to 90 minutes
- Creating a secure, reliable and dependable Internet with a "zero perceived" downtime for services provision
- Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people
- Enabling advanced user-controlled privacy.

The "Neutral Host" model implies the need to segment the various types of resources that can be used by third parties according to the capability that the mobile network can be partitioned into "slicing" destined for different services and purposes.

Through the modular virtualization capabilities activated and coordinated by the orchestrator, it could be possible to monitor and manage multiple performance metrics at the same time to better differentiate the network capabilities to be guaranteed according to individual service requests.

Together with the above-mentioned options, other evaluation areas may be:

- The ability to allocate or deallocate resources (NW slices/shares and MEC nodes) to the Service Providers according to their own SLA (QoS, etc.)
- The ability to dynamically reallocate resources to the Service Providers to align with the changing needs of different users and applications
- The ability for Service Providers to supply End-Users with connectivity services on top of "Neutral Host" infrastructure (i.e. ordinary mobility management and session management procedures, user plane procedures, etc.)
- The ability for End-Users to consume the services provided by Media / Smart Cities through the connectivity services supplied by their own Service Providers, hosted by the "Neutral Host" (quality of End-User experience)
- The ability of the 5GCity solution to provide security and separation of Service Providers slices/shares/MEC nodes (multitenancy).

To summarize, the "Neutral Host" model implies the need to segment the various types of resources that can be used by third parties according to the capability that the mobile network can be partitioned into a variety of resources "sliced" destined for different services and purposes. For example, a slice can be allocated to a MVNO or an enterprise customer, to an IoT domain, etc. From these requirements arise other related provisioning activities (and the opposite of de-provisioning), modification, and isolation / separation of different slice instances depending on expected SLAs.

3.2.5. Requirements

The "Neutral Host" model must provide for the availability of some specific applications and must provide services to third parties using the 5G network.

It allows building of segmented slicing networks or mapping an application to a network slice: the re-allocation of resources, based on resource utilization, in order to increase the performance for the End-Users and align with the changing needs of different users and applications. In terms of network management, processes are required to ensure that hosted clients can continue to provide the expected levels of customer support and network management, including fault resolution, when users are within the coverage of a Neutral Host.

We can summarize in Table 5 the most important requirements.

ID	Requirement Name	Description
1	Multi-tenancy	Multi-tenancy at edge level is a fundamental feature of cloud infrastructures and is fundamental for supporting the service deployment, resource allocation, monitoring and control in the case of the Neutral Host to ensure resources, performances as requested.
2	Elastic resource allocation	*The "Neutral Host" correlates the resource requirements with the available physical infrastructure and dynamically manage network functions according to the processing load and the interested geographic distribution. For these reasons, i*t is necessary that the Neutral Host will implement elastic resource allocation schemes, giving access according to the priority schema and radio and cloud available resources. This requirement allows to balance the service demands versus the level of available resources: it is required to deal with the increasing or decreasing the number of VNFs, their location in the cloud infrastructure, their priorities. Based on the integration of cloud and access resources it will allow to implement also the radio resource sharing using the multi tenancy approach. The distribution of the radio resource has to be dynamic and scalable not statically assigned. These are the requirements for creating a dedicated subnet (e.g. for a MVNO, a public / private enterprise, a service provider) as part of a "Neutral Host" service. The model has to allow the hosted entity to manage its subnet – according to the Anything as a Service approach - and it has to optimize the composition and delivery of services based on the operation data for the real actual network infrastructure. Also the street cabinets (MEC nodes) will have special requirements in terms of computer resources, as working power and consumption requirements.
3	E2E slicing	It is important to allocate radio, network and cloud resources according to the requests and prioritized services. In mission critical Use Case, the infrastructure owner provides the requirement network, cloud and radio slicing capabilities with dedicated SLA to the different tenants. The "Neutral Host" model in this way able to define the slicing subnet for a given set of applications and to activate the necessary network functions by assigning the necessary configurations and parameterizations. The orchestration shall allow to create/terminate network slices and network shares, as well as to allocate constrained resources at the edge of the network on single board computers / street cabinets (MEC nodes), on demand basis.

4	Service QoE / SLA	The Neutral Host model has to guarantee high priority and low latency services. To monitor the resources utilization for each Service Provider in relation to SLAs, a dashboard will be required. The solution of the Neutral Host shall allow re-allocation of resources, based on resource utilization, in order to increase the performance for the End-Users and align with the changing needs of different users and applications. The solution shall also enforce the policies to ensure the correct application of the SLA for each Service Provider, the “Neutral Host” shall form an SLA with hosted clients to set agreed performance standards and the processes are required to ensure that the terms of SLAs are being met. The “Neutral Host” shall agree an SLA with hosted clients to set performance standards values and the SLAs monitoring procedures.
5	Latency and jitter	The Neutral Host has to prioritize services in order to reduce jitter and to support also cases requiring very low latency.
6	System response time	The Neutral Host model has to guarantee the operability of the services according to the expected system response time.
7	Security	The Neutral Host model has to ensure that the hosted client's network security is comparable to that offered by individual hosted clients dedicated resources.
8	Charging	The “Neutral Host” shall provide wholesale charging to the hosted client for usage of “Neutral Host” resources. Define charging method to evaluate total benefits.

Table 5. Use Case 2 Requirements

3.2.6. Expected Impact

As introduced, 5G will offer new service capabilities for consumers and industrial stakeholders: vertical industries, service providers and infrastructure owners and providers. The 5G infrastructure will cover the network needs and contribute to the digitalization of vertical markets such as smart city management, utilities, media, transportation, automotive, banking and education among others.

In the new model, scalability and flexibility will be more and more important and to assure the required features for the new services the network functions will be more and more “virtualized” on general purpose, programmable offering resources for data transport, routing, storage and execution.

5G will integrate telecom, compute and storage resources into one programmable and unified infrastructure, which will allow for an optimized usage of all distributed resources. This infrastructure will deal with the multi-tenancy, this way the operators will add to their services portfolio the possibility to be asset providers (infrastructure, network functions, platform offered as a service) for other operators or other players like integrators. Leveraging on this fundamental design principle will offer digital solutions according also to the new model of the single digital market.

In 5GCity the “Neutral Host” combined with the cloud computing capabilities will introduce new business models involving more and more partners delivering a part of the value and will allow new players to access the ecosystem to improve the innovation aspects.

There will be distinct Service Providers using the infrastructure with specific SLAs for their environment. Each Service Provider will have its own users and a dashboard will be available to view each slice. The slices will be dynamically allocated in the network and on Mobile Edge Computing with a changeable capacity on demand, extending through the radio infrastructure. Besides, the “Neutral Host” model will offer also a potential reduction of the Energy consumption because of the infrastructures and ICT equipment reduction.

5GCity solution allows better usage of the network infrastructure, mostly in dense and urban areas, where it is not appropriate/feasible to have different network operators each with its own network infrastructure.

The “Neutral Host” model is expected to be the fundamental element to unlock the commercial take-up of dense 5G wireless networks.

As a result of these scenarios implementation it is expected a big number of End-Users making high use of point to point multimedia services through any of the mobile operators. Expecting to count a number of End-Users much higher than a usual operation can hold making use of the project deployed services.

In conclusion, all the expected impacts could be summarised in this: 5G will make possible the fundamental shift from the current “service provisioning through controlled ownership of infrastructures” paradigm to a new schema “unified control framework through virtualization and programmability of multi-tenant networks and services”.

3.3. Video Acquisition and Production

3.3.1. Overall Description

The proliferation of different types of communication forms had enabled the bridging of persons with similar tastes that are geographically spread. However, communities get stronger, not only from online communication but also from physical relationships. For this latest part, live events play a key role in strengthening the overall sense of belonging to a community. These are events that generally bridge age, sex race and creed. It should be noted that this doesn´t only happen in large events such as music festivals or football matches but also in small events sponsored by a Municipality.

With the significant growth of live events in a city and the increase in video quality that you can get from a standard smartphone, it is quite common to see people at the event pointing their smartphones to the stage, recording it in video for later play and share. However, the non-authorized acquisition of this type videos and it´s subsequently publishing in social networks or dedicated platforms poses a large problem in terms of media rights.

Nowadays, and at the same time, event organizers are not only worried about the logistics of the event itself but also in creating a full pack of experiences for the audience that complements the main content/show. However, these experiments are intended to be used in an individualized way lacking an overall sense of community. At the same time, it is quite common to deploy a broadcasting professional system in these types of scenarios. Multiple cameras are spread out around the premises, covering the different perspectives of the event. The cameras will send multiple high-quality content video feeds to a control room in which an editor/director is able to visualize them in a multi-screen view selecting the most appropriated one to be transmitted for the End-Users, that can be in the event venue or at home if the rights owners allow it. This sort of secondary and complementary way of watching at a show is widespread in different types of events allowing the audience to switch its eyes from the stage to other visualization devices in a dynamic way.

The broadcasting and live event production world is aware that to achieve optimal user experience in an event, and increase its potential revenues, platforms must be designed to provide the user with a community and a massive user engagement experience such as the ones provide by Facebook or YouTube.

Current live event production needs:

- Expensive equipment (OB Vans, Video Switchers, professional cameras)
- High end codecs
- Dedicated personnel (camera operators, journalists, editors, producers, directors)
- Dedicated network connections (fiber or SDI links).

Placing the user in the role of a possible contributor to this larger experience and using cloud computing as a driver to enable this type of community, using 5GCity, is a much effective way of engaging the public in the event.

In this Use Case, in the context of 5GCity:

- We will conceptualize and develop a mobile application capable of acquire high quality video in an event it and stream it through the 5G platform, using Wi-Fi connections, to a designated cloud-based application
- We will conceptualize and develop a cloud-based application capable of receiving multiple streams from the 5G City platform and dynamically switch different videos inputs based on the producer/director commands
- The 5GCity tool will communicate with the media services, configure them and establish the necessary communication channels between to enable the user scenario and application logic that was defined by the end-users
- Deploy this application in Barcelona and Bristol.

This will allow:

- To reduce the equipment necessary to cover an event
- To lower the need for dedicated expensive personnel
- A more sustainable cover of events.

3.3.2. Actors Involved

According to the adopted schema as described in section 2.3, the actors that take part are the following:

HW vendors

MOG will develop and deploy the necessary hardware (rack mount video servers) for media ingest and processing to be used in order to build the live editing private cloud.

SW developers

MOG will develop the smartphone application for capturing user-generated content. It will need some support from event organizers in order to promote the service among citizens and foster their engagement. MOG personnel will be in charge of deploying the application, namely by providing smart installation methodologies, installing, managing and running the cloud switching application.

Infrastructure owner

The infrastructure owner (Bristol and Barcelona) will need to give MOG the necessary permissions and authorizations to deploy the Use Case in the city and to give MOG the necessary access to buildings and facilities.

Network Operator

Will be responsible for guaranteeing the connectivity of the 5G platform between the smartphones and the private cloud.

Content/Service Provider

Will be responsible for organizing the events, (possibly) editing the content, engaging the users and (eventually) distributing the live content in their own content distribution networks. Event organizers will need to market the Use Case in order to engage the maximum number of users in it. In order to optimize this process, the demonstration of the Use Case will be done in parallel with an existing event.

End-User

The End-User need to install MOG´s software in their smartphones, and connect to the available 5G/Wi-Fi access point provided by the network operators. After that, they will capture content and send it to MOG´s private cloud where it will be edited in real-time.

3.3.3. Deployment topology

Figure 13, shows the topology of the Use Case. The users are covered in the venue with several access points. Each access point can cover a certain part of the venue, helping the QoS and QoE be higher and stable. All the access points are connected to the 5GCity infrastructure and the users connected to the access points can use the smartphones to stream a video footage of the venue. These streams are sent through the 5GCity infrastructure to the MOG cloud. The MOG cloud is inside of the 5GCity infrastructure, improving this way the overall experience and lowering the jitter and latencies.

A producer is connected to the MOG's cloud, making the decision of choose what stream is sent out for the broadcasters, local screens or any other media partners interested in the selected video footages.

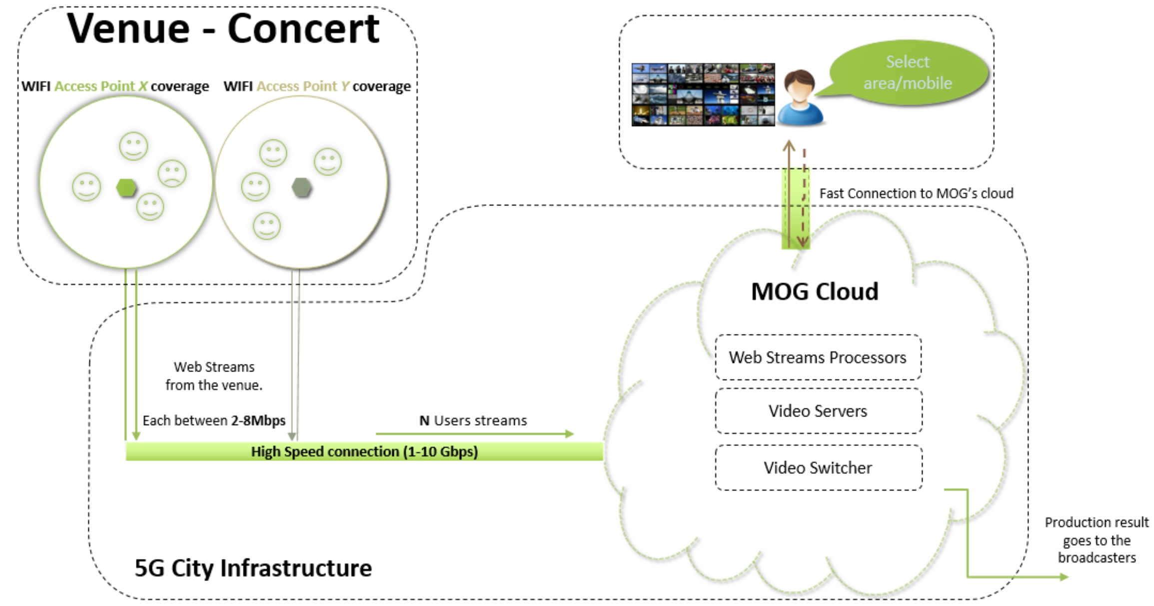

Figure 13. Use Case 3 overview

3.3.4. Evaluation

The evaluation will be measure with the following criteria:

- Low jitter
- No artefacts in the final video
- Low delay

- High quality video resolution
- Fast switching between streams
- Seamless adding/removing of users.

3.3.5. Requirements

The Use Case will be deployed in cities that can guarantee the requirements listed in Table 6.

Rn	Description
1	Multiple (at least two) Wi-Fi/LTE/5G hotspot distributed in the project area
2	2-8 Mbps per device
3	End to end low latency
4	At least 50 Mbps connection to internet
5	Connection between the hotspots (venue) and the central data center (private cloud)
6	Ethernet connection (10 Gbps) between the 5GCity infrastructure and MOG cloud servers
7	Access to cities DCs for storing the video servers (private cloud)

Table 6. Use Case 3 Requirements

3.3.6. Expected Impact

We expect five main impact topics:

- Lowering costs – the automatic switching of the content in the cloud, instead of using an expensive dedicated video switcher together with the automatic configuration of possible outputs lowers the costs associated with media covering a live event. At the same, in the case where only mobiles are used for the generation of the output signal, the deployment of expensive cameras and associated dedicated resources is also not necessary
- Ensuring transmission rights – the engagement of the audience in this application case will diminish the number of unauthorized people who will spread/publish media content that is protected by specific transmission rights
- Freeing resources – the need for qualified personnel to manually cover a life event through media technologies is reduced and therefore these resources can be redirect to more relevant types of tasks and activities
- Increasing of QoE – The usage of personalized content as the output of the application will improve the Quality of Experience that the audience will have when compared to existing systems
- Increasing of revenues – The success of the application will increase the average number of people attending a live event and therefore increase the corresponding revenues.

3.4. UHD Video Distribution Immersive Services

People habits and expectations concerning media consumption are profoundly changing and the new frontier of UHD/4K and immersive services is coming soon.

While linear TV on a stationary display (TV set), possibly supported by local caching for non-real-time viewing, will continue to be a very important element, the overall Media and Entertainment user experience is growing and deepening rapidly.

This refers to types of services (linear media, on-demand content, user-generated content, sport, tourism, games etc.), environments in which consumption takes place (on the move, in mobility, in the transportation network) and user devices (smartphones, tablets, wearables, watches, virtual reality devices, Tv sets with IP connection).

M&E services have to cope with increasing demand regarding data rates, number of concurrent users and/or more stringent QoS requirements. High quality and high-resolution audio-visual services are the most important drivers for increased downlink data rates; whereas user generated content, including sharing of social media, is the driver for increased uplink data rates with percentage of growth really impressive.

The immersive part of the Use Case could be arranged in order to allow the end-user moving in a city to obtain additional content related to the surrounding environment (monuments, objects ...) by using smartphones and/or HoloLens[1]-like devices.

Additional content could be automatically retrieved, for example from Television Archives, in form of 2D video, panoramic video and 3D models that will augment the reality in which the user is immersed. New 4K/UHD contents will be available for the users, just to create “digital pills” in a hypothetical journey that include more information and A/V.

Another experience offered to users exploring another city (e.g. a user in Barcelona visiting Lucca, considering that the main operas are presenting at Liceu and Palau de la Musica, Puccini and Verdi firsts) is to allow viewing an immersive panoramic video enriched in the same way. The Use Case could also exploit the bi-directional 5G network capabilities in order to have feedback from the users, an example could be the 3D models generated from the final user exploited as further content for the enrichment enabling in this way also the involvement of citizens.

Finally, LTE Broadcast features could also be tested in case the city network infrastructures would be able to support this feature.

3.4.1. Overall Description

Two characteristics of the 5G technology are of special interest of M&E scenario: the very wide band, which should enable to carry high quality 4K UHDTV signals, and a very low system latency, which should enable to implement effective interactive applications.

For testing the first characteristic, RAI and CODI will produce video 360 material in the 4K (UHDTV) format to be exploited both as VoD and as “live” streaming.

For testing the second one, two different examples are foreseen: first a “viewport” coding algorithm and an application based on the Microsoft HoloLens where augmented reality TAGs and 3D models are shown after object recognition.

In more detail, from the user point of view:

While visiting, for example, the Puccini House Museum[2] in Lucca or other venues in Barcelona or Bristol the user wears a Mixed Reality device (hybrid of both Augmented Reality and Virtual Reality, i.e. Microsoft HoloLens). A proper application on the device will display visual appealing 3D informative TAGs attached to the real objects seen by the user.

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[1] Please see: https://www.microsoft.com/en-us/hololens
[2] Please see: http://www.puccinimuseum.org/en/

Moreover, a selection of video contents from Rai Archives could be suggested to the user. In order to support such user experience, the images or video of the city captured by the camera on the device have to be sent in real-time to a remote server (via the 5G network infrastructure).

Extracts from Turandot[3] o La Rondine[4] in 4K could be available *(Nessun dorma[5] or Chi il bel sogno di Doretta[6]),* interviews and historic pills, to create an **immersive experience** through 5G meeting cultural masterpiece.

Taking advantage from Puccini interest in the world *(in 2016, Puccini's works dubbed Beethoven's patrimony in representations and MET in NY looking to this new digital frontier)* the Use Case in Puccini Home Museum could represent an important avant-garde in the creative industry with the relevant support by the technological r-evolution.

In general, advanced deep-learning algorithms able to classify objects such as buildings, streets, monuments, and to link them semantically to material available in RAI archives, must be deployed at the edge. Then, processed information is sent back from the edge to the user application.

In another scenario, the end-user could see in real-time a reconstruction of antique city buildings and towers overlapping the real ones. In general, the device is able to scan the physical environment and to create a 3D map of it, so the device knows exactly where and how to place digital content into that space. The user can dynamically interact with the 3D model, rotate it and zoom on details using gestures.

The 3D models could also be user-generated contents made available from other users on a dedicated web platform.

In Use Case 4 the video 360 material is produced with specific camera systems, which have a minimum of two sensors, and two lenses, in order to have a Field of View (FoV) as large as the whole spherical horizon around the camera.

The different video contributions needed to be processed in suitable applications where the stitching of the different images, the colour correction, the projection – usually in the equirectangular format – and the coding were performed, could exploit the computational capability offered by the edge cloud of the 5G infrastructure.

The distribution of live or VOD 360° video services over IP networks can follow two possible approaches [3], [4]:

1. "Viewport-Independent" approach
2. "Viewport-Dependent" approach with tiled encoding.

In both cases, it is assumed that an equirectangular projection is used for conversion of the 360° video into a two-dimensional rectangular video before the encoding stage.

Virtual Reality, Mixed Reality and Augmented Reality will be focused from this Use Case to provide an immersive experience for the final user. Augmented reality provides an efficient and intuitive way to display computer-generated information overlaid and aligned with objects in the real environment. For this reason, AR solutions have been used to increase user experience in the context of cultural tourism. For example, many museums provide AR applications that, using markers, recognize the location and orientation of the user and overlap computer generated assets on the artwork the user is interested in. On

[3] Please see: https://en.wikipedia.org/wiki/Turandot
[4] Please see: https://en.wikipedia.org/wiki/La_rondine
[5] Please see: https://en.wikipedia.org/wiki/Nessun_dorma
[6] Please see: https://en.wikipedia.org/wiki/La_rondine

the other hand, there are several challenges for outdoor solutions: first, the user tracking is not easy: there are GPS solutions but they do not accurately provide position and orientation of the user. Moreover, there are places, such as urban canyons, where GPS does not work. The second issue is related with problems with the positioning of markers or target images in outdoor environment and problems with lighting control.

There are several prefixes added to the term Reality: Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR).

The term VR includes video 360 where a view is recorded in each direction at the same time thanks to omnidirectional camera or collections of aligned and calibrated camera.

VR is further subdivided into:

- 360 videos when the content is mostly based on video
- CG VR (Computed Generated VR), when the content is mostly rendered by 3D models, in real-time in the user's device
- 360/VR when both 360 video and CG content are present at the same time

The difference between the terms AR and MR is as follows:

- AR: is an overlay of content on the real world but such content is not anchored with it or part of it. Real-world content and CG content do not interact with each other
- MR is an overlay of synthetic content that is anchored on the real world and interacts with it. For example, a virtual character who is placed on the table of the real world and walks on it. The key feature of MR is that virtual and real content interact with each other.

Both VR and MR provide different degrees of immersion, i.e. the perception of being physically present in a real or imaginary world.

To achieve this, realistic audio (e.g. binaural or 3D audio), high-resolution images and support for natural user interaction are necessary. Such interaction with the world of VR/MR must be as close as possible to the one experienced by the user in real life, such as looking around from a fixed point: 3DOF, (Degree of Freedom) or moving freely in the real world and looking around objects: 6DOF.

One of the aims of Use Case 4 is to develop an application that uses Mixed Reality, user movement tracking and computer vision algorithms to create an augmented tourist guide that can work both indoors and outdoors.

The system will provide semantic information and additional content on monuments and sculptures to tourists visiting the involved cities.

The main features of the Use Case are as follows:

- Recognition of monuments and sculptures
- Showing information and history
- Possibility of viewing additional content
- Virtual reconstruction of monuments.

The visual search allows matching images or videos captured by the user, such as buildings, statues, paintings, with contents present in databases thanks to visual similarities, without the need for manual query input using algorithms based on Compact Descriptor for Visual Search (CDVS). These algorithms offer a robust and interoperable technology to create visual search applications in image or video databases [5].

One of the fields in which the 5G network will have a greater impact is visual search, thanks to the ability to offer Edge computing to speed up data analysis, low latency and the ability to transport more information.

In order to provide an immersive experience, it was considered necessary to use a Head Mounted Display and the Microsoft HoloLens device was selected for the mixed reality application.

3.4.2. Actors Involved

The described Use Case has a strong impact in the 5G ecosystem in terms of involved actors. Referring on what defined in section 2.3 it is possible to identify the following actors:

Hardware (Equipment) manufacturers / vendors

Providing the necessary equipment in the 5GCity architecture in order to cover all requirement to run the Use Case on different parts, ICT related, networking equipment and End-User devices.

Software Developers

Developing services (VNFs) and applications that can benefit potentialities and performances of the 5GCity architecture fulfilling the requirements of media vertical users.

Infrastructure owners

Hosting the computing, storage and networking infrastructure needed to run the Use Case.

Network Operators (ICT infrastructure providers)

Exploiting the physical resources of the network.

Content/Service Providers

Taking advantage from the 5GCity architecture and the Neutral Host concepts in order to develop new and innovative services.

End-Users

Enjoying new services and new devices that, exploiting 5G features, will be offered from all different actors involved in the telecommunication ecosystem, also taking into account that the End-User can become a content producer for new services.

3.4.3. Deployment topology

Figure 14 shows the scheme of the system architecture and the relevant data flow to be implemented for the considered Use Case.

Over the existing network architecture, we need to use 5G Access to connect devices (cameras, HoloLens, smartphones, VR Kits) to the core network with edge computation features. In the edge, various services will be enabled in order to exploit full 5G capabilities.

The main services to be deployed for this Use Case are the Encoding System, the Streaming System, the Search Engine, the Access to the TV archives, the Content Storage and the 3D model repository.

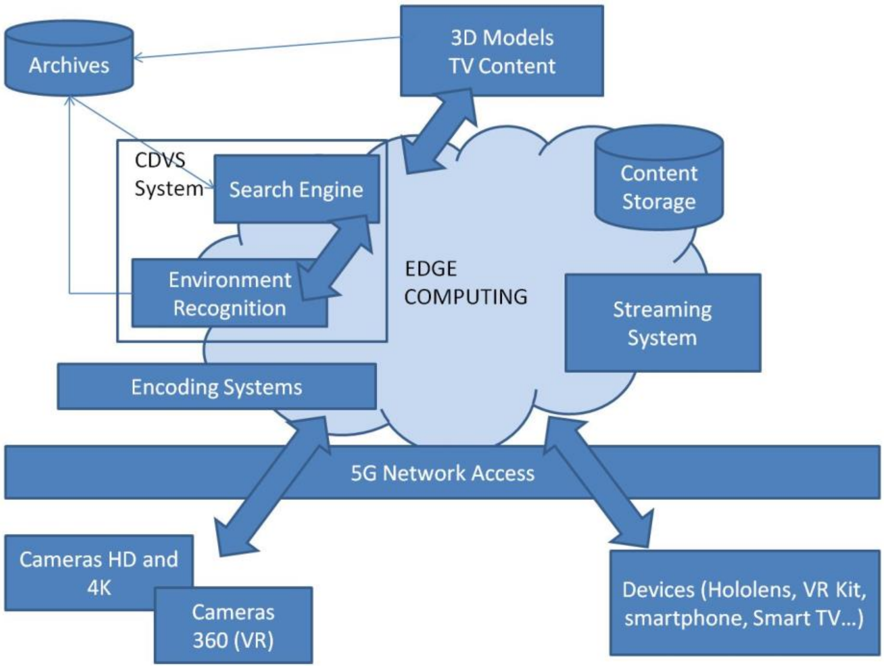

Figure 14: Use Case 4 data flow reference schema

3.4.4. Evaluation

The evaluation will be measured in terms of:

- Increased service and network performance compared to those available with 4G systems, with particular reference to user experience of content usage
- Availability of High Definition Content (UHD), VR and various formats directly in the locations where users are located and on a variety of technology platforms (5G smartphones, VR viewers, smart TVs, multimedia totems
- High level of involvement of people in the historical / cultural / costume of interest through experimenting with new content-enjoyment tools
    - high bit rate between the mobile devices and the cloud applications
    - low end to end latency.

Metrics and performance targets:

- Acquired images/scenes (even in mobility): HD, UHD 4K and Video 360
- Peak Data Rate: Total Capacity Managed by an Access Point 5G of 20 Gbps DL and 10 Gbps UL
- User Experienced Data Rate: Capacity offered at terminals up to 100 Mbps DL and 50 Mbps UL
- User Plane Latency: 1 ms (uRLLC)
- Control Plane Latency: 20 ms
- Reliability: 99,999%.

Service metrics:

- Improving vision experience (cross-platform) and the level of involvement of people at the events of interest
- Improve the quality of content distributed in places of interest, even in mobility and in "massive" mode
- Reduce the amount of time it takes to make the content selected by users available for use even in the case of advanced video formats.

3.4.5. Requirements

This section contains a first analysis of the Use Case in order to obtain technical requirements in term of network bandwidth usage and services offered in the edge. This could be the starting point for the discussion about the network architecture to be implemented in 5GCity.

The Use Case 4 is divided in two phases:

- Production phase (see Table 7)
- User viewing phase (see Table 8).

Each phase is represented by the set of components needed to obtain the whole scenario:

- UHD
- Video 360
- 3D Models
- Additional Content.

For each component this is a tentative to give network and services requirements.

	Network	Edge Services
UHD This is the generic television production environment. Probably this case will be not covered by the project due the huge bandwidth needed. Shooting phase could be done offline.	Download: not critical [see note] Upload: 100 Mbps (XAVC[7] encoding) Latency: not critical Reliability:	Storage
Video 360 This is the User generated Content (UGC) of video 360 environment using non professional (or semi-professional) cameras. In case of professional equipment, the shooting phase could be done offline.	Download: not critical Upload: 5-20Mbps (H.264[8] encoding) Latency: not critical Reliability: not critical	Storage Stitching and encoding possible [to be discussed]
3D Models NA	Download: Upload: Latency: Reliability:	
Additional Content NA	Download: Upload: Latency: Reliability:	

Table 7. Use Case 4 Requirements - production phase

[7] Please see: http://www.xavc-info.org/
[8] Please see: https://www.itu.int/rec/T-REC-H.264

	Network	Edge Services
UHD User viewing of UHD video content, it could be additional content to enrich the immersive experience.	Download: 8-10 Mbps, max 20 Mpbs (H.264) Upload: not critical Latency: not critical Reliability: not critical	Streaming Server
Video 360 Content is played using users' Smartphones or VR headset. In this case the requirements could be different due the streaming mode used (Full frame or Viewport)	Download: 8-10 Mbps, max 20 Mpbs in case of full frame; 4-5 Mbit/s in case of viewport (H.264) Upload: not critical (slightly higher in case of viewport) Latency: not critical if full frame, Critical in case of viewport Reliability: -	Streaming Server
3D Models Mixed Reality Content is viewed with Microsoft Hololens. Pictures uploaded by users to be processed by the Visual Search Engine server	Download: 5-10 Mbps (for the duration of file download) Upload: 1-2 Mbps (bursty, i.e., for the duration of each file download) Latency: critical Reliability: not critical	Visual Search Engine 3D Model repository
Additional Content Addition content will be automatically searched using a Visual Search Engine able to perform image retrieval from the Television archives in the context of applications.	Download: Video HD - UHD 2-5 Mbps Upload: 1-2 Mbps Latency: not critical Reliability: not critical	Visual Search Engine Query System to television archive (subset)

Table 8. Use Case 4 Requirements - "user viewing" phase

3.4.6. Expected Impact

The purpose of the Use Case is to contribute to the valorisation of cultural events taking place within the territory of the cities involved in the experimentation. In particular, it aims to broaden the media coverage of events by helping to deliver content to tourists present or transit through the city. In addition, live 360 ° shooting of events, distributed through a specific App on smartphones, will give tourists and locals a full immersion experience in the place thanks to the VR viewers. This aspect will help to improve local, national and international tourism with social and economic utility for cities.

3.5. Mobile Backpack Unit for Real-time Transmission

3.5.1. Overall Description

Currently almost all TV stations are using what in popular language we call "backpack" units (Figure 15); it is a backpack with a kind of computer inside.

The computer can be a general purpose one or a specific one designed for this purpose, in particular it can include:

- Digital video input (HD-SDI, SD-SDI or HDMI…)
- Codec or video compressor to encode the video signal in a more lightweight format
- Bonding system to split the compressed signal in slices to be sent using more than one modem or transmitting devices.

So far, for transmitting the video content can be used:

- Up to six 4G (or 3G) modems
- A fibre link
- Wi-Fi access.

There are two main problems with this kind of technology:

- Overcrowding of the cell
- Low bandwidth available for transmission (QoS issue).

Figure 15. Mobile Backpack unit

3.5.2. Actors Involved

Referring on what defined in section 2.3 it is possible to identify the following actors:

Hardware (Equipment) manufacturers / vendors

Providing the necessary equipment in the 5GCity architecture in order to cover all requirement to run the Use Case on different parts, ICT related, networking equipment and End-User devices.

Software Developers

NA

Infrastructure owners

Hosting the computing, storage and networking infrastructure needed to run the Use Case. - IMI

Network Operators (ICT infrastructure providers)

Exploiting the physical resources of the network. - Cellnex

Content/Service Providers

The broadcaster provides backpack equipment. He takes advantage from the 5GCity architecture and from the Neutral Host concepts. - BTV

End-Users

TV users will get an overall improvement of the quality of a TV transmission, mainly for news; the ENG (Electronic News Gathering) will be able to speed up video transmission from the backpack unit to the TV studio.

3.5.3. Deployment topology

The system will work over the system deployed in the test area, using LTE/5G modem or Wi-Fi connectivity to send the images/videos produced in the streets directly to the TV studio.

3.5.4. Evaluation

Subjective:

- Video quality.

Objective:

- QoS, sustained 8Mbps (minimum) per camera/backpack
- Priority of connection (network slicing)
- Low latency (video services)
- Multicamera availability.

3.5.5. Requirements

We can summarize in Table 9 the most important requirements.

Rn	Description
1	Multiple Wi-Fi/LTE/5G hotspots distributed in the project area
2	At least 8 Mbps Uplink per camera/backpack
3	A minimum 100Mb/s connection to internet, in order to send the signal to the TV studios
4	LTE/5G modems (six per backpack) - 5G USB Wi-Fi adapter per camera/backpack
5	Processing capability at the edge processors to sync several cameras

Table 9. Use Case 5 Requirements

3.5.6. Expected Impact

The purpose of this Use Case is:

- Improving video quality of live connections (real-time transmission)
- Enabling the mobile unit to utilize more bandwidth (provisioning a specific slice with a guaranteed QoS)

- Enabling the use of edge computing processing capabilities for production of video contents at the edge.

3.6. Cooperative, Connected and Automated Mobility (CCAM)

3.6.1. Overall Description

The current Use Case is focused on CCAM (Cooperative, Connected and Automated Mobility), mainly on Vehicle-to-network (V2N) communications, using cellular technology with a companioning ITS (Intelligent Transportation System) service.
The growing number of self-driving and connected cars are redefining our view of transportation and posing new requirements in the existing road infrastructure (roadway and road signs). With the purpose of keeping up with this ever-increasing intelligence on the vehicle domain, current infrastructure must aid and support this network of mobile nodes, providing highly reliable and instrumental information, in real-time, to enable a safe driving experience. This network must be able to support and adapt to different types of communications: V2V (Vehicle-to-Vehicle), V2I (Vehicle-to-Infrastructure), Vehicle-to-Pedestrian (V2P) and V2N (Vehicle-to-Network). While technologies such as 802.11p, [7], have been developed (2005-2010) to tackle some of these network requirements (e.g. ad-hoc communications with low latency in a non-line-of-sight manner), it cannot address all of the safety-related requirements. As an example, there is the much-needed Device-to-Network link, which enables cloud services to be part of the end-to-end solution. Because of this, the automotive industry and telecommunications operators are leaning towards cellular technology (5G Automotive Association – 5GAA) and exploiting Cellular-V2X (initially defined as LTE V2X in 3GPP Release 14). Ultimately, there is the urge for "governments, automotive, telecommunications and other sectors to strongly consider the business and value proposition as well as the overall societal benefit of Cellular-V2X defined by 3GPP", [8]. The differential factor here lies in the V2N link and its ability to work in tandem with other ad-hoc communication links, providing a much-needed value when it comes to cloud services' information relayed through the cellular network. The connection between these mobile nodes and the network can also leverage NFV technology, allowing for the deployment of a particular network slice where the required KPIs (packet loss, latency, among others) are monitored and guaranteed to achieve the established SLA. Furthermore, the operator's edge infrastructure is also key to enable a secure time-sensitive data channel where privacy matters.
Having this in mind, in the context of 5GCity, Ubiwhere proposes to deploy a network topology where strategically instantiated MEC applications can leverage its proximity to CPEs, with LTE/5G connectivity, to deliver the much needed network KPIs for this specific CCAM Use Case. Furthermore, the proposed architecture will demonstrate how 5G relevant technologies like SDN, NFV, MEC and V-RAN are crucial to deliver a flexible and robust solution for such mission-critical scenarios. The overall goal is to provide an ultra-reliable and low-latency communications (uRLLC) channel between vehicles, infrastructure and network. Within the vehicle-to-network domain, the data transmission flow should not be affected by the natural handover process, ensuring there will always be a full-duplex connection since it is envisioned that the vehicle's MEC application is both producing and consuming from the other different MEC application as closed to the edge as possible. The Use Case will demonstrate how 5G technological ecosystem is a perfect fit for CCAM scenarios, and how and why it can and should work in tandem with other wireless technology like 802.11.p, [7], to deliver a full end-to-end solution in such scenarios.
The Use Case's scope is specifically concerned with safety-related data, so a centralised cloud service shall be responsible for aggregating this info, categorised by type of alert in a geographically organised manner. This centralised cloud service will provide an aggregation of both crowd-sourced and third-party safety mobility-related data. Due to the fast-moving nature of these mobile nodes (vehicles), it is not feasible to query a cloud service every time a passing car needs to retrieve data from a central repository. Because of this, a dedicated MEC application (running in a street cabinet, most likely) will have an always-on connection to this central cloud service, subscribing only to data (alerts) occurring within its surrounding

area (tuneable parameter), effectively locally storing relevant data as a cache. Thus, as the passing car connects to the edge small cell, the MEC application running in that same premise will stream down this cached data immediately. Furthermore, this same application will also publish any relevant data collected by the car's own intelligence system. The maximum speed at which this Use Case can be trialled will depend on the expected speed limits of a typical urban environment and the potential limitations that Small Cell platforms can have with regard to the maximum Doppler effects they can support.

3.6.2. Actors Involved

In this CCAM Use Case, different actors with different roles are involved. For coherence's sake, a detailed description following the ones listed in section 2.3 is provided.

Focusing on the role of the Infrastructure Owner, providing that this Use Case will only be deployed in one city, only Barcelona will play the role of Infrastructure Owner. There is in fact a strong dependency on the city's available infrastructure (cabinets and lampposts), overall network topology and connectivity (4G/5G radio and fibre optic for the front-haul and back-haul links, respectively). As such, Barcelona's Municipality will be the entity who owns and provides the infrastructure on which this Use Case will be deployed: lampposts, street cabinets and the fibre optic connectivity between lampposts, street cabinets and the metro. It is Ubiwhere's responsibility, though, to provide a radio-compliant CPE (Customer Premise Equipment). Focusing on the role of Hardware Provider, this role will most likely also be played by Barcelona's Municipality since at this point it is envisioned that it will be their responsibility to acquire the necessary MEC hardware on which the different MEC applications will run. At this point, there is also an ongoing evaluation on the usage of Prismtech's (Adlink) MEC nodes. Should these nodes be deployed in Barcelona city, then Prismtech will also be considered as a Hardware Provider of the current Use Case. Regardless of the MEC hardware on which the different applications will run, another actor, Accelleran, is crucial for this Use Case also as a Hardware Provider (small cell deployed on different lampposts). Acelleran's role, however, is not restricted to being solely a Hardware Provider, but also as a Software Developer: as the Use Case relies heavily on uRLLC (Ultra-Reliable Low Latency Communications), there is a strong dependency on a flexible RAN architecture with a close link between the vBBU and the MEC platform, as to tackle mobility challenges (handover) and the required latency.

Other actors which might play a Software Developer role on the Use Case are NEC and Prismtech as to facilitate the adoption of specific technology which would aid on achieving the necessary KPIs: unikernels (NEC) and DDS protocol implementation (ADLINK). Ubiwhere, however, remains as the main Software Developer of the Use Case. When it comes to Network Operators (ICT Infrastructure Provider), Barcelona City and i2Cat are the main actors, as they are the ones providing the fibre optic connectivity and the Metro DC, respectively. In addition, regarding the cellular connectivity and the mobile network core (EPC), at this point, it is still unclear which mobile network operator will provide the necessary spectrum and EPC. As for Content Providers, the main involved actors are the CPEs themselves (mobile nodes sharing relevant data to the network) and the external service which aggregates all of this shared data and distributes to every connected cabinet's MEC app. Finally, these CPEs are this Use Case's End Users, as they consume and produce all of these relevant shared data.

We can summarize as following:

HW vendors

- Barcelona City: MEC hardware
- Ubiwhere: CPEs
- Accelleran: Small Cells
- ADLINK: MEC hardware (possibly).

SW developers

- Ubiwhere
- Accelleran
- NEC and ADLINK (facilitators).

Infrastructure owner

- Barcelona City: Lampposts, Street cabinets.

Network Operator

- i2Cat: Metro DC
- Mobile Network Operator (TBD).

Content/Service Provider

- Vehicles (providing sensed data)
- External broadcasting service.

End-User

- Vehicles (consuming data).

3.6.3. Deployment topology

The CCAM Use Case requires, at least, three different connected edge nodes: one street cabinet with a backhaul link to the internet and two other connected base stations providing the fronthaul link.

The diagram referenced in Figure 16 depicts this architecture.

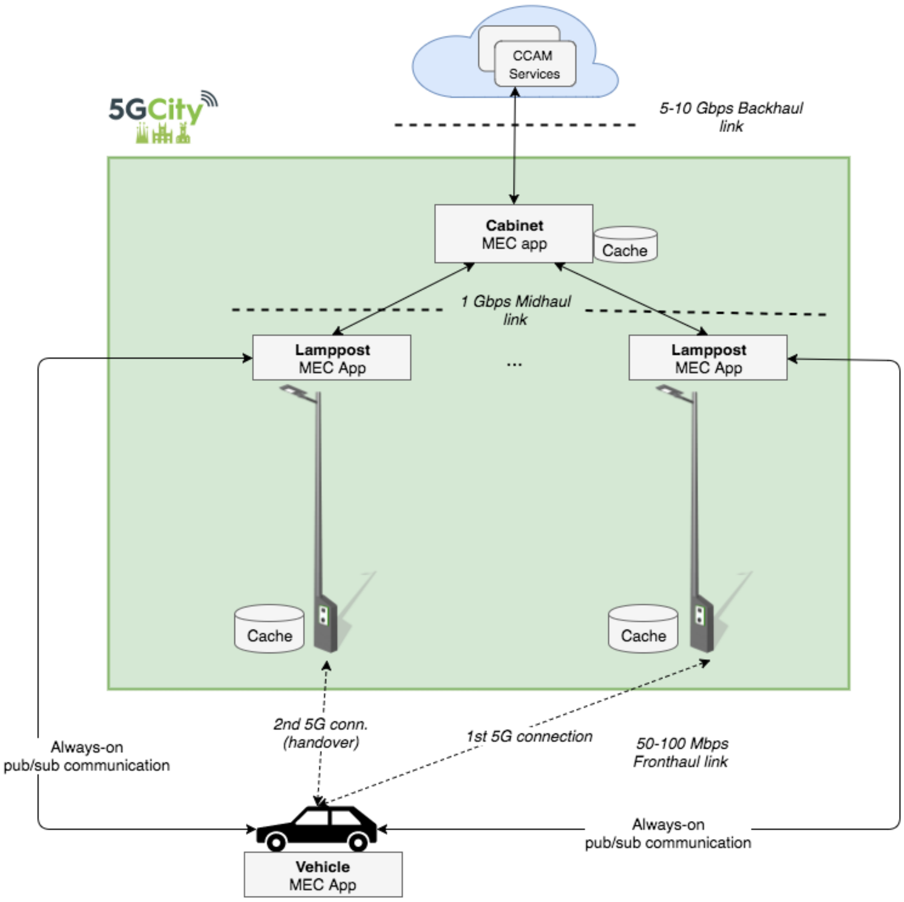

Figure 16. Use Case 6 Architectural diagram overview

3.6.4. Evaluation

The Use Case deployment will prove to be successful if the following conditions are met:

- Extremely low end-to-end (from mid to fronthaul link) overall packet loss and latency
- Very fast instantiation of different MEC applications across the different domains
- Seamless handover process with uninterrupted data flow between the vehicle's application and the other running on the edge.

3.6.5. Requirements

We can summarize in Table 10 the most important requirements.

Rn	Description
1	One single CPE with LTE capabilities (vehicle as a mobile node); real on-the-move LTE compliant CPE
2	Two different physical base stations with LTE connectivity (small cell), storage and computational power (with virtualization support) to orchestrate and manage the different MEC applications, while also providing a seamless handover process and the ultra-low latency and reliable communication with vehicle
3	A third network component (which will very likely be a street cabinet) with internet connectivity and local connection to the other base stations. Regarding network capacity, the midhaul link should not be lower than 1Gbps, while the backhaul link should be of, at least, 5Gbps
4	End to end network slicing
5	Storage service at the edge

Table 10. Use Case 6 Requirements

3.6.6. Expected Impact

With the proposed Use Case, 5GCity will be proving how 5G, NFV and MEC technology are key enablers for the V2X/CCAM domain. The proposed solution will demonstrate how such architecture and adopted technologies can achieve 5G KPIs, significantly improving road safety, the comfort of driving and smarter coordination between connected autonomous cars, road infrastructure and cloud services.

Such designed solution will allow for a broader contextualised shared knowledge, where every car will have indirect access to each other's intelligence, with very low latency in LTE/5G cellular networks, leveraging MEC technology. Such solution will effectively improve and aid these smart vehicles capability to take the right decision in a timely manner, autonomously.

3.6.7. Clarifications on Use Case requirements

The CCAM use case is specifically targeting a V2I/N scenario with no real direct V2V connectivity. The designed architecture intends to showcase how MEC-based applications can be leveraged to disseminate such warnings and alerts to vehicles connected to different RAT (small cells or Wi-Fi-based). The purpose is to distribute such content in a more efficient manner, when imagining such use cases at an extremely large scale where vehicles will be constantly exchanging data in a bi-directional way with the network and infrastructure, regardless of the available RAT.
Using the available 5GCity-coined Far Edge and Edge nodes, respectively deployed at lamppost and street cabinet-level, passing vehicles connecting to the built-in small cells will receive such warnings which are referencing a specific geographical area. Specifically, this geographical area should be the corresponding

accumulative coverage area of the RAN cluster. As such, the original assumption for this particular V2X scenario and the underlying URLLC requirements regarding a maximum latency of no more than 10ms does not refer to the E2E, that is, from the moment the original vehicle's (Va) initial detection of a road hazard to the moment the warning is received by other vehicles (Vb). Contrarily, it has actually been designed having in mind the two different moments and links: the initial Va2I message and the later I2Vb. In conclusion, the 99% reliability and sub 10ms latency requirements deriving for this use case do not explicitly mention this bidirectional latency between vehicle and infrastructure, but rather the maximum amount of latency allowed across the different nodes (Core, Edge and Far Edge). As mentioned in 5GCity deliverable D5.1, sub 3ms latency at the UE should be considered for the aforementioned bidirectional V2I links. As there is no way to benchmark such latency relative to the amount of passed time between the original transmission of data and caching period, the real relative initial period has been quantified in terms of event "generation time" (Va2I) and "after a successful connection" (I2Vb).

The Use Case scenario will be further explained with more detail in future deliverables (i.e. D5.2, D5.3) to ensure the URLLC network requirements are properly explained and mapped to the different events and periods.

4. Overall Requirements and KPI

The fifth generation of mobile technology (5G) will enable new applications and these bring many challenges to the network. The technological evolution of the 5G will be a profound transformation giving an answer to the demand for mobile broadband that will continue to increase in the next years.

Compared to previous generations of wireless communication technologies, including the 4G, the driver for developing the 5G is to increase mobile broadband capacity to provide specific functionality not only for consumers but also for Industries and society in general.

The 5G requirements have to handle a variety of scenarios (Uses Cases) with very different specificities: some of them aim to provide low latency in the order of few milliseconds and high reliability compared to the current values. Besides 5G networks have be to improve the flexibility in the architecture to reach the targets. For these reasons, 5G intends to become a "facilitator" of a variety of services required by a wide variety of heterogeneous vertical sectors, such as utilities, healthcare, media, industry and transport. 5G connectivity will provide new functionality and will allow new ways of defining performance monitoring, assurance, the quality of service and how to evaluate the customer experience of the final involved users.

According to the introduced aspects, 5G, compared to previous technologies, has the ambition to cover extremely heterogeneous service classes as described in Figure 17.

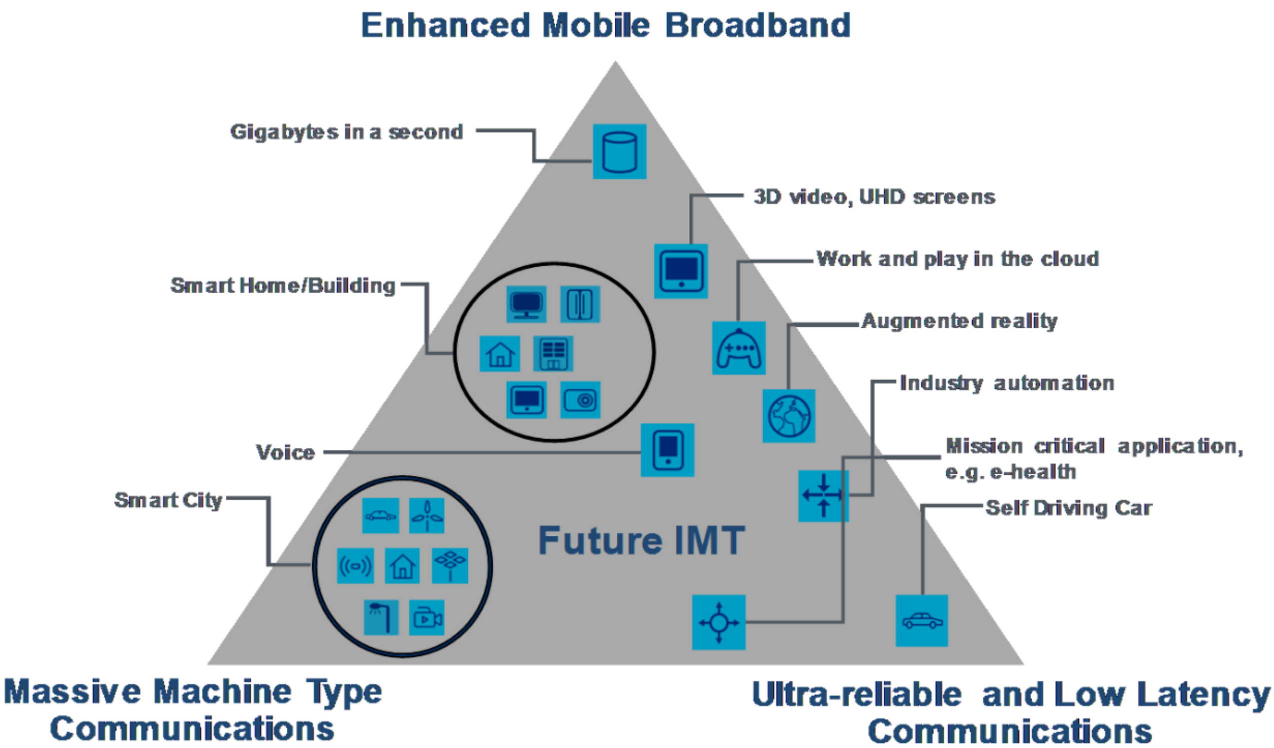

Figure 17. 5G Use Cases representation

- Enhanced Mobile Ultra Broadband (eMBB), optimized for Gbps video transmission and throughput
- Massive Machine Type Communication (mMTC) enabling to connect a massive number of devices through the ability to scale down in data rates, power and mobility to provide extremely lean and low-cost solutions
- Ultra Reliable and Low Latency Communication (URLLC/uMTC) communication and very low latency, typical of many of the most demanding industry and vertical demand markets.

Based on the previous elements the 5G Use Cases demand very diverse and sometimes extreme requirements and it is required more than a single solution to satisfy all the extreme requirements at the same time. We provide different tiers of KPIs for the creation of a KPIs set according to the 5GCity project aspects; in Table 11 it is possible to see how the 5GCity Use Cases cover the technical aspects related to 5G, according to the IMT-2020 vision. It is also important for the 5GCity project to underline that the requirements coming from the different Use Cases are above all correlated to the Enhanced Mobile Ultra Broadband (eMBB), optimized for Gbps video transmission and throughput.

IMT-2020 5G Groups	5G CITY Use Cases
eMBB - Broadband access everywhere	All the media related use cases: UC1, UC3, UC4, UC5
mMTC - Massive internet of things	UC4, UC5, UC6 if deployed at large scale
Extreme real-time communication	UC4 for immersive service scenarios, UC6 for CCAM safety-related app services
URLLC/ uMTC - Ultra reliable communication and Low latency Communication	UC6 for CCAM safety-related app services

Table 11. 5G Groups vs 5GCity Use Cases

All the specification of the system-level requirements, according to needs, the actors and technical constraints for each Use Case in the framework of the Neutral Host, have been described for each foreseen Use Case in the previous section as described in in section 3.

Several aspects can be taken into account, for example:

- The access network domain, characterized by type of communicating end points, like smartphones, smart glasses or tablets
- The diameter of the region to be covered e.g. < 10km
- The End-Users mobility, e.g. moving or pedestrian

According to the requirements of the different Use Cases described, it is possible to associate a set of telco parameters, for example “User density” (UD), “User data rate” (UDR), “Mobility” (Mob), “Infrastructure” (Inf), “Traffic Type” (TT), “Latency” (Lat), “Reliability” (Rea), “Availability” (Ava), and the correlated requirements from a 5G solution point of view.
In few cases, it is possible to indicate the expected threshold as quantitative value; in other cases, it is possible only to export a qualitative value.
According to the 3GPP TS 22.261 recommendation as reported in [9], the main KPIs to be monitored can be summarise in Table 12 . In this case, the parameters are “qualitative” and it is possible to associate a value according to the correspondent range. For example, we define a device density as low if the number of

devices involved in the area are less than 1000; following the same approach, we can create different clusters of the parameters under evaluations.

No	5G Traffic Requirement	Parameters Description	Low	Medium		High	
1	Device density	(dev/km^2)	< 1000	1000 ÷ 10.000		≥ 10.000	
2	Mobility	Km/h	< 3 (pedestrian)	3 ÷ 50 (slow moving vehicles)		> 50 (fast moving vehicles)	
3	Infrastructure	If small cells are requested or the macro cells are sufficient	Macro cell coverage	Small number of small cells		Big number of small cells	
4	Traffic type	Type of traffic generated by users or devices	Continuous	Burst	Event driven	Periodic	All types
5	User Data Rate	Mbps	< 50	50 ÷ 100		100 ÷ 1000 (≥ 1000 very high)	
6	Latency	ms	1 ÷ 10	10 ÷ 50		> 50	
7	Reliability		< 95 %	95 ÷ 99 %		> 99 %	
8	Availability		< 95 %	95 ÷ 99 %		> 99 %	

Table 12. General Telecom KPIs

In the specific case of the 5GCity project, the following (see Table 13) mapping among the parameters and each Use Case is presented:

5G Traffic Requirement	UC 1	UC 2	UC 3	UC 4	UC 5	UC 6
Device Density	Low	High	Medium	Medium	Medium	High
Mobility	Static/Low	High	Medium	Medium	Medium	High
Infrastructure	Medium	Medium	Medium	Medium	Medium	Medium
Traffic Type	Period/ Event driven	All types	Continuous/ Event Driven	Continuous/Event Driven	Continuous/ Event Driven	Continuous/ Event Driven
User Data Rate	Low	High	Low	High	Medium	Medium
Latency	Low	Low	Low	Low	Low	Low
Reliability	High	High	High	High	High	High
Availability	High	High	High	High	High	High

Table 13. General Telecom KPIs and 5GCity Use Cases

In the previous table we reported the expected threshold as qualitative value; even if each Use Case has an own context it is interesting to understand that it is necessary always a telecom network able to offer low latency, high reliability and availability to delivery and deal with the new expected services.

For this reason, all the telco requirements for each Use Case of the 5GCity can be summarized in three contexts:

- Network
- Operational
- Business.

4.1. Network Requirements

In this section, the network requirements are analysed and listed in Table 14.

Requirement ID	Description	Acceptance criteria	Note
TLC			
Net_001	Device density	High: ≥ 10000 devices per km2; Medium: 1000 – 10000 devices per km2; Low: < 1000 devices per km2	According to the Use Case requirements
Net_002	User data rate	Very high data rate: ≥ 1 Gbps; High: 100 Mbps – 1 Gbps; Medium: 50 – 100 Mbps; Low: < 50 Mbps	Generally, 2-10 Mbps per device in UL will be required in the different Use Cases. In the case of Use Cases 4 and 5 we have to deal with a greater UL bit rate: 100 Mbps to connect a 4K camera directly to the network. According to the Use Case requirements: in a few conditions, the parameters will be mandatory (e.g., ultra HD Video requires Very High data rate; in case of alarms it could be requested but it will be not mandatory). Generally, 2-10 Mbps per device also in DL will be required for the different Use Cases. In the case of Use Case 4 and 5 the requirement will be higher to improve the user experience; initially 5-20 Mbps will be required.
Net_003	Mobility	Static user;/Low (0-3 Km/s); Medium (3-50 Km/s); High (>50 Km/s)	
Net_004	Infrastructure	Limited (only macro cell) Medium (macro and limited small cell); High (many small cells available)	It should be requested according to the Use Case scenario: multiple Wi-Fi/4G/5G hotspots distributed in the project area. At least 100 Mbps connection to internet; in the Use Cases 4 and 5 1-10 Gbps for the backhaul are requested.

Net_005	Traffic type	Continuous Burst Event driven Periodic Mixed all type	Different types of traffic have to be considered
Net_006	Latency	Low: 1-10 ms; Medium: 10 – 50 ms: High: >50 ms	Generally Low latency network connectivity is requested according to the Use Case requirements: in a few conditions, e.g. Use Case 4, the parameters will be mandatory (e.g., ultra HD Video requires Low Latency data rate; in other it could be requested but it will be not mandatory).
Net_007	Reliability	high > 99%; medium 95- 99%; low < 95%	To allow compute and processing capacities and to deliver final services
Net_008	Availability	High > 99%; Medium 95-99%; Low < 95%	To allow compute and processing capacities and to deliver final services.

Table 14. Network Requirements

4.2. Operational Requirements

It is necessary to include several KPIs focused on operational efficiency for measuring the E2E service quality, monitoring the service providers on the base of the transport services already provided by the Telco Operator above all in the context if the Neutral Host scenario.

These requirements are listed in Table 15.

Requirement ID	Description	Note
	Operational KPIs	
OP_009	Connectivity	To assure ubiquitous coverage including all the elements involved.
OP_010	Accessibility (service)	Correlated to the “Availability” KPI – TLC requirements.
OP_011	Service usage	In the Use Cases, it will be required to guarantee for max/min values; besides it is required a monitoring and management of the service.
OP_012	90-90-90	Using the 5GCity solution, is required to save up to 90% of energy per service provided and to reduce time in the initial service deployment and onboarding phase from 90 hours to 90 minutes.
OP_013	Service establishment time	For remote services delivered in the different 5GCity context to setup a communication path towards a dedicated station, which provides specific QoS has to be obtained in the range of 10 min to 1 hour.

OP_014	QoS flow perform.	Support a set of different configurations for the traffic for each network components in order to obtain the expected QoS value.
OP_015	Busy hour flow invocation capacity	Enhancing the wireless area capacity for different service capabilities when the request is done during the Busy Hours.
OP_016	Maximum event response time	Able to deal with short response time to enriched experience to the final users when a service is requested.
OP_017	QoS Flow installation time	Deal with the installation of each components to increase the benefits for the involved operators.
OP_018	QoS Flow removal time	Deal with the removing process of each components to reduce the impacts for the involved operators.
OP_019	VM installation time	Reduce the costs of installing dedicated infrastructures, in particular as far as concerning the Virtual machines for the provided flexibility.
OP_020	VM removal time	Reduce the costs when it is necessary to remove dedicated infrastructures, as far as concerning the Virtual machines.
OP_021	Memory/CPU usage	Control the usage of Memory and reduce the costs of installing dedicated infrastructures, in particular as far as concerning the Virtual machines for the provided flexibility.
OP_022	% of parameters exchanged	It is important to control this exchange of data among the different components because it is a measure of the complexity.
OP_023	Node discovery time	To monitor the time used to discover a new node and/or multi-domain orchestrator system.
OP_024	Single touch orchestration	It is the minimum number of workflow interventions to provision a multi-domain service; for this reason, it is a measure of automation of the complete process.
OP_025	Seamless service offers in multiple domains	The degree to which connectivity, network and compute/storage resources can be integrated together seamlessly.
OP_026	Re-scaling of compute/storage	Re-scaling of compute/storage into and out of a service depending on demand.

Table 15. Operational Requirements

4.3. Business Requirements

The business requirements are strictly correlated to the contribution that the project offer to the global 5G-PPP Projects eco-system. Each project is based on the outcomes of the other project and offers new contributions to improve the global 5G context as far as concern the performances, the impacts of the solution on the society and the expected economic results.

In general, the performance, the societal and business aspects are described in 5G PPP KPIs in order to harmonize the viewpoints of different projects and to offer a common framework for the outcome evaluation for each project from these three different aspects.

Table 16 summarise the elements for each class of KPIs.

Item	Description	KPI	5G-PPP KPIs Performance	5G-PPP KPIs Societal	5G-PPP KPIs Business-related
Interoperability	The Interoperability among the different components is requested: in particular, it is requested that the network architectural components provide external APIs to allow the access the offered functionality or for managing the VNF or other components.	Accessible information and functionality of 5GCity components.	P4: Creating a secure, reliable and dependable Internet with a "zero perceived" downtime for services provision.	S2: Reduction of energy consumption per service up to 90% (as compared to 2010). (*)[9] S3: European availability of a competitive industrial offer for 5G systems and technologies. S4: Stimulation of new economically-viable services of high societal value like U-HDTV and M2M applications.	B2: Target SME participation under this initiative commensurate with an allocation of 20% of the total public funding.

[9] S2 KPI description as received in the excel file from 5G-PPP: "5G-PPP Phase 2 KPI and WG relevance"

Resource Monitoring	It is required that the information both from physical and virtual components are monitored; to reach this goal it is necessary to include in the provisioning phase of the architectural components all the elements necessary to achieve these data collections. Using these elements, it will be possible to evaluate the value of the different parameters involved in the SLA.	We include all the different retrievable information from networks.	P5: Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people.	S2: Reduction of energy consumption per service up to 90% (as compared to 2010). S4: Stimulation of new economically viable services of high societal value like U-HDTV and M2M applications.	
Dynamic configuration of virtual resources	Virtualization management it is requested; it is requested that the components have to support the dynamic configuration and scaling of virtual resources. The programming model of 5G CITY must support scalability of a VNF depending on the user demand.	Time to reconfigure the deployment of VNFs.	P2: Saving up to 90% of energy per service provided.	S2: Reduction of energy consumption per service up to 90% (as compared to 2010). S3: European availability of a competitive industrial offer for 5G systems and technologies. S4: Stimulation of new economically-viable services of high societal value like U-HDTV and M2M applications.	B2: Target SME participation under this initiative commensurate with an allocation of 20% of the total public funding.

Hardware and network acceleration	It is necessary to evaluate if to improve the VNF performance hardware and/or network accelerators are required.	VNF performance in terms of processing speed and resource consumption.		S3: European availability of a competitive industrial offer for 5G systems and technologies. S4: Stimulation of new economically-viable services of high societal value like U-HDTV and M2M applications.	
Service function chaining	It is necessary to evaluate if it is possible offer different services composed by many VNFs. Also, the Service mapping complexity and time will be evaluated.	Number of services and VNFs in the chain supported without impacting on the network performance.	P1: Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010. P3: Reducing the average service creation time cycle from 90 hours to 90 minutes. P6: Enabling advanced user-controlled privacy.	S1 Enabling advanced User controlled privacy. S2: Reduction of energy consumption per service up to 90% (as compared to 2010). S3: European availability of a competitive industrial offer for 5G systems and technologies. S4: Stimulation of new economically-viable services of high societal value like U-HDTV and M2M applications.	B2: Target SME participation under this initiative commensurate with an allocation of 20% of the total public funding.

Multiple IoT Sensor Vendors	In the project, it is necessary to support traffic from different IoT sensor vendors.	The information coming from the different sensors must be processed in the same way.	P1: Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010. P3: Reducing the average service creation time cycle from 90 hours to 90 minutes. P5: Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people.	S3: European availability of a competitive industrial offer for 5G systems and technologies. S4: Stimulation of new economically-viable services of high societal value like U-HDTV and M2M applications.	

Table 16. Business Requirements (5G PPP KPIs)

In many performance KPIs it is mentioned the condition '*as compared to 2010*' which is the benchmark term introduced by the 5G PPP in [10] to evaluate the programmatic target improvement of performances expected by the EC through the 5G PPP action and to be considered by the projects. In particular, this benchmark applies to wireless area capacity and to energy consumption per service.

4.4. 5G PPP KPIs: Relevance and Impact on 5GCity

In order to complete the analysis and having a comprehensive vision, we have selected a subset of the previous elements to indicate their relevance for the 5GCity Use Cases.

5G-PPP KPI	Relevance for 5GCity
P1	5GCity will highlight the requirements of the Smart City context and identify the advantages and limitations of current network infrastructures and the new proposed model Neutral Host.
P2	According to the proposed solution we have to obtain a saving up to 90% of energy per service provided.
P3	The available VNF catalogue will enable a new range of services to be created in minutes / hours.
P4	The trusted, scalable applications will be deployed thanks also to solutions based on edge network equipment.

P5	The new functions proposed in the 5GCity will increase reliability and minimize latency; besides scalability will be increased and we will minimize latency for enabling solutions capable of instantaneous response to massive requests.
S2	Indicatively, tasks offloading to edge components will enable significantly lower energy consumption.
S3	The 5G core functionalities, including uMTC and mMTC will be implemented as VNFs and VNF chains deployed on generic edge network equipment developed in Europe.
S4	5GCity will stimulate of new economically viable services of high societal value like U-HDTV and M2M applications by testing the new capabilities in the Multimedia area.
B1	5GCity will increase European competitiveness for industry addressing the 5G communication issues to eliminate risks that hinder investment in services.
B2	5GCity will increase European competitiveness for industry above all the SME; in particular promoting the rising of European standards for interfaces that lower market entry barriers especially for SME's. Besides, 5GCity will offer concrete solution guidelines and close to market implementations of new SME products.

Table 17. 5G PPP KPIs: Relevance and Impact on 5GCity

4.5. Key Performance Indicators

In order to evaluate the results of the solutions proposed and implemented within 5GCity it is necessary to quantify the measurable impacts which contributes to the specific EU policy goals according to the 5G PPP programs, identifying some of KPIs before introduced. The select KPIs help to underline objectives, aim to highlight the added value of 5GCity and monitor the performance of the different Use Cases of the project. According to this, KPIs' role is to be used from the different points of view expressed in the Use Cases to contribute in future decisions concerning 5G solutions deployment in Europe, in particular, for other European research activities and projects using the obtained results as starting point for future improvements.

In this document, we listed the KPIs of interest for 5GCity; for each one of those KPIs we will derive relevant KPI requirements, based on 5G PPP commitments, for evaluating the project results versus the project goals.

The complete set of targets values will be defined, for the different Use Cases, in the activities related to Work Package 5 (WP5) that will build and deploy the project pilot demonstrators. The main objective is to get KPIs values based on measurements, obtained from the real implementations (both HW/SW components).

We will consolidate the KPIs of interest and collect their figures considering the application components developed in the 5GCity context (Table 18).

Consolidated Projects KPI\UCs	Crowded Venues	Smart Cities	Performance equipment	50+ Mbps everywhere	Mobile BB in vehicles
Device Density	1000– 10000 devices per km2 for UC3, UC4, UC5	< 1000 devices per km2 for UC1 ≥ 10000 devices per km2 for UC6	3 days batteries (smart phones) and more than 10 days (less performing devices): for all	Far remote rural: 500 Mbps/km² Rural: 5 Gbps/km²	Urban:1000-3000 veh/km² for UC6

			UCs	Suburban: 25 Gbps/km² for all UCs	
Mobility	0-3 Km/s: for UC1, UC2, UC3, UC4, UC5 3-50 Km/s: for UC1, UC2, UC3, UC4, UC5 >50 Km/s: for UC6	0-3 Km/s: for UC1, UC2, UC3, UC4, UC5 3-50 Km/s; for UC1, UC2, UC3, UC4, UC5 >50 Km/s: for UC6	3 days batteries (smart phones) and more than 10 days (less performing devices): for all UCs		>50 Km/s for UC6
Infrastructure	Medium (macro and limited small cell) for all UCs	Medium (macro and limited small cell) for all UCs		Medium (macro and limited small cell) for all UCs	Medium (macro and limited small cell) for all UCs
Traffic Type	Mixed	Mixed	All	Continuous	Mixed
User Data Rate	100Mbps – 1Gbps: for UC2, UC4 50 – 100Mbps: for UC3, UC5, UC6 < 50 Mbps UC1			DL: 50 Mbps (100 Mbps, if possible) UL: 25 Mbps	
Latency	<= 10 ms: for all UCs	<= 10 ms: all UCs			< 10 ms for UC6
Flexibility/versatility/re-configurability					
Resilience and continuity	For all UCs: 95-99% expected. For UC2 and UC6: > 99 %	For all UCs: 95-99% expected. For UC2 and UC6: > 99 %			> 99 % for UC6

Table 18. Key Performance Indicators in 5GCity

This way facilitates monitoring the KPI values in order to evaluate if additional efforts are needed for the successful achievement of the KPIs target objectives.

5. Conclusions

The real strength of 5GCity project in terms of real-world impact lies in the deployment of its 5G-based edge platform in three distinct smart cities: Barcelona, Lucca and Bristol.

To this aim, the project has identified three main scenarios which groups the project Use Cases, namely the Neutral Host, Industry vertical (Media and Entertainment) and City services of great interest, within the envisaged three-tier architecture of 5GCity.

In particular, the Neutral Host (the open access model) plays a key role in a Smart City, especially when considering the indoor and urban environment, where densification of cells will be required to serve businesses, shopping districts, and crowded events.

Six specific Use Cases, relevant to the three scenarios, have been described and analysed, investigating the involved actors, the deployment topology, the evaluation process, the expected impact as well as the main requirements.

Furthermore, the overall requirements and KPIs have been grouped and summarized, providing different tiers of KPIs for the creation of a set, according to the 5GCity project aspects, to the network, operational and business aspects and to the 5G PPP KPIs.

The next objectives of WP2 include the definition of the overall 5GCity system architecture as well as the technical specifications of interfaces and system workflows.

6. References

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Abbreviations and Definitions

6.1. Abbreviations

3GPP	3rd Generation Partnership Project
5G-PPP	5G Infrastructure Public Private Partnership
AR	Augmented Reality
BBU	Baseband Unit
CAPEX	Capital Expenditure
CCAM	Cooperative Connected and Automated Mobility
CDVS	Compact Descriptor for Visual Search
CP	Control Plane
CPE	Customer Premise Equipment
DC	Data Center
DDS	Data Distribution Service for Real Time Systems
DOF	Degree of Freedom)
eMBB	Enhanced Mobile Ultra Broadband
eNB	Evolved Node B
E2E	End to End
EPC	Evolved Packet Core
FDD	Frequency Division Duplex
FoV	Field of View
GPS	Global Positioning System
H24	24 Hours a day operation
HD-SDI	High Definition Serial Digital Interface
HDMI	High Definition Multimedia Interface
HR	High Resolution
ICT	Information Communication Technology
IoT	Internet of Things
IP	Internet Protocol
ITS	Intelligent Transportation System
ITU-T	International Telecommunication Union – Telecommunication Standardization Bureau
LTE	Long Term Evolution
LTE-A	Long Term Evolution Advanced
LPWA	Low Power, Wide Area (network)
mMTC	Massive Machine Type Communication
M2M	Machine to Machine
M&E	Media & Entertainment
MEC	Multi access Edge Computing
MR	Mixed Reality
MNO	Mobile Network Operator
MOCN	Multi Operator Core Network
MORAN	Multi-Operator Radio Access Network
MVNO	Mobile Virtual Network Operator
NGMN	Next Generation Mobile Networks

NFV	Network Function Virtualization
NFVI	Network Function Virtualization Infrastructure
NFVO	Network Function Virtualization Orchestration
NS	Network Service
OPEX	Operative Expense
OTT	Over-The-Top Player
PoP	Point of Presence
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RAT	Radio Access Technology
RF	Radio Frequency
RO	Resource Orchestrator
RRH	Remote Radio Head
RU	Radio Unit
SD-SDI	Standard Definition Serial digital interface
SDK	Software Development Kit
SDN	Software Defined Network
SLA	Service Level Agreement
SME	Small Medium Enterprise
TAG	Text and Graphics
TDD	Time Division Duplex
uRLLC/uMTC	Ultra reliable communication/Low latency Communication
UHD	Ultra High Definition
UHDTV	Ultra High Definition Television
UP	User Plane
vBBU	virtual Baseband Unit
V2I	Vehicle-to-Infrastructure
V2N	Vehicle-to-Network
V2P	Vehicle-to-Pedestrian
V-RAN	Virtual Radio Access Network
VIM	Virtual Infrastructure Manager
VM	Virtual Machine
VoD	Video on Demand
VR	Virtual Reality
VNF	Virtual Network Function
VNFM	Virtual Network Function Manager

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