Alliance for Internet of Things Innovation

IoT Relation and Impact on 5G

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Executive Summary

This report highlights several IoT vertical domain use cases collected by AIOTI (Alliance for IoT Innovation) and determines the specific requirements they impose on the underlying network infrastructure. These use cases and requirements can be used by SDOs (Standards Developing Organizations), such as 3GPP (3rd Generation Partnership Project) as requirements for automation in vertical domains focusing on critical communications.

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Abbreviations

3GPP	3rd Generation Partnership Project
4G	4th Generation
5G	5th Generation
ABS	Anti-lock Braking System
ADApp	Autonomous Driving Application
AIOTI	Alliance for IoT Innovation
App	Application
AS	Application Server
AVP	Automated Valet Parking
BVLOS	Beyond Vision Line of Sight
CAD	Connected and Automated Driving
CAGR	Compound Annual Growth Rate
CAM	Cooperative Awareness Message
CAPEX	Capital Expenditure
CSS	Car Sharing Service
C-ITS	Cooperative-Intelligent Transportation System
D2X	Device to everything
eMBB	Enhanced Mobile Broadband
ETSI	European Telecommunication Standardisation Institute
GPS	Global Positioning System
GSM	Global System for Mobile communications
IP	Internet Protocol
IoT	Internet of Things
ITS	Intelligent Transportation System
LDM	Local Dynamic Map
LOS	Line Of Sight
LP-WAN	Low Power Wide Area Network
LTE	Long Term Evolution
LTE-V2X	LTE Vehicle to Everything
mMTC	Machine-Type Communications
NB-IoT	Narrowband IoT
NoLOS	Non Line of Sight
OBU	On-Board Unit
OGC	Open Geospatial Consortium
OPEX	Operational Expenditure
RSU	Road Side Unit
SAS	Service Alerting System
SCADA	Supervisory Control and Data Acquisition

TC	Technical Committee
TCP	Transmission Control Protocol
MEC	Multi-Access Edge Computing
SDO	Standards Developing Organizations
TMC	Traffic Management Center
XML	Extensible Markup Language
UAV	Unmanned Aerial Vehicle
UAS	Unmanned Aerial System
UMTS	Universal Mobile Telecommunication System
uRLLC	Ultra-reliable and Low-latency Communications
UTM	Unmanned Traffic Management system
V2V	Vehicle to Vehicle
VRU	Vulnerable Road Users
WAVE	Wireless Access in Vehicular Environments
WiMAX	Worldwide Interoperability for Microwave Access

1 Introduction

The Internet of Things is projected to consist of 50 billion devices by 2020 [2] ranging from connected temperature sensors to autonomous vehicles. The vast scope of different device types from different verticals corresponds with highly diverse requirements for the communication infrastructure. While battery-driven sensors need a highly energy efficient communication technology, industrial IoT applications call for ultra-reliable connections with a minimum latency. As of today these diverse requirements are covered by several wireless communication technologies (e.g. (Wireless Local Access Network) WLAN, Sigfox®, ZigBee, LoRa Wide Area Network (LoRaWAN), Narrowband-IoT (NB-IoT)) which all have their specific strengths and weaknesses and that are making the Internet of Things somewhat of a "rag rug".

This is where 5th Generation (5G) becomes to be relevant, with its highly flexible architecture designed to be adaptable to almost any use case in the IoT space using advanced techniques like network slicing and Network Function Virtualization (NFV), see e.g., [1], [5]. By offering a unified communications platform for the IoT, 5G has the potential of being a catalyst for IoT growth – and vice versa.

Compared with previous generations of mobile technologies, 5G systems will extend mobile communication services beyond mobile telephony, mobile broadband, and massive machine-type communication into new application domains, so-called vertical domains.

The main goal of this report is to highlight specific IoT vertical domain use cases and determine the specific requirements they impose on the network infrastructure. These use cases and requirements can be used by SDOs (Standards Developing Organizations), such as 3rd Generation Partnership Project (3GPP) as requirements for automation in vertical domains focusing on critical communications.

In subsequent versions of this report, these requirements will be mapped to the 5G features according to the current 3GPP design documents and subsequently analyse potential gaps of 5G related to IoT use case requirements and give recommendations on how to close these gaps.

2 IoT Use Cases and Requirements

This section describes the IoT vertical domain use cases that are being developed in IoT focused projects. Moreover, this section describes he specific requirements that these use cases impose on the underlying network infrastructure.

The use cases listed in this section have been described using the use case description template provided in Annex II.

2.1 Smart Mobility

2.1.1 Automated Valet Parking (AVP)

2.1.1.1 Description

The concept of Valet Parking is widely used all over the world; for example, by the more luxurious hotels and restaurants, stores and other businesses.

Once a customer arrives with his/her vehicle at the hotel, he/she gets out of the vehicle and hands over the car-keys to the hotel personnel, which will then drive the vehicle to its parking spot, relieving the customer from that task. In the meantime, the owner of the vehicle can e.g. check-in or attend a meeting. Likewise, the vehicle is returned by the hotel personnel upon the request of the relevant customer. Utilising the technology evolution of self-driving vehicles, it is a logical next step to also automate the valet parking concept, further referred to as Autonomous Valet Parking, or AVP.

By deploying this use case several stakeholder types can participate and profit from its value chain, such as: Autonomous Valet Parking application provider, IoT Devices manufacturer, Communication Network supplier/provider/operator and IoT platform provider.

In this use case, IoT plays an important role being applied to improve the operation of an autonomous driving vehicle when used in Valet Parking scenarios.

In AVP, see Figure 1 , the autonomous vehicle will park itself after the driver has left the car (step 1) at a drop-off point, which may be located near the entrance of a parking lot. The autonomous vehicle will find an available parking spot (step 2) and drive and park itself (step 3). When the driver wants to leave the site, he/she will simply request from the autonomous vehicle to return by itself (step 4) to the collect point, using (for example) a Smartphone app.

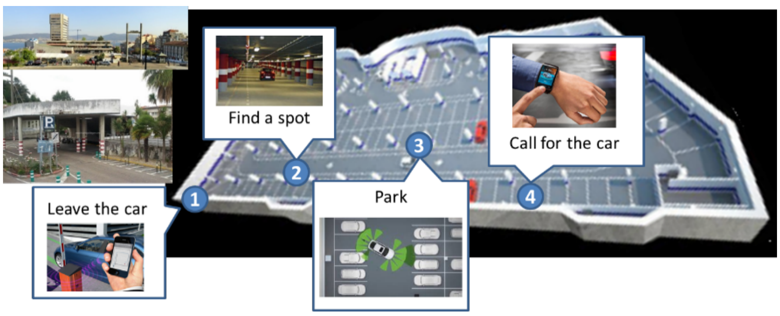

Figure 1: Automated Valet Parking sequence, based on [EC H2020 AUTOPILOT project]

To navigate safely around the parking lot to its destination, the automated vehicle uses driving functions based on knowledge about the environment around the vehicle. An example would be a navigation functionality based on a digital map, positions of the automated vehicle and vacant parking spots. The vehicle can use its own functions and sensors to observe immediate environment, but it can also benefit from gathering additional data going beyond what its sensor can observe – like accessing IoT platforms which can provide data and functions based on IoT enabled sensors like parking cameras, as well as position info from other vehicles driving (or being parked) at parking. Furthermore, IoT platforms may provide information to support services for booking a parking place and arranging (automated) payment.

One of the main challenges when using IoT data as additional source, is that we need a suitable common architecture of sharing information between different sensor systems (e.g., vehicle, garage equipment), such that any vehicle can park itself in any parking garage. For scenarios in which the parking lot is equipped with an extended set of sensors, more and accurate information can be shared with the AVP-vehicle, such it can perform its task better (with shorter time to park, less fuel consumed), compared to parking lots that lack additional sensors.

2.1.1.2 Source

EC H2020 AUTOPILOT project

2.1.1.3 Roles and Actors

- Vehicle owner / driver / passenger in the vehicle: Profits from the AVP service by decreasing the required time to park the vehicle and at the same time increasing the probability of finding a free slot in the parking area and decreasing the probability of vehicle accidents in the parking area.
- IoT platform provider: It operates an IoT platform which is collecting data from vehicles, parking spots, roads, other participants in traffic present, and from surrounding associated infrastructure (traffic lights, cameras, etc.). Necessary information/data is provided to any devices that are subscribed to the IoT platform.
- Autonomous Valet Parking application provider: Party that is providing Automated Valet Parking application (AVPApp) which runs on AS (Application Servers). AVPApp connects to the IoT platform, and from there it collects relevant data needed to run an Autonomous Driving App (ADApp) - for example Local Dynamic Map (LDM).
- Communication Network supplier/provider/operator: Supplies and/or provides and facilitates connectivity between vehicles, roads and associated infrastructure. This covers both wireless (for example Long Term Evolution (LTE), LTE-Vehicle to Everything (LTE-V2X), Intelligent Transportation System –G5 (ITS-G5) and Wireless Access in Vehicular Environments (WAVE) and fixed connections. The Network supports receiving requests for data transfers that require low latency and low probability of packet losses. It is not expected or mandated that a single network operator provides the end-to-end connectivity.
- IoT Devices manufacturer: Manufacturer provides IoT devices that are embedded in vehicles, roads and associated infrastructure, parking garage /terrain, traffic lights, as well as in devices used by other participants in traffic (pedestrians, cyclists). Each IoT

device collects and sends data to IoT platform, and can receive data from the IoT platform.

2.1.1.4 Pre-conditions

The vehicle supports autonomous driving - meaning that it is capable of (1) autonomously driving, and (2) transmitting and receiving data from other vehicles, road and other infrastructure, and as well other participants in traffic (pedestrians, cyclists).

2.1.1.5 Triggers

The AVP function (sending vehicle to park itself, as well as calling it back to collect point) is activated by the vehicle driver.

2.1.1.6 Normal Flow

1. The vehicle continuously collects data from own sensors and sends them to the IoT platform. The transmitted data includes information from the internal state of the vehicle (Anti-lock Braking System (ABS) status, brake switch, accelerator pedal switch, etc.) as well as data on observed surroundings of the vehicle (such as radar, LIDAR, cameras).
2. Road infrastructure (such as roads, traffic lights, cameras) continuously collects data from its sensors and sends it to the IoT platform. Examples include events such as vehicles driving on top of sensors placed on the road, the state of traffic lights, the detected vehicles driving (observed by cameras).
3. Devices belonging to other participants in traffic (such as pedestrians, cyclists) continuously collect data from their sensors (such as position, accelerometers) and send it to the IoT platform.
4. The IoT platform hosts the collected data from abovementioned sources. Upon request the IoT platform will send it to AS where Automated Valet Parking application (AVPApp) is running. The AVPApp is subscribed to the IoT data from all participants in traffic in area of parking garage / terrain and immediate surroundings.
5. Processed information from AVPApp is sent back to IoT platform, and is made available to all ADApp subscribed participants in traffic.
6. Each participant in traffic is responsible for interpretation and action based on the received ADApp data.

2.1.1.7 Alternative Flow

None.

2.1.1.8 Post-conditions

Vehicle stays in autonomous driving mode until it is switched off by the driver.

2.1.1.9 High Level Illustration

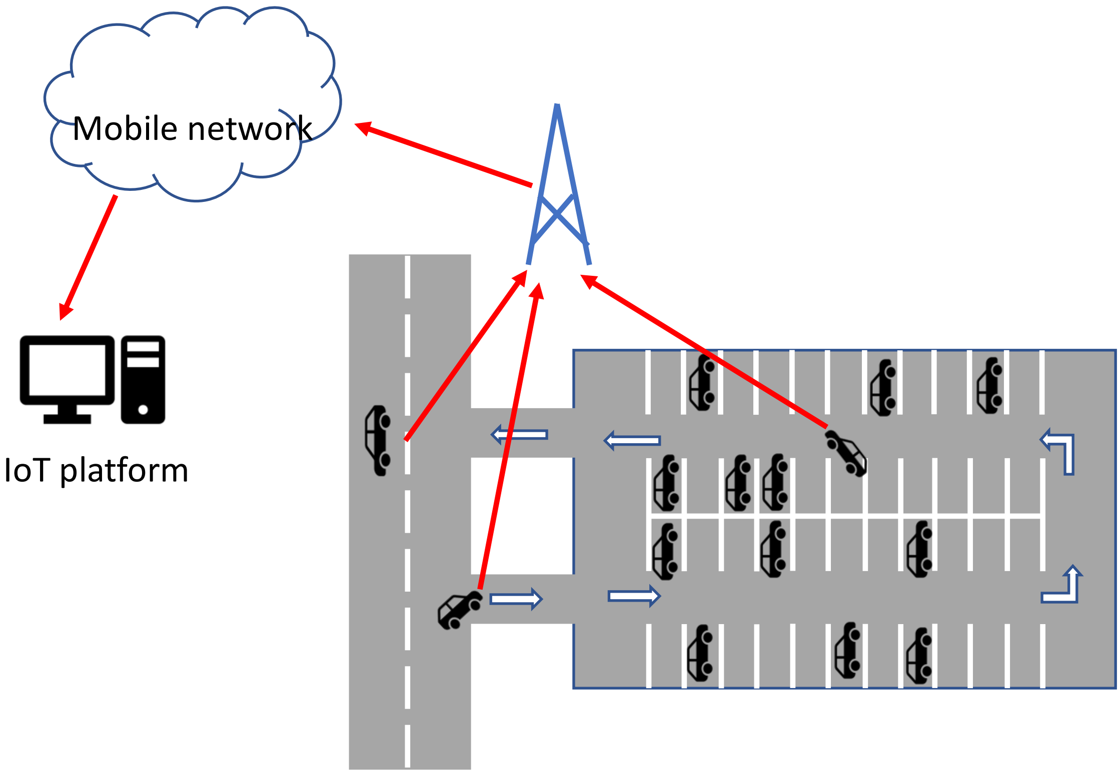

Figure 2: Example of IoT data streams and corresponding communication networks, based on EC H2020 AUTOPILOT project

Figure 3: Sensors used in a parking garage, based on EC H2020 AUTOPILOT project

2.1.1.10 Potential Requirements

The AVP functionality can be divided into two key components. One component is focusing on the process of autonomous driving, and the other one is responsible for providing information to vehicles on available parking spots.

The Information on available parking spots, that also possibly include route information (detailed or just waypoints) is not considered to be time critical, since it is expected that vehicles move with low speeds within the parking terrain / garage. This route information includes start and end points, with possibly waypoints in between, and as well the whole planned / advised route to destination. Therefore, the total amount of transmitted data will not be significantly large. It is expected that current 5G promises on performance capabilities, see e.g., [1], will be able to support the performance requirements imposed by the AVP use case on the underlying communication network.

2.1.1.11 Radio Specific requirements

Autonomous driving is dependent on the timely information about other participants in traffic. The ETSI TC ITS (European Telecommunication Standardisation Institute Technical Committee Intelligent Transport Systems) has defined a number of standards on what type of data and how often to exchange data between cooperating vehicles. These messages are typically known as CAM (Cooperative Awareness Messages), and they are sent periodically. As expected the higher the speed of the vehicle, the higher the frequency of sending CAM data. This frequency ranges from 1 Hz (period is 1000ms) to 10Hz (period is 100ms). There are also requirements supported on how long the received CAM data is valid. Effectively this is the maximal allowed end-to-end latency, which for cooperative awareness applications is around 100ms (end-to-end, including processing).

Note that for autonomous driving scenarios, one of the assumptions is that whatever the use case, a vehicle will have local (vehicle internal) intelligence to process the collected data received from own sensors and as well as from external sensors and sources, e.g., other vehicles and road side systems. Adequate strategies have been developed which allow vehicles to handle unreliable connections. It is important to note that in the EC H2020 AUTOPILOT project, it is considered that an autonomously driving vehicle will be able to autonomously operate and drive even if this vehicle is not communicating with external sensors and sources. In situations that the autonomously driving vehicle uses communication means and data generated by external sensors and sources it can make better and more accurate decisions on how to act.

Current 5G promises on performance capabilities, see Table 1, are able to support the requirements imposed by the AVP use case even on more complex and demanding processing and on supporting roadside systems to gather more data from other sensors and sources.

Table 1: 5G promises on performance capabilities, based on [1]

Requirement	Explicit 5G Promises
Real-time capability- Latency	5 ms (e2e)
Reliability	99.999%

Outdoor terminal location accuracy	<1m
Multi-tenant support	yes

2.1.2 Car Rebalancing

2.1.2.1 Description

The driverless car rebalancing service is targeted to offer rebalancing of several AD vehicles distributed over several collect points within a car sharing concept. The AD vehicles will be able to drive automatically (speed limit of 10 km/h) between dedicated collect points on specific areas such as University campuses, using pre-defined and 3D-mapped tracks and IoT data to improve its world model. The scenario associated with this use case comprises areas, such as University campuses, where no lane markings, no traffic signs, no pedestrian crossings, no RSUs and no traffic lights are used and where aside from the multiple vehicles, there are several pedestrians and cyclists moving into the campus. This creates a challenging urban environment for Automated Driving vehicles.

The concept of IoT is used to connect probabilistic & historical data not available yet in AD vehicles for Urban Driving using different sources to improve the world model of an AD vehicle:

- Use campus lecture schedule data to adapt probabilistic models in the AD vehicle's World Model. Statistically predict the probability of large amount of Vulnerable Road Users (VRUs) on the roads. And so, decide when to drive and when better not to do so or adapt dynamically the vehicles driving behaviour.
- People tracking through a phone app. The app acts as position sensor and this position data facilitates data-association and tracking for improving the AD vehicle's World Model
- Get actual weather and daylight information from internet. Reconfigure sensors to better perform under various weather and daylight conditions.

The key benefits of the car rebalancing use case are:

- Increase Safety: by decreasing time to detect and avoid collisions with VRUs.
- Increase availability of vehicles in real time, i.e., min. response time between request and delivery.
- Increase utilization of parking spaces.
- Decrease the errors (i.e., false/negative events) in obstacle detection.
- Increase routing prediction, i.e., less rerouting, due to better prediction of blocked routes due to VRU detection.
- Increase localization accuracy, by using among others localisation provided by IoT enabled Smartphone apps.
- Increase dynamical obstacle motion accuracy.
- Improve prediction of demand for requested vehicles.

2.1.2.2 Source

EC H2020 AUTOPILOT project

2.1.2.3 Roles and Actors

- Vehicle owner / driver / passenger in the vehicle: The car rebalancing service provides several benefits to the vehicle owners/drivers/passengers, such as: (1) increase safety, by decreasing time to detect and avoid collisions with VRUs, (2) Increase availability of vehicles in real time, i.e., min. response time between request and delivery, (3) Decrease the errors (false/negative events) in obstacle detection, (4) Increase routing prediction, i.e., less rerouting, due to better prediction of blocked routes due to VRU detection.
- IoT platform provider: It operates an IoT platform which is collecting data from vehicles, roads, other participants in traffic present, and from surrounding associated infrastructure (such as traffic lights, cameras). Necessary information/data is provided to any devices that are subscribed to the IoT platform.
- Car rebalancing service provider: Provides the car rebalancing service. The car rebalancing service collects information on the available vehicles on each known collect points. If rebalancing is needed (i.e., vehicles need to be redistributed) then it will make use of routing and motion planning function, to lead the vehicles to the selected collect points/parking. The AD vehicle moves, using a routing and motion planning function, over the campus to the newly designated collect point/parking, using both its environmental sensors and information from IoT devices, such as (1) weather information, (2) detecting VRUs using localization provided by IoT enabled Smartphone apps and (3) TU/e lecture course scheduling.
- Communication Network supplier/provider/operator: Supplies and/or provides and facilitates connectivity between vehicles, roads and associated infrastructure. This covers both wireless (for example LTE, LTE-V2X, ITS-G5 and WAVE) and fixed connections. The Network supports receiving requests for data transfers with required latency and with required packet losses. It is not expected or mandated that single network operator provides all of connectivity.
- IoT Devices manufacturer: Manufactures IoT devices that are embedded in vehicles, roads and associated infrastructure, parking garage /terrain, traffic lights, as well as in devices used by other participants in traffic (pedestrians, cyclists). Each IoT device collects and sends data to IoT platform, and can receive data from platform.

2.1.2.4 Pre-conditions

The car rebalancing service can obtain vehicle information (such as current location, destination) and information on the available vehicles on each known collect points/parking, and as well the maximum capacity of the known collect points/parking.

2.1.2.5 Triggers

Car rebalancing service is activated when it is observed that (1) not enough vehicles are available at collect points/parking (2) a higher (than a predefined threshold) number of vehicles is parked at a collect point/parking.

2.1.2.6 Normal Flow

1. Vehicle provides to the IoT platform its current location, destination, number of available places and maybe other conditions (such as dogs accepted or not, luggage accepted or not).
2. Parking collect points/parking sends information to the IoT platform on the available vehicles on each known collect points/parking
3. Information regarding campus lecture schedule data to adapt probabilistic models in the AD vehicle's World Model is sent to the IoT platform.
4. Information regarding weather and daylight information is sent to the IoT platform.
5. VRUs: information for pedestrian detection is sent to the IoT platform.
6. The IoT platform hosts the collected data from abovementioned sources, and upon request it will send it to AS where car rebalancing application (Car rebalancing App) is running. Car rebalancing App is subscribed to the IoT data from all participants in traffic in urban area.
7. The car rebalancing service collects information on the available vehicles on each known collect points. If rebalancing is needed (i.e., vehicles need to be redistributed) then it will make use of routing and motion planning function, to lead the vehicles to the selected collect points/parking. Processed information from Car rebalancing App is sent back to IoT platform, and is made available to all Car rebalancing App subscribed participants in traffic.
8. Each participant in traffic is responsible for interpretation and action based on received Car rebalancing App data. In particular, the AD vehicle moves, using a routing and motion planning function, over the campus to the newly designated collect point/parking, using both its environmental sensors and information from IoT devices, such as (1) weather information, (2) detecting VRUs using localization provided by IoT enabled Smartphone apps and (3) TU/e lecture course scheduling

2.1.2.7 Alternative Flow

None

2.1.2.8 Post-conditions

Vehicle stays in car rebalancing mode until the car rebalancing service provider or the vehicle owner decide that the vehicle cannot support the car rebalancing service anymore;

2.1.2.9 High Level Illustration

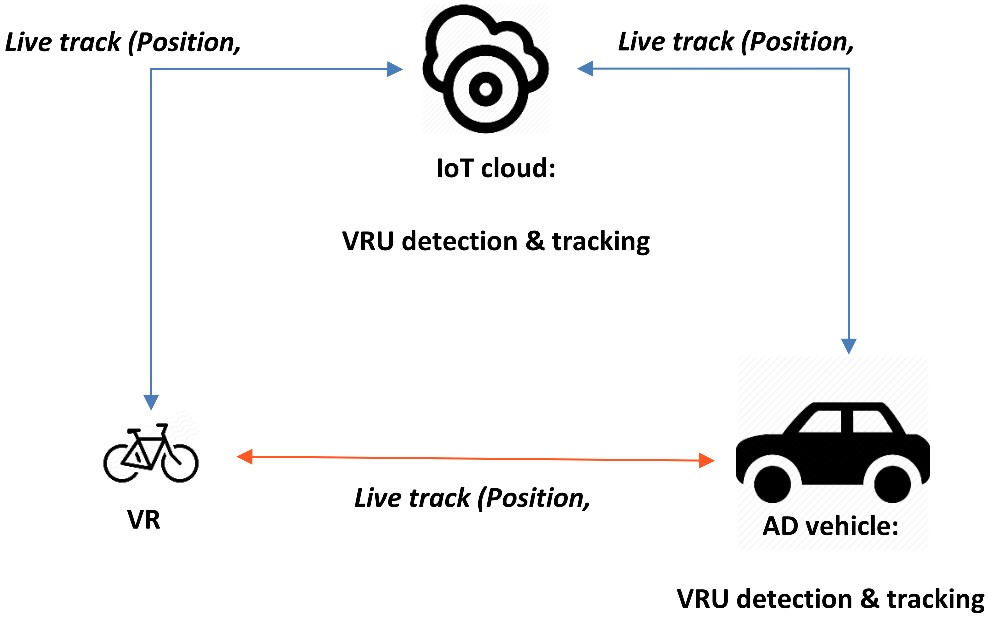

Figure 4: Example of IoT data streams and corresponding communication networks, based on EC H2020 AUTOPILOT project

2.1.2.10 Potential Requirements

Car rebalancing can be divided into two key components. One component focuses on the process of autonomous driving, and the other one is responsible to get the vehicle from its current location (typically parking terrain/ garage) to the place where it should collect the passenger, or where it should wait until the passenger arrives (for example drive during the night and park at a big parking terrain, where it will be picked up in the morning).

The distribution and collection of destination data is considered to not be time critical. The vehicle can receive the route information from the car rebalancing service, which includes the start (i.e., current vehicle's location) and end point, and possibly waypoints in between and even the whole planned / advised route to destination. In any of the above described car rebalancing scenarios, the total amount of transmitted data will not be large. Therefore, current 5G promises on performance capabilities, see Table 1, can support these requirements.

2.1.2.11 Radio Specific requirements

In car rebalancing, the rebalancing planning component, including the need to rebalance, and planning to destinations, is considered to not be time critical. The autonomous driving component is the one which is critical, and is therefore imposing performance requirements on the underlying communication network.

Autonomous driving is dependent on the timely information received from other participants in the traffic. As discussed in Section 2.1.1.11, it is important to note that in the EC H2020 AUTOPILOT project, it is considered that an autonomously driving vehicle will be able to autonomously operate and drive even if this vehicle is not communicating with external sensors and sources. In situations that the autonomously driving vehicle uses communication means and data generated by external sensors and sources, it can make better and more accurate decisions on how to act.

Current 5G promises on performance capabilities, see Table 1, are able to support the requirements imposed by both the car rebalancing use case components, which are the autonomous driving and the rebalancing planning.

2.1.3 Car Sharing

2.1.3.1 Description

A car sharing service is intended to be used as a tool to enable different customers to make use of a fleet of cars (either self-driving or not) shared amongst them. Car sharing can be interpreted as a service that finds the closest available car and assigns it to a single customer, or drive the closest available car to the interested customer. Car sharing can also be intended as ride sharing, where multiple customers that possibly have different origins and destinations share a part of the ride on a common car. Finally, car sharing services can also be considered as services that allow customers to specify pick-up and drop-off time-windows to increase flexibility and planning.

The service takes as input customers' requests, and based on those, outputs car sharing schedules (plans) including pick-up and drop-off locations and times for each passenger, itineraries, etc.

Unlike current car sharing solutions, the IoT-enabled cars will be able to compute how costly it is to pick up a given customer, in terms of time, changes in current schedule, etc., and they will send this information to the "assignment" engine. The latter will then compute the optimal car-customer matching. Moreover, cars will be able to share information relevant to each other's journeys. They will benefit from the openness of the IoT platform to receive relevant information from any device that is available in the network (traffic lights, drones, other car sensors, etc.) without the need for cars to know what each device is and/or how it operates.

Car sharing is part of the growing mobility-on-demand effort to re-think the transportation infrastructure of large urban areas. It is well-known that most urban vehicles are underutilized. A typical (urban driving) car would be confined to 20-30 km/h speeds and be parked 90% of the time.

2.1.3.2 Source

EC H2020 AUTOPILOT project

2.1.3.3 Roles and Actors

- Vehicle owner / driver / passenger in the vehicle: For the vehicle owner it enables him/her to own a fleet of vehicles that can be shared among a number of customers (i.e., drivers and/or passengers). For customers (i.e., drivers and/or passengers), it enable them to make use of a fleet of vehicles (either self-driving or not) shared amongst them. Moreover, it enables customers to specify pick-up and drop-off time-windows to increase flexibility and planning.

- IoT platform provider: It operates an IoT platform which is collecting data from vehicles, roads, other participants in traffic present, and from surrounding associated infrastructure (such as traffic lights, cameras). Necessary information/data is provided to any devices that are subscribed to the IoT platform.

- Car sharing service provider: Party that is providing Car Sharing Service (CSS) which runs in cloud. CSS collects requests from users (authenticated) and matches them with vehicles (users) and their destinations. For that, it will also make use of routing function, to lead user to the rendezvous point, where it will meet / be picked up by vehicle.
- Communication Network supplier/provider/operator: Supplies and/or provides and facilitates connectivity between vehicles, roads and associated infrastructure. This covers both wireless (for example LTE, LTE-V2X, ITS-G5 and WAVE) and fixed connections. The Network supports receiving requests for data transfers with required latency and with required packet losses. It is not expected or mandated that single network operator provides all of connectivity.
- IoT Devices manufacturer: Manufactures IoT devices that are embedded in vehicles, roads and associated infrastructure, parking garage /terrain, traffic lights, as well as in devices used by other participants in traffic (such as pedestrians, cyclists). Each IoT device collects and sends data to IoT platform, and can receive data from platform.

2.1.3.4 Pre-conditions

The car sharing service can obtain vehicle information (such as current location, destination) and their preference whether they are offering car sharing or not. Moreover, the car rebalancing service can obtain information on the available vehicles on each known collect points/parking, and as well the maximum capacity of the known collect points/parking.

2.1.3.5 Triggers

The car sharing service is activated by any driver of vehicle, thus indicating that it is willing to provide this service. This information is passed on to the car sharing service.

The end-user that wants to make use of car sharing service, must indicate to car sharing service that it is looking for a ride, and indicate its destination.

2.1.3.6 Normal Flow

1. Vehicle driver (owner) indicates that it is willing to provide the car sharing service.
2. Vehicle sends its current location, destination, number of available places and maybe other conditions (such as dogs accepted or not, luggage accepted or not) to the IoT platform.
3. Parking collect points/parking sends information to the IoT platform on the available vehicles on each known collect points/parking.
4. The IoT platform hosts the collected data from abovementioned sources, and upon request it will send it to AS where car sharing application (Car Sharing App) is running. Car sharing App is subscribed to the IoT data from all participants in traffic in urban area.
5. End-user looking for a ride sends request to car sharing service for car sharing with (optimal arrival or departure time and) destination.

6. Upon verification of request, CSS may request additional info from end-user (depending on conditions set by vehicle driver). If all criteria are met, CSS matches end-user to vehicle and send it location for pick-up to the IoT platform.
7. Processed information from App is sent back to IoT platform, and is made available to all Car sharing App subscribed participants in traffic.
8. Each participant in traffic is responsible for interpretation and action based on received App data.

2.1.3.7 Alternative Flow

None

2.1.3.8 Post-conditions

Vehicle stays in car sharing mode until the car sharing provider or vehicle owner decide that the vehicle cannot support the car sharing service anymore.

2.1.3.9 High Level Illustration

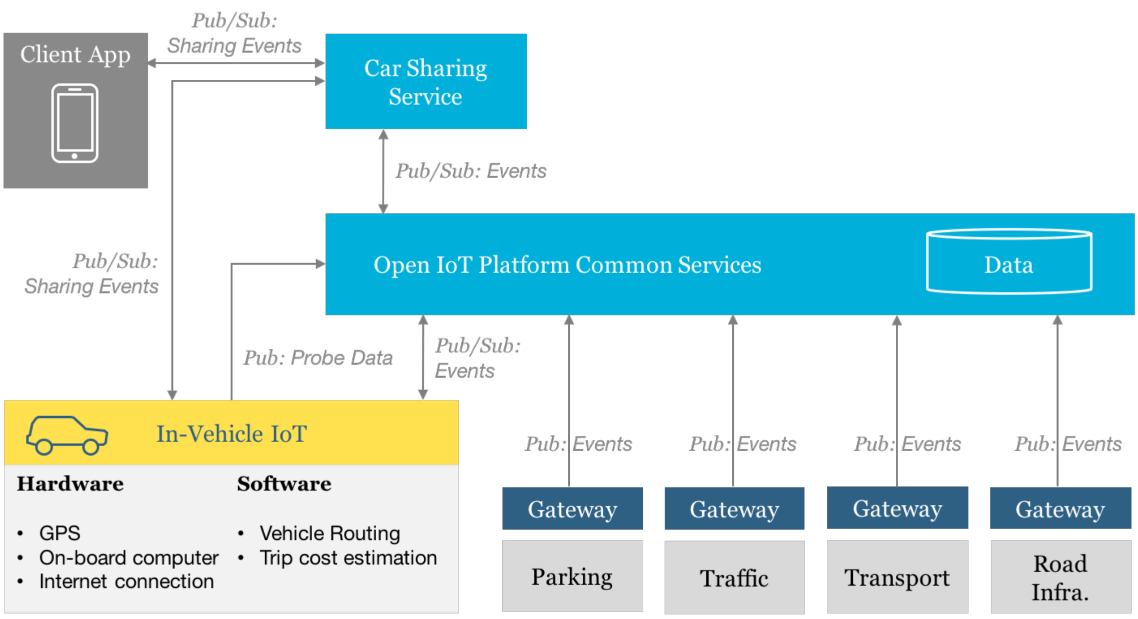

Figure 5: Example of IoT data streams and corresponding communication networks, based on EC H2020 AUTOPILOT project

2.1.3.10 Potential Requirements

Car sharing can be divided into two key components. One component focuses on the process of autonomous driving, and the other one is responsible to match the vehicles and their destinations to the potential customers (co-passengers).

The car sharing service is collecting requests for car sharing / co-riding from end-users (potential passengers) which includes their locations, arrival or departure times, and their destinations. Based on the pool of available vehicles, the car sharing service matches them to potential passengers. The vehicle which is matched to a particular passenger will receive new waypoints, including the place/location where the new passenger should be picked up. Note that this information on distributing the pick-up location is considered not to be time critical.

2.1.3.11 Radio Specific requirements

In car sharing, the car sharing planning component (passenger locations, and their destinations) is considered not to be time critical. The autonomous driving component is the one which is critical, and is therefore imposing performance requirements on the underlying communication network.

Autonomous driving is dependent on the timely information received from other participants in the traffic. As discussed in Section 2.1.1.11, it is important to note that in the EC H2020 AUTOPILOT project, it is considered that an autonomously driving vehicle will be able to autonomously operate and drive even if this vehicle is not communicating with external sensors and sources. In situations that the autonomously driving vehicle uses communication means and data generated by external sensors and sources, it can make better and more accurate decisions on how to act.

Current 5G promises on performance capabilities, see Table 1, are able to support the requirements imposed by both the car rebalancing use case components, which are the autonomous driving and the car sharing planning.

2.1.4 Highway Pilot

2.1.4.1 Description

It is expected that autonomous driving will radically reshape transport networks around the world by reducing congestion, fatalities and fuel consumption, and improving other driving conditions, in particular on highway environments. Moreover, it is expected that autonomous driving in highway environments will reduce costs in the line-haul trucking industry by (up to) 40%;

The Highway Pilot function automates highway driving, meaning that steering and speed adjustments are executed by the automated driving system. As the name of the function already implies, the Highway Pilot is intended for use on Highways only. The added-value of this function is its ability to enhance drivers' and automated vehicles' awareness on potential road hazards on route and to assist them to adapt their driving accordingly.

Road hazards may refer to several events and situations, such as:

- emergency braking vehicles / slow vehicles;
- stationary vehicles (breakdowns or accidents);
- fast approaching emergency vehicles;
- traffic jams and queues;
- road works / route modifications;
- nearby presence of bicycles or pedestrians;
- fallen objects (from vehicle, trees);
- road defects (potholes, bumps, gravel);
- weather related road changes (puddles, ice);

Receiving anticipated warning information about such events is useful on all types of road environments, including a highway context; where vehicles move at high-speed require shortened reaction time.

Furthermore, anticipated warning information also benefits all modes of driving:

- In Manual Driving mode, thanks to experience, drivers learn to handle hazardous situations. However, a sudden action from a driver (ex: trajectory change, quick deceleration) may become another hazard for others.
- In Assisted Driving mode, which is more and more used on Highway roads, drivers considerably relax their attention on the road, hence increasing their response time when a hazard occurs.

- In Automated Driving mode, passengers depend on the detection of the vehicle's own sensors. The hazard must enter the sensors perception range and be identified as such before the vehicle reacts. If the hazard is hidden around the corner, the reaction may be abrupt. For passengers' comfort and acceptance of AD functions, it is a priority that AD driving is as smooth as possible.

Finally, not all hazards will trigger pre-emptive actions from drivers and vehicles. For example, near missed potholes and slippery surfaces may go unnoticed and be noticed too late.

2.1.4.2 Source

[EC H2020 AUTOPILOT project]

2.1.4.3 Roles and Actors

- Vehicle owner / driver / passenger in the vehicle: Profits from the Highway Pilot service by decreasing the probability of vehicle damage/accidents in the highway environment and at the same time reducing the vehicle journey time when the road traffic jams on the highway are minimized or eliminated.
- IoT platform provider: It operates an IoT platform which is collecting data from vehicles, parking spots, parking entrances and exits, other participants in traffic present at the parking, and on the way to/from parking (such as pedestrians, cyclists), from surrounding roads and from surrounding associated infrastructure (such as traffic lights, cameras). Necessary information/data is provided to any devices that are subscribed to the IoT platform.
- Highway Pilot service provider: Party that is providing Highway Pilot service which runs on AS. Highway Pilot App connects to the IoT platform, and from there it collects relevant data needed to run an ADApp - for example LDM.
- Platooning manager provider: Party that is providing Highway Pilot Service which runs on AS. AVP App connects to the IoT platform, and from there it collects relevant data needed to run an ADApp - for example LDM.
- Communication Network supplier/provider/operator: Supplies and/or provides and facilitates connectivity between vehicles, roads and associated infrastructure. This covers both wireless (for example LTE, LTE-V2X, ITS-G5 and WAVE) and fixed connections. The Network supports receiving requests for data transfers with required latency and with required packet losses. It is not expected or mandated that single network operator provides all of connectivity.
- IoT Devices Manufacturer: Manufactures IoT devices that are embedded in vehicles, roads and associated infrastructure, parking garage /terrain, traffic lights, as well as in devices used by other participants in traffic (pedestrians, cyclists). Each IoT device collects and sends data to IoT platform, and can receive data from platform.

2.1.4.4 Pre-conditions

The vehicle supports autonomous driving - meaning that it is capable of autonomously driving, also transmitting and receiving data from other vehicles, road and other infrastructure, other participants in traffic (such as pedestrians, cyclists).

2.1.4.5 Triggers

Highway pilot is activated automatically, when vehicle is driving on the highway, which can be determined in different ways (such as the location on the map).

2.1.4.6 Normal Flow

1. Vehicle detects that it is on the highway, and starts collecting data on obstacles on the road and damage (such as potholes, cracks) in the road surface. This information is sent to the IoT platform.
2. IoT in vehicle platform: is connected to the IoT open platform and to other IoT devices, also manages the LDM which contains all vehicles in vicinity and their current state (such as speed, acceleration / deceleration, changing lanes) and other traffic information like traffic light status or VRUs position.
3. 3rd party service: collects information from the highway environment about the road network and topology and about any obstacles on the road and damage (such as potholes, cracks) in the road surface and sends it to the IoT platform.
4. The IoT platform hosts the collected data from abovementioned sources, and upon request it will send it to AS where Highway Pilot application (Highway Pilot App) is running. Highway Pilot App is subscribed to the IoT data from all participants in traffic in urban area.
5. Processed information from Highway Pilot App is sent back to IoT platform, and is made available to all the Highway Pilot App subscribed participants in traffic.
6. Each participant in traffic is responsible for interpretation and action based on received Highway Pilot App data.

2.1.4.7 Alternative Flow

None

2.1.4.8 Post-conditions

Vehicle stays in highway pilot mode until it leaves highway, which can be determined by e.g., vehicle’s location.

2.1.4.9 High Level Illustration

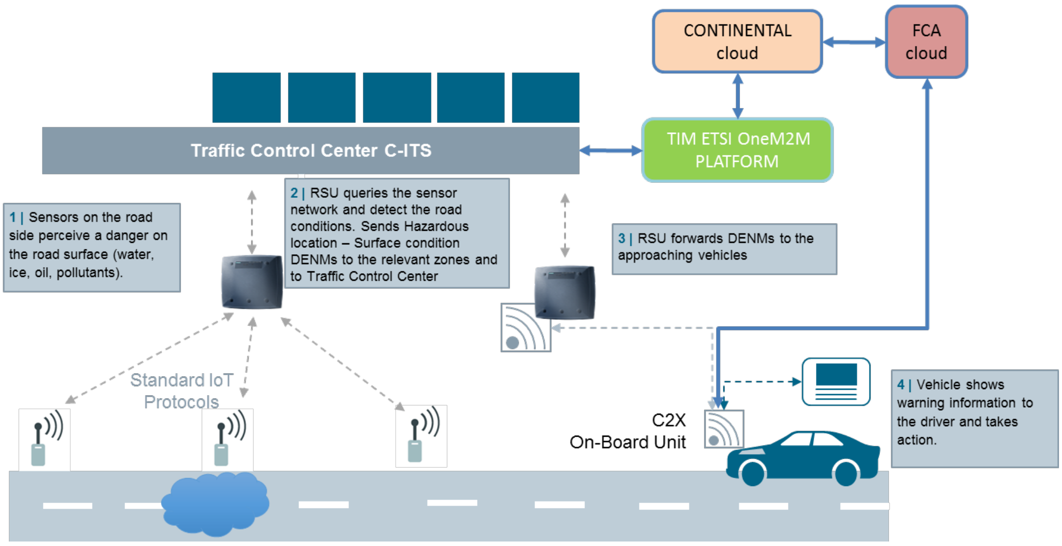

Figure 6: Example of IoT data streams and corresponding communication networks, based on [EC H2020 AUTOPILOT project]

2.1.4.10 Potential Requirements

The Highway pilot use case can be divided into two key components. One component focuses on the process of autonomous driving, and the other one is responsible to detect obstacles on the road and to inform the vehicle to adapt its driving behaviour accordingly.

Obstacles of (or in) road surface can be detected by different sensors in vehicle. That can be accomplished by detecting activation of ABS sensors in absence of braking which can indicate a piece of ice or mud (or something else slippery), or by other means such as LiDAR, RADAR.

The collected information can be sent to other vehicles, most likely via a central platform which will collect data on detected obstacles from vehicles, and which can share that information with other vehicles approaching that particular spot on the road, and which can then adjust their driving accordingly.

2.1.4.11 Radio Specific requirements

The Highway Pilot components: (1) detection of obstacles on the road and (2) sharing this information to vehicles to adapt their driving behaviour on the road accordingly, are considered not to be time critical. The autonomous driving component is the one which is critical, and is therefore imposing performance requirements on the underlying communication network.

Autonomous driving is dependent on the timely information received from other participants in the traffic. As discussed in Section 2.1.1.11, it is important to note that in the EC H2020

AUTOPILOT project, it is considered that an autonomously driving vehicle will be able to autonomously operate and drive even if this vehicle is not communicating with external sensors and sources. In situations that the autonomously driving vehicle uses communication means and data generated by external sensors and sources, it can make better and more accurate decisions on how to act.

Current 5G promises on performance capabilities, see Table 1, are able to support the requirements imposed by both the highway pilot use case components, which are (1) the autonomous driving and (2) the detection of obstacles on the road and sharing this information to vehicles to adapt their driving behaviour on the road accordingly.

2.1.5 Platooning

2.1.5.1 Description

Platooning, see Figure 7 and Figure 8, is a use case where a vehicle is automatically following another vehicle at a relatively close distance. Driving in a platoon requires vehicles to use inter-vehicle communications to anticipate timely on manoeuvres of other vehicles in the platoon.

Figure 7: Platooning vehicles on public road, lead vehicle has driver

Figure 8: Platooning trucks on public road, lead vehicle has driver

Several aims and motivations for vehicular platooning exist, such as: (1) improvement of traffic throughput and homogeneity, (2) enhancement of traffic safety due to small speed variations and relative low impact velocities in collisions, and (3) reduction of fuel consumption and emissions due to lowering the air drag. These objectives can to a certain extent already be achieved by non-automated driving systems (i.e. human driver monitors the environment and may execute e.g. the steering task), although a higher level of automation is considered to contribute in a positive way. Automated driving (system performs all aspects of the dynamic driving task) can offer additional benefits in terms of comfort (relieving the driver from the driving task) and efficiency (no driver required in vehicles).

The following vehicles have automated steering and distance control to the vehicle ahead, and the control is supported by advanced Vehicle to Vehicle (V2V) communication extended with additional IoT data. In addition to driving in a platoon, forming of the platoon is also a challenging task.

Note that for practical purposes we will consider a platoon as logical entity which is extended (elongated) virtual vehicle.

2.1.5.2 Source

[EC H2020 AUTOPILOT project]

2.1.5.3 Roles and Actors

- Vehicle owner / driver / passenger in the vehicle: Profits from the Platooning service by enhancing traffic safety for vehicle driver and passenger, due to small speed variations and relative low impact velocities in collisions, and as well reduction of fuel consumption and emissions due to lowering the air drag.
- IoT platform provider: It operates an IoT platform which is collecting data from vehicles, roads, other participants in traffic present, and from surrounding associated infrastructure (such as traffic lights, cameras). Necessary information/data is provided to any devices that are subscribed to the IoT platform.
- Platooning service provider: Party that is providing Platooning Service (PS) which runs in cloud. It does authentication of vehicles that want to make use of platooning, collects info on currently running platoons, and provides 'rendezvous' info needed for vehicle to meet platoon. Note that this service will (very likely) make use of route planning function, not covered here.
- Platooning manager provider: Party that is providing Platooning Service (PS) which runs on Multi-access Edge Computing (MEC) node. Note that it is possible to have this function also running on cloud.
- Platooning function provider: Platooning function runs in vehicles and is responsible for maintaining the position of the vehicle in the platoon (distance to other vehicles, follow trajectory of lead vehicle), as long as the vehicle is a member of the platoon.
- Communication Network supplier/provider/operator: Supplies and/or provides and facilitates connectivity between vehicles, roads and associated infrastructure. This covers both wireless (for example LTE, LTE-V2X, ITS-G5 and WAVE) and fixed connections. The Network supports receiving requests for data transfers with required latency and with required packet losses. It is not expected or mandated that a single network operator provides the whole end-to-end connectivity.
- IoT Devices manufacturer: Manufactures IoT devices that are embedded in vehicles, roads and associated infrastructure, parking garage /terrain, traffic lights, as well as in devices used by other participants in traffic (pedestrians, cyclists). Each IoT device collects and sends data to IoT platform, and can receive data from platform.

2.1.5.4 Pre-conditions

The vehicle supports autonomous driving as well as platooning - meaning that it is capable of autonomously driving, also transmitting and receiving data from other vehicles, road and other infrastructure, other participants in traffic (such as pedestrians, cyclists).

2.1.5.5 Triggers

Platooning is activated by vehicle driver. Driver can start this function either before starting a trip, by indicating where it needs to go, and its current location is taken as staring point, or it can do it during the (started) driving session.

The PS will match this user (and its vehicle) to one of existing (or yet forming) platoons. After calculating the route for this user, the platooning service will provide this data so vehicle will rendezvous with chosen platoon.

2.1.5.6 Normal Flow

Three phases in platooning are distinguished:

1. Finding platoon going in preferred direction: This is done by platooning service, which runs in cloud, and has overview or large swath of particular country, and view on all platoons (their origin, current location and state, and destination).
2. Joining or leaving the platoon – happens when vehicle comes into vicinity of chosen platoon.
3. Driving in the platoon.

2.1.5.6.1 Normal Flow 1: Finding platoon - Platooning service

1. User contacts the PS, authenticates itself and states its own destination and leave / arrival time.
2. PS searches all platoons that travel to the preferred destination, verify their leaving /arrival times, and matches user (and its vehicle) to one platoon that fulfils the user request.
3. PS collects current platoon's state via IoT platform and uses that info to plan a route for user's vehicle so it can meet / join the platoon.
4. PS informs user's vehicle on chosen route and rendezvous point.
5. Vehicle starts riding to the rendezvous point.

2.1.5.6.2 Normal Flow 2: Joining the platoon - Platooning manager

The condition is that the vehicle that wants to join a platoon is in vicinity of the platoon, but it has not yet joined the platoon.

1. Platoon manager keeps track of the platoon and the vehicle that wants to join.

2. When the distance between those two is small enough and it is safe to perform the manoeuvre of joining the platoon (enough space, no traffic lights in vicinity, no other

participants), it will instruct (1) the leading vehicle of the platoon, (2) trailing vehicle of the platoon and (3) the vehicle wishing to join that they can start process of joining.

3. The signalling during the joining process uses V2V communication.

2.1.5.6.3 Normal Flow 3: Driving - Platooning

1. Vehicle receives messages from other vehicles in the platoon and acts accordingly.

2.1.5.7 Alternative Flow

None

2.1.5.8 Post-conditions

Vehicle stays in the platooning mode until:

1. It arrives at destination, or comes close to it, when it leaves platoon and drives the rest of the way autonomously to the destination.
2. It can be triggered by user to leave a platoon – and continue autonomously
3. It receives information from the platooning service that it can / should leave the current platoon and join other platoon. An example is the multi-hop platooning, where a vehicle member of a platoon, say platoon 1, which follows a certain route, will need to leave at a calculated position and time the platoon 1 and join another platoon, say platoon 2, which will follow a different route to a different destination than platoon 1. During the short time that the vehicle needs to switch between the two platoons, the vehicle can drive autonomously.

2.1.5.9 High Level Illustration

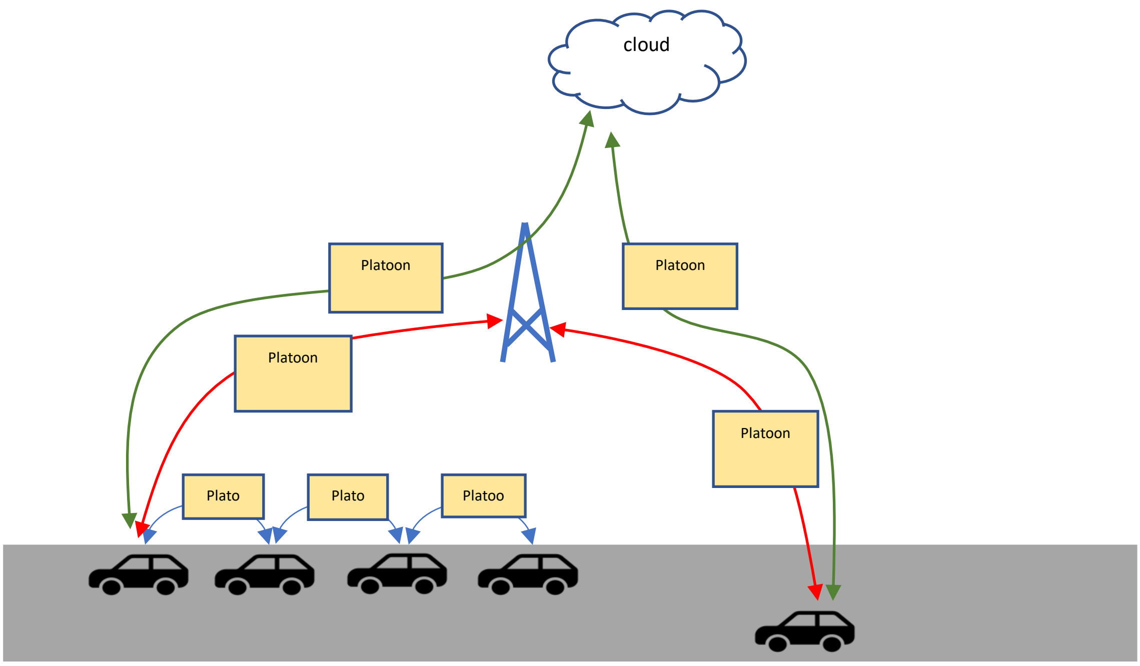

Figure 9: Data flows in platooning, based on [EC H2020 AUTOPILOT project]

2.1.5.10 Potential Requirements

Platooning is a time critical cooperative activity, and vehicles are continuously engaged with the creation and maintenance of the dynamic driving behaviour world models. The Platooning use case can be divided into two key components. One component focuses on the process of autonomous driving, and the other one is responsible to create and maintain the dynamic driving behaviour world model, which defines the autonomously driving behaviour of the vehicle.

Besides, the actual autonomous driving component there is also another time critical component to continuously update the vehicle's dynamic driving behaviour world models.

When driving in a platoon, the actual distance between vehicles driving in the platoon depends on a number of factors like vehicle's speed and state of roads. The higher the speed – the longer will be the distance between vehicles. The slower the processing of data in vehicle (longer time needed) – the more distance is needed between vehicles. The unit that is used to measure the distance between two vehicles is denoted as time headway and represents the time between vehicles in a transit system. The minimum time headway is the shortest such distance or time achievable by a system without a reduction in the speed of vehicles.

One of the motivations for driving in a platoon is to increase the vehicle road traffic flow by decreasing the minimum time headway. Driving in a platoon decreases as well (1) the total processing time of a vehicle traffic participant that needs to send information on its performed driving actions and (2) the time that other vehicle traffic participants will process that message and act accordingly.

2.1.5.11 Radio Specific requirements

Autonomous driving is dependent on the timely information received from other participants in the traffic. As discussed in Section 2.1.1.11, it is important to note that in the EC H2020 AUTOPILOT project, it is considered that an autonomously driving vehicle will be able to autonomously operate and drive even if this vehicle is not communicating with external sensors and sources. In situations that the autonomously driving vehicle uses communication means and data generated by external sensors and sources, it can make better and more accurate decisions on how to act.

Current 5G promises on performance capabilities, see Table 1, are able to support the requirements imposed by both the Platooning use case components, which are (1) the autonomous driving and (2) the creation and maintenance of the dynamic driving behaviour world model, which defines the autonomously driving behaviour of the vehicle.

2.1.6 Urban Driving

2.1.6.1 Description

Autonomous vehicles have the potential to remove human error and reduce instances of accidents caused by driver error, drunk driving or distracted drivers, in particular in Urban Driving environments.

Urban Driving, see Figure 10, assisted by IoT has the main objective to support Connected and Automated Driving (CAD) functions through the extension of the Electronic Horizon of an automated vehicle. Thus, the vehicle can process data from external sources which enrich those provided by its own sensors (such as Camera, LIDAR, Radar). The type of relevant information that automated vehicles may access as IoT elements, concerns:

- Traffic lights at intersections.
- Information from infrastructure cameras (such as pedestrian, bicycle, obstacle presence).
- Information from VRU.
- Information from other vehicles captured by their own sensors and shared as IoT elements.

Taking this type of information into account, the CAD systems will adapt their behaviour according to the additional environmental information, available through their connection to an onboard IoT platform.

Figure 10: Urban driving scenario, based on EC H2020 AUTOPILOT project

2.1.6.2 Source

EC H2020 AUTOPILOT project

2.1.6.3 Roles and Actors

- Vehicle owner / driver / passenger in the vehicle: Profits from the Urban Driving service by decreasing probability of vehicle damage/accidents in the urban environment and at the same time reducing the vehicle journey time when the road traffic jams on the urban roads are minimized or eliminated.

- IoT platform provider: It operates an IoT platform which is collecting data from urban traffic data sources such as: (1) Traffic lights at intersections, (2) Information from infrastructure cameras (such as pedestrian, bicycle, obstacle presence), (3) Information from VRUs, (4) Information from other vehicles captured by their own sensors and shared as IoT elements. Necessary information/data is provided to any devices that are subscribed to the IoT platform.
- Urban Driving service provider: Party that is providing Urban Driving Service which runs on AS. Urban Driving App connects to the IoT platform, and from there it collects relevant data needed to run an ADApp - for example LDM.
- Urban Driving manager provider: Party that is providing Urban Driving Service which runs on AS. Urban Driving App connects to the IoT platform, and from there it collects relevant data needed to run an ADApp - for example LDM.
- Communication Network supplier/provider/operator: Supplies and/or provides and facilitates connectivity between vehicles, roads and associated infrastructure. This covers both wireless (for example LTE, LTE-V2X, ITS-G5 and WAVE) and fixed connections. The Network supports receiving requests for data transfers with required latency and with required packet losses. It is not expected or mandated that single network operator provides all of connectivity.
- IoT Devices manufacturer: Manufacturer provides IoT devices are embedded in vehicles, roads and associated infrastructure, parking garage /terrain, traffic lights, as well as in devices used by other participants in traffic (such as pedestrians, cyclists). Each IoT device collects and sends data to IoT platform, and can receive data from platform.

2.1.6.4 Pre-conditions

The vehicle supports autonomous driving - meaning that it is capable of autonomously driving, also transmitting and receiving data from other vehicles, road and other infrastructure, other participants in traffic (such as pedestrians, cyclists).

2.1.6.5 Triggers

Urban Driving is activated automatically, when vehicle is driving on the urban environment, which can be determined in different ways (location on the map, for example).

2.1.6.6 Normal Flow

1. Traffic light: information about the traffic light status and time to change is sent to the IoT platform.
2. Road smart camera: information about pedestrian detection is sent to IoT platform.

3. Traffic sensors or TMC (Traffic Management Center): information about 3 possible events: traffic jam, accident and road work warning are sent to the IoT platform.
4. VRUs: information for pedestrian detection is sent to the IoT platform.
5. 3rd party service: gives information about the road network and topology.
6. IoT in vehicle platform: is connected to the IoT open platform and to other IoT devices, also manages the LDM which contains all vehicles in vicinity and their current state (speed, acceleration / deceleration, changing lanes etc.) and other traffic information like traffic light status or VRUs position.
7. The IoT platform hosts the collected data from abovementioned sources, and upon request it will send it to AS where Urban Driving application (Urban Driving App) is running. Urban Driving App is subscribed to the IoT data from all participants in traffic in urban area.
8. Processed information from Urban Driving App is sent back to IoT platform, and is made available to all Urban Driving App subscribed participants in traffic.
9. Each participant in traffic is responsible for interpretation and action based on received Urban Driving App data.

2.1.6.7 Alternative Flow

None

2.1.6.8 Post-conditions

Vehicle stays in urban driving mode until it leaves the urban road environment, which can be determined by e.g., the vehicle's location.

2.1.6.9 High Level Illustration

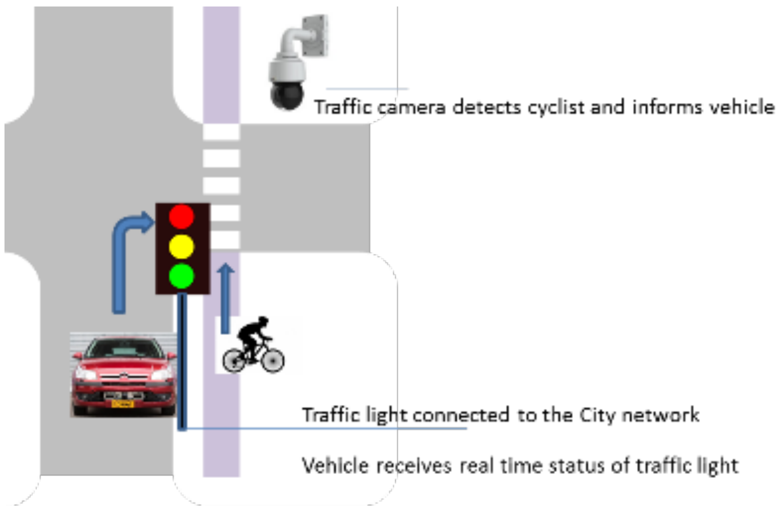

Figure 11: Example of IoT data streams and corresponding communication networks, based on [EC H2020 AUTOPILOT project]

2.1.6.10 Potential Requirements

The urban driving use case can be divided into two key components. One component focuses on the process of autonomous driving, and the other one is responsible to (1) collect data from external sources and (2) use this collected data by the vehicle's CAD system to adapt vehicle's driving behaviour according to the additional environmental information.

One of the major challenges in urban driving is the large number of participants in traffic. The vehicle speed is not really a challenge, which is limited (50 km/h, or 30 km/h in residential areas). Due to the higher density of vehicle traffic participants, the distances between them are in average shorter than other environments, and the corresponding time headways are smaller. For example, when vehicle is driving with 50 km/h, it covers almost 14 meters per second. If for example, data is being sent with frequency of 10Hz, the vehicles will send data every 100ms. Due to the higher density of vehicle traffic participants, each vehicle will receive data that is sent data by a large number of vehicles. This fact will (1) increase the throughput of data that each vehicle needs to process, (2) will require larger transmitting and receiving buffers and (3) will decrease the available time that each vehicle needs to activate actuators (brakes for example).

2.1.6.11 Radio Specific requirements

Autonomous driving is dependent on the timely information received from other participants in the traffic. As discussed in Section 2.1.1.11, it is important to note that in the EC H2020 AUTOPILOT project, it is considered that an autonomously driving vehicle will be able to autonomously operate and drive even if this vehicle is not communicating with external sensors and sources. In situations that the autonomously driving vehicle uses communication means and data generated by external sensors and sources, it can make better and more accurate decisions on how to act.

Current 5G promises on performance capabilities, see Table 1, are able to support the requirements imposed by the urban driving use case components, which are (1) the autonomous driving, to (2) collect data from external sources and (3) use this collected data by the vehicle's CAD system to adapt vehicle's driving behaviour according to the additional environmental information. However, it is important to note that the urban driving use case will require from vehicles to maintain larger transmitting and receiving buffers and as well requires a shorter processing time to activate actuators (brakes for example).

2.1.7 Vehicle Monitoring

2.1.7.1 Description

Data gathering from vehicles is currently done in commercial solutions using cellular networks, although the research direction for this type of communications focus on Cooperative Intelligent Transportation Systems (C-ITS) solutions including On-Board Units (OBU) with more complex networking solutions. For example, including hybrid schemes alternating IEEE 802.11p with cellular technologies, such as LTE, LTE-V2X. This is, however, a clear case where the IoT paradigm comes into play, given that the vehicle could be considered a moving sensor or, even more, a moving smart environment composed of a set of them. In this sense, IoT communication technologies in the segment of Low-Power Wide Area Networks (LP-WAN) could be considered for these vehicular scenarios.

LP-WAN technologies would allow the access to on-board sensor information over long ranges, at the same time battery consumption of devices installed in non-common vehicles, such as bikes or motorbikes, is maintained low. Technologies such as SigFox and LoRa can be complemented with those in line with 5G trend, such as Narrowband-IoT (NB-IoT) or Massive Machine-Type Communications (mMTC). NB-IoT is the first step of 3GPP specifications to cover the LP-WAN segment, while mMTC will be a fundamental building block of 5G in this particular area of cellular support for IoT.

Vehicle monitoring using IoT cellular technologies could be especially useful, for instance, in urban mobility scenarios, where cars, bikes, mopeds or even skates could be monitored to adapt traffic lights, recommend green tracks, avoid traffic jams, suggest secure riding areas, or speed-up the adoption of healthy transport habits.

2.1.7.2 Source

IoT projects that were accomplished by AIOTI members and are described in the below listed publications:

- S. Barrachina-Munoz, B. Bellalta, T. Adame, and A. Bel. Multi-hop communication in the uplink for LP-WANs. Computer Networks, 123:153 – 168, 2017.
- Ramon Sanchez-Iborra, Jesús Sánchez-Gómez, José Santa, Pedro J. Fernández, Antonio F. Skarmeta. Integrating LP-WAN Communications within the Vehicular Ecosystem. The 2017 International Symposium on Mobile Internet Security (Mobisec 2017). Jeju Island, Republic of Korea, 2017.
- Ramon Sanchez-Iborra, Jesús Sánchez-Gómez, José Santa, Pedro J. Fernández, Antonio F. Skarmeta. IPv6 Communications over LoRa for Future IoV Services. 4th IEEE World Forum on Internet of Things (WF-IoT 2018). Singapore, Singapore, 2018.

2.1.7.3 Roles and Actors

The following list of actors is identified in the vehicle monitoring use case when applying cellular IoT technologies:

- Vehicle: common cars, vans, trucks, bikes, motorbikes, mopeds, skates, and any other kind of vehicles, with especial implication of those involved in urban mobility scenarios.
- Telecomm operator: providing the IoT network access.
- Service provider: in charge of feeding their applications to provide services to final users.
- Final user: who uses services powered by monitoring data probably processed.

2.1.7.4 Pre-conditions

The next preconditions are identified:

- The vehicle should be equipped with a proper OBU that allows monitoring its status.
- The telecom operator should have deployed the needed network infrastructure to offer connectivity.
- The OBU is provided with sensors (e.g., Global Positioning System (GPS)) or with access to on-board sensors where to gather data (e.g. diagnosis port).

2.1.7.5 Triggers

No special triggers are identified, although, with the aim of save communication resources, monitoring of specific parameters could be only performed once significant changes are perceived or some time has elapsed, for instance.

2.1.7.6 Normal Flow

Data is generated or accessed in a regular basis by the OBU, which uses the cellular LP-WAN link to transmit it to a remote server through the operator's network. Usually the remote server will be a cloud service. After the data is processed, a service in the same node or a different one is fed with it to finally create a value-added service for users. This service could be accessed through an App or a web interface, for instance, from regular or mobile devices with Internet access.

2.1.7.7 Alternative Flow

None

2.1.7.8 Post-conditions

The final user is informed of specific events in a particular scenario, such as pollution areas, secure riding tracks, non-congested roads, or vehicle faults detected or predicted.

2.1.7.9 High Level Illustration

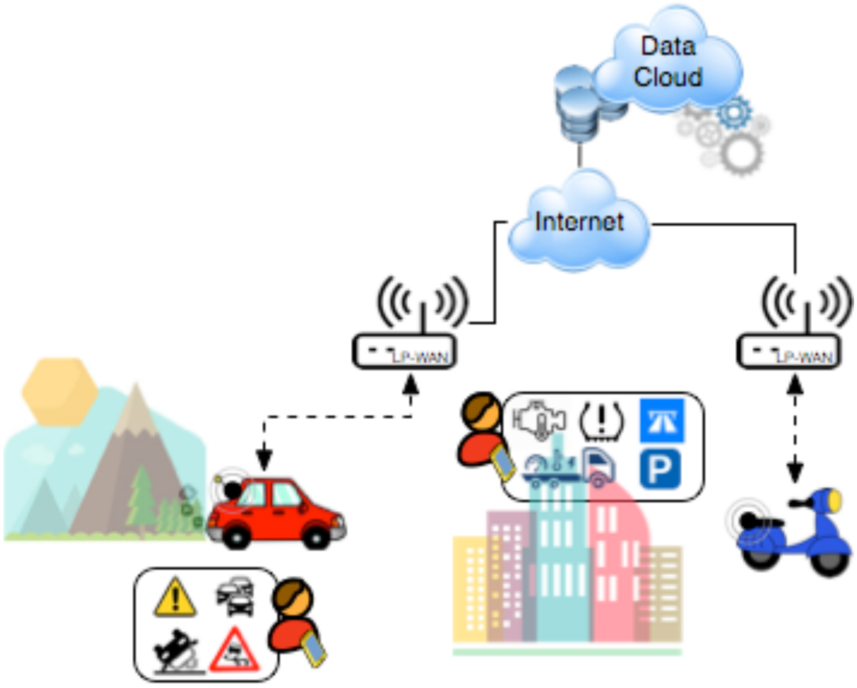

Figure 12: Vehicle Monitoring - High level illustration

2.1.7.10 Potential Requirements

The following non-functional requirements are identified:

- The service should accommodate to cover vehicles within a limited area, considering challenges scenarios such as the urban ones, and it should scale to many communication units under particular circumstances, such as festivals or rush hours.
- The 3GPP standard deployment in Europe, at least, should support the normal operation of the monitoring operation in a cross-border fashion.
- Privacy issues should be considered to avoid tracking risks, among others.

2.1.7.11 Radio Specific requirements

Table 2: Vehicle Monitoring radio specific requirements

Requirement	Explicit 5G Promises, see [1]	Vehicle Monitoring requirements
Real-time capability- Latency	5 ms (e2e)	1 s
Real-time capability- Jitter	-	Tolerant
Bandwidth	Peak data 10 Gbps	100 kbps
Time period of information loss during failures	-	none (seamless failover)
Availability / coverage	-	Ubiquitous
Range (distance between communication neighbours)	-	> 1 Km (long-range)
Reliability	99.999%	70%
Mobility	500km/h	200 Km/h
Outdoor terminal location accuracy	<1m	<10m
Multi-tenant support	yes	Yes
Non-standard operating conditions	energy reduction by 10	Possible powered device with >1 day lifetime Vibrations in a car
Harsh environment (weather)		Subject to in-vehicle temperature
Ease of use	-	Plug and Play device (just like a sensor)
Communication service approach		yes
SLA Tooling	-	Service Level Agreement (SLA) monitoring
Service deployment time	90min	days
Private 5G infrastructure	-	no
Scalability: Number of devices per km2	1.000.000	100
Globally harmonized definition of Service Qualities	-	-
Technology availability	-	> 15 years
Globally simplified certification of ICT components	-	Yes
Assured Guarantees	-	Relaxed

2.1.7.11.1 Radio Coverage

- Radio cell range
  - Long range (> 1 Km) under Line of Sight (LOS) and Non Line of Sight (NoLOS) conditions.
- Does the radio link crosses public spaces? Or is it constrained to indoor or customer premises?
  - The radio link crosses public spaces mainly outdoors, given the monitoring features for vehicles.
- Is Multicell required?
  - It is not required, but it is supposed that in urban settings multicell will be present to improve the network capacity.
- Is handover required? Seamless? Tolerable impact in delay and jitter?
  - There are not special handover requirements, given that the loss of some packets in a monitoring service could be supported. The same applies to delay and jitter.
- Mobility: maximum relative speed of UE/FP peers
  - Low to high mobility, considering potential vehicle types and mobility patterns. Maximum speeds of 200 Kmph should be supported or highway scenarios.
- Special coverage needs: i.e., maritime, aerial
  - No, only terrestrial.

2.1.7.11.2 Bandwidth requirements

- Peak data rate:
  - 100 Kbps.
- Average data rate
  - 10 Kbps.
- Is traffic packet mode or circuit mode?
  - Packet mode.

2.1.7.11.3 URLLC requirements

- Required Latency
  - Usually one-way communication with latency tolerance up to 1 second.
- Required Reliability
  - 70% (tolerant to losses).
- Maximum tolerable jitter
  - 1 second (no especial jitter requirements).

2.1.7.11.4 Radio regimens requirements

- Desired and acceptable radio regimens
  - When possible, it is preferred licence – public mobile, in order to improve interoperability support and wide coverage of the service.

2.1.7.11.5 Other requirements

- UE power consumption

    - Rechargeable or primary battery?
        - When possible, a rechargeable battery should be used for the system if the communication unit is mounted in a two-wheeled vehicle.
    - Acceptable battery life
        - At least enough to cover a trip (e.g. one day).
- Is terminal location required? location accuracy?
    - Yes. Accuracy bellow 10 meters would be highly beneficial for the kind of services to be fed by the monitoring system.

2.2 Smart City

2.2.1 Public Warning System in critical infrastructures

2.2.1.1 Description

Our main intention is to provide efficient, standard and secure communication of emergency to a broad name of stakeholders related to the critical infrastructures (e.g. vicinity/citizens, emergency bodies, governmental bodies, civil protection organizations and/or other related critical infrastructure -cascading effects-). To specifically build an effective emergency communication, secure communication protocols with the critical infrastructure (like 5G) are needed. Moreover, protocols with the emergency stakeholders and vicinity/citizens (e.g. Global System for Mobile communications (GSM), Universal Mobile Telecommunications System (UMTS), TCP/IP, 3GPP) should be performed. The proposed public warning system that is presented in this section considers the combination of Cell Broadcasting Systems and Web-Based services such as Open Geospatial Consortium (OGC) (Service Alerting System (SAS), Sensor Observation Service and Web, Web processing Service, etc.). This system broadcasts the emergencies to geographic areas using a combination of traditional (radio, phone) and innovative communications (RSS, Social Media, Extensible Markup Language (XML), JSON). Moreover, the possibility to include Reverse 112 (R112) is explored as another innovative emergency communication, which is currently not widely deployed in Europe.

2.2.1.2 Source

STOP-IT H2020 European project

2.2.1.3 Roles and Actors

- Citizens & Vicinity. People who lives (near) a critical infrastructure and needs to be protected or informed about potential major disaster incident risks that could affect their lives.

- Critical Infrastructure. Central element source of vulnerabilities that can become real risks (natural or cyber risks).
- Emergency Bodies. Stakeholders dedicated to minimizing the effects of the risks once them happens (such as hospitals, fireman's).
- Governmental bodies. Stakeholders required to organize the society and provide insights at higher level.
- Civil Protection Organization. Stakeholders dedicated to mobilizing and organize the citizens in emergency situations.

2.2.1.4 Pre-conditions

Main pre-condition is to live a potential risk in the critical infrastructure (such as water, energy, transport) that could create damage to other critical infrastructure or the society (such as critical infrastructure attacks, floorings, earthquakes).

2.2.1.5 Triggers

The triggers used in this use-case are: (1) the major disaster incident happens, or (2) the major disaster incident is detected by the critical infrastructure before occurring.

2.2.1.6 Normal Flow

Commonly, the steps are the follows:

1. Critical infrastructure systems (such as IoT systems, Supervisory Control and Data Acquisitions (SCADAs), informational systems, risk management systems) are continuing monitoring the critical infrastructure until a potential risk is detected or a major disaster incident occurs.
2. At this moment, the critical infrastructure communicates with other related critical infrastructures that could be affected by these risks (transport, energy, water, etc.).
3. In parallel, the critical infrastructure that is suffering from the incident, establishes the contact with emergency bodies (in case of required) and civil protection bodies.
4. Once the risks have been minimized or solved, the critical infrastructure informs the citizens, vicinity and governmental bodies about the incidents that happened.

2.2.1.7 Alternative Flow

None

2.2.1.8 Post-conditions

Once the risks have been minimized or solved, the critical infrastructure informs the citizens, vicinity and the governmental bodies about the disaster incidents that happened. Moreover, informative actions are established towards the vicinity and governmental bodies about the critical infrastructure situation.

2.2.1.9 High Level Illustration

2.2.1.10 Potential Requirements

Functional Requirements

- Real-time communication with the stakeholders in case of emergency.
- Reliable communication between the stakeholders.
- Scalable communication between systems to interconnects different critical infrastructures.
- Standard-based communication between critical infrastructure to align emergency information exchange with new and legacy systems.

Non-Functional Requirements

- Secure communication between the emergency bodies due to the information nature.
- Interoperability between communication protocols (linked also with the possibility to use standard communication protocols between the systems).

2.2.1.11 Radio Specific requirements

2.2.1.11.1 Radio Coverage

Long transmissions are required due to transmit the emergency messages to the neighbourhood and community (around 10-20km).

2.2.1.11.2 Bandwidth requirements

- Peak data rate
- Average data rate
- Is traffic packet mode or circuit mode? If circuit mode, is isochronicity required?
    - The system needs to be prepared for working in public areas/spaces. Considering the transmission, WAN or GSM are needed with peak data rates of less than 70kbps.

2.2.1.11.3 URLLC requirements

- Required Reliability
    - 99,99999%

2.2.1.11.4 Radio regimens requirements

- Desired and acceptable radio regimens
    - Expected to use emergency radio bands

2.2.2 Unmanned Aerial Vehicles (UAV) as Multi-access Edge Computing (MEC) Nodes for Emergency Operations Support

2.2.2.1 Description

5G and Internet of Things will need to coexist and interoperate with each other. However, the adopted communication technologies and the actual requirements of the end-devices in both paradigms will be notably different. While 5G devices will make an intensive use of the network, in terms of throughput and volume of exchanged data, IoT end-nodes will require low bandwidth but high reliability and controlled energy-consumption for their communication tasks. Therefore, it is clear that gateways or access points with different Radio Access Technologies providing connectivity to different-nature end-nodes will be demanded shortly. Besides, following the MEC or fog paradigms, approaching processing or storage capabilities to the end-users will increase the performance of the system in terms of reduced latency and improved network efficiency. Up-to-date, these elements, i.e., communication gateways and processing nodes, have been located in fixed position hence, presenting a notable lack of flexibility for properly developing certain services. However, recent advancements in the design and use of Unmanned Aerial Vehicles (UAV) have turned these devices to a potential alternative for hosting communication, processing, and storage elements with the aim of offering next-generation services in situations where there is not a pre-existent communications infrastructure.

These features enable a plethora of novel services related with many actuation fields such as smart agriculture and farming, natural disaster monitoring, search and rescue, high-scale monitoring, etc. Concretely, the use case presented here focuses on using UAVs in emergency situations as support nodes for the rescue service, e.g., fire brigade, military units, etc. In the envisioned application, the UAVs are equipped with different communication and sensing technologies in order to provide novel services to the fire brigade that will help operational managers to make smart decisions by having a more complete information in real-time about the state of the managed event, e.g. fire extinction, rescue operation, etc. Thereby, a low-weight mini-computer is placed onboard the drone for providing multi-access communications to the fire brigade and enabling real-time aerial visualization of the scenario as well. Other sensors such as thermal or infrared are also considered for enriching the information provided to the management team.

2.2.2.2 Source

Based on IoT projects that were accomplished by AIOTI members; some of these IoT projects are described in the below listed publications:

- D. Carrillo and J. Seki, “Rural area deployment of internet of things connectivity: LTE and LoRaWAN case study,” Proc. 2017 IEEE 24th Int. Congr. Electron. Electr. Eng. Comput. INTERCON 2017, 2017.

- N. H. Motlagh, M. Bagaa, and T. Taleb, "UAV-Based IoT Platform: A Crowd Surveillance Use Case," IEEE Commun. Mag., vol. 55, no. 2, pp. 128–134, 2017.
- S. Hayat, E. Yanmaz, and R. Muzaffar, "Survey on unmanned aerial vehicle networks for civil applications: a communications viewpoint," IEEE Commun. Surv. Tutorials, vol. PP, no. 99, pp. 1–1, 2016.
- E. Yanmaz, S. Yahyanejad, B. Rinner, H. Hellwagner, and C. Bettstetter, "Drone networks: Communications, coordination, and sensing," Ad Hoc Networks, vol. 68, pp. 1–15, 2018.
- Jawhar, N. Mohamed, J. Al-Jaroodi, D. P. Agrawal, and S. Zhang, "Communication and networking of UAV-based systems: Classification and associated architectures," J. Netw. Comput. Appl., vol. 84, no. 31, pp. 93–108, 2017.

2.2.2.3 Roles and Actors

As aforementioned, the users for the proposed use case, are rescue services that will increase the accuracy and efficiency of their operations. The safety of these teams will be enhanced as well due to the constant monitoring of both, the conflictive scenario and the own rescue individuals. In general, all the public forces will take advantage of this architecture in events where aerial support provides clear advantages for managing the situation.

From the network operator perspective, 5G communications are envisioned to provide UAVs with high-speed and low-latency connectivity. In case of lack of 4G-LTE or 5G coverage, other broadband alternatives can be considered such as WiFi (IEEE 802.11) or Worldwide Interoperability for Microwave Access (WiMAX), i.e., IEEE 802.16. It is also proposed the use of Low Power Wide Area Network (LP-WAN) for low-bandwidth and very-long distance communications. In the case of these alternatives, a private third-party may be in charge of deploying and operating the temporary network hence making transparent its use for the end-users.

Considering the sensing and monitoring equipment on-board the UAV, multiple alternatives depending the situation can be adopted. As IoT controller, mini-computers with very low weight such as Raspberry Pi series or similar devices are a feasible alternative. Multiple sensors or cameras can be integrated within the system so IoT-device manufacturers are definitely involved in this process for providing equipment able to meet the challenging demands of the considered scenarios.

2.2.2.4 Pre-conditions

In order to provide UAVs with stable and reliable 5G communications, it is necessary to have an extensive cellular deployment covering large areas with 5G connectivity. In other case, temporary networks will be deployed. Note that the presented use-case should assume no pre-existent conditions for its successful development.

2.2.2.5 Triggers

The first trigger is the utility of the proposed use case. Public forces may be highly interested in the presented use case for managing disaster or critical situations:

- Rescue missions.
- Fire extinction.
- Individuals and fleet tracking.
- Accident-situation management.

The presented use case increases both the efficacy of the operations and the safety of the field team, so the utility and interest of potential users seem clear.

The technology needed for developing the current use case is already ready, with the exception of the upcoming 5G wide deployment. However, this is an important element for triggering this use case as it will provide very high-bandwidth and low-latency connectivity that will enable real-time services to the system managers.

2.2.2.6 Normal Flow

It is envisioned that the UAV will provide real-time video to the management team, as well as other information gathered by the on-board sensors (thermal, infrared, pollution, etc.). With this multiple purpose platform, different services will be provided to the emergency service:

- Real-time video-surveillance of the situation.
- Tracking of the team in the field.
- High-accuracy conditions monitoring, such as:
    - Pollution levels.
    - Gasses composition.
    - Temperature.
- Fleet tracking and organization

This information need to be forwarded to the ground control station, where the operative managers make use of it. In order to establish a reliable and sufficient link (in terms of bandwidth and latency) some communication technology can be considered. Therefore, depending on the state of the pre-existent infrastructure, e.g., cellular communications, the UAV would be equipped with different communication alternatives. For broadband communications, in case of having accessible the cellular network, 4G-LTE and future 5G services are the perfect options due to the high bandwidth provided, and the long-range reached. However, in case of disaster events, where all the communication infrastructure is down, other options such as WiFi (IEEE 802.11) or WiMAX (IEEE 802.16) are good options for establishing UAV-to-UAV (U2U) or UAV-to-Ground (U2G) links. These links are fundamental for providing the operational team with the information retrieved by the onboard monitoring and sensing devices. In case of not having direct connectivity with the ground base station or the pre-existent infrastructure, U2U communications might be adopted for reaching these gateways.

Besides, LP-WAN communications are also considered in this use case for specific services. Due to the limited data-rate and bandwidth of these technologies, they are not intended for transmitted high-volumes of data but for specific tasks. One interesting application is monitoring the position of field brigades and their individual components. In case of dense smoke of low-visibility area, e.g. forest or jungle scenarios, camera tracking is not enough for succeeding in this task. Thus, by using a GPS device integrated in the user-terminal, it could be able of periodically sending the current coordinate to the UAV by means of this long-range and highly reliable link. In addition, alert messages associated with specific events, e.g., down man, might be enabled as well.

2.2.2.7 Alternative Flow

One of the most appreciated features of multi-access systems is their capability of switching to the most proper communication technology in case of the failure of one of them. Therefore, in a disaster situation in which the pre-existent infrastructure (4G-LTE or 5G) is unstable, the UAV can provide other alternatives for enabling broadband communications, e.g., WiFi or WiMAX)

2.2.2.8 Post-conditions

It is expected that this use case will improve both the efficiency of the operations and the safety of the field brigades.

2.2.2.9 High Level Illustration

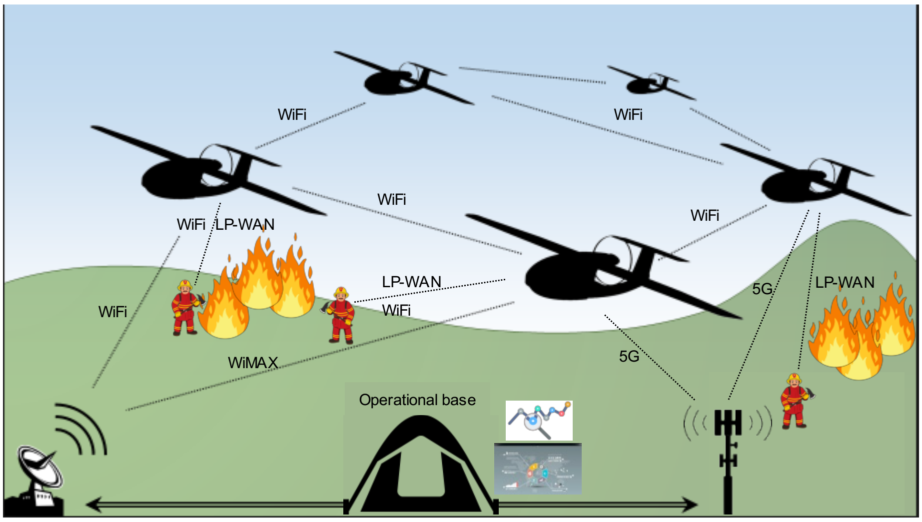

Figure 13: UAV as MEC nodes for emergency support operations - High level illustration

2.2.2.10 Potential Requirements

The main requirements of the proposed use case are twofold:

- Highly effective communications. As aforementioned, depending on application scenario the U2U and U2I communications will be enabled by different communication alternatives. However, in all cases, it is demanded that these technologies provide i) stable, ii) high-bandwidth, and iii) low-latency connectivity.
- Energy issues. One of the main limitations of current UAVs is their batteries lifetime. For that reason, it should be considered to use low weight devices for reducing the payload on-board the UAV and also it would be highly desirable making use of low energy-consumption equipment regarding communication and processing tasks.

2.2.2.11 Radio Specific requirements

2.2.2.11.1 Radio Coverage

- Radio cell range
    - For LP-WAN based transmissions, very long transmission ranges are required (10 km LOS and 4 km NoLOS). Regarding other communication technologies such as cellular or WiMAX, transmission distances of over 1 km are required.
  - Does the radio link crosses public spaces? Or is it constrained to indoor or customer premises?
    - The proposed system is devoted to work in public spaces
- Is Multicell required?
    - No, it is not required
- Is handover required? Seamless? Tolerable impact in delay and jitter?
    - No handover is required in this application
- Mobility: maximum relative speed of UE/FP peers
    - The initial proposal just considers end-terminal carried by people, but it could be extended to rescue vehicles as well.
- Special coverage needs: i.e., maritime, aerial
    - The proposed system is based on aerial communications.

2.2.2.11.2 Bandwidth requirements

- Peak data rate
- Average data rate
- Is traffic packet mode or circuit mode?
- If circuit mode, is isochronicity required?

- The system works in circuit switched mode and the bandwidth requirements differ depending on the considered transmission technology and the provided service. For example, LP-WAN technologies need very low data-rates of about 1 kbps (peak). For live video-transmissions, peak data rates of less than 10 Mbps might be enough for properly providing this service.

2.2.2.11.3 URLLC requirements

- Required Latency
    - (specify if it is one way or roundtrip)
- Required Reliability
    - (i.e., 99,99999%)
- Maximum tolerable jitter
    - The latency requirement for live streaming services should be lower tan 10ms. Other less demanding transmissions may have more relaxed latency requirements. Similar values may be considered for the jitter.
    - Due to the adverse transmission conditions of the proposed system, it is difficult to establish a precise value for the required reliability.

2.2.2.11.4 Radio regimens requirements

- Desired and acceptable radio regimens (describe the desired and acceptable radio regimens: I.e.: licensed - public mobile, licensed – specific license, license-exempt)
    - It is envisioned the use of license-free bands.

2.2.2.11.5 Other requirements

- The UE equipment will use batteries for powering. At least, it is needed a battery lifetime of 1 day.
- The terminal location is needed with a high accuracy in order to enable efficient operation-management activities.

2.2.3 UAS (Unmanned Aerial System) operations in U-Space

2.2.3.1 Description

- Drones have emerged as one of the fastest growing markets for a unique ecosystem of electronics. The global commercial drone market size was estimated to be USD 552 million in 2014 and is expected to grow at a Compound Annual Growth Rate (CAGR) of 16.9% till 2022.
- Safety concerns are one of the main obstacles hindering the development of many high potential drone applications. For example, drone provided logistics are still not allowed in the US. Safety and the lack of a mature airspace management system are the primary reasons.
- As UAS are developed like IoT devices - in contrast to vehicles and aircrafts both mandated to follow many safety standards and certifications resulting in costly and weighty solutions - alternatives including redundancies possibly from other segments like IoT security and Automotive need to be defined and implemented.
- A real-time airspace management system needs a standardized communication system, so all drones can communicate with each other, their surroundings and the airspace controller.
- The main goal of Device to everything (D2X) communication is to avoid accidents. Drones are required to broadcast their UAV-ID, position, speed, heading, surrounding and other information. By establishing wireless connections between drones/infrastructure and enabling information sharing among them collision risks can be identified and avoided.
- The establishment of a communication standard for drones makes it possible to implement such a real-time airspace management system and collision avoidance system, which will further increase the possibilities and market growth for drone applications.

Example use case:

- Preparation of drone mission: The drone operator plans the mission with the help of U-Space services such as weather forecast, traffic density reports, flight planning assistance and anti-collision analytics services.
- Submission of a flight request and receipt of an acknowledgement: A flight request is submitted to the authorities which grant permission or suggest mission adjustments. While airborne the drone receives information on the local airspace conditions and broadcasts its own unique ID to allow for tracking.

- Execution of the flight: If the drone is equipped with a detect-and-avoid system it can safely avoid unforeseen obstacles in its flight path. Geo-fencing capability allows for flexible airspace restrictions (e.g. after accidents creating temporary non-flying zones) which prompt all drones to avoid the restricted zones based on shared information.

- Mission completion: After the drone arrives at its destination/completes its mission it is ready for its next mission.

2.2.3.2 Source

- City ATM, Braunschweig: Demonstration of a UAV traffic management in urban airspace, see (visited in May 2018): http://www.dlr.de/fl/en/desktopdefault.aspx/tabid-1149/1737_read-50670/
- UAV hook on device : Testing a UAV position reporting system using 4/5G hook on devices, see (visited in May 2018): https://www.dfs.de/dfs_homepage/en/Press/Press%20releases/2017/09.10.2017.-%20Drones%20saving%20lives/

2.2.3.3 Roles and Actors

- Drone operating businesses: The actors who conduct drone operations in U-Space.
- Authorities / Airspace controlling entity: National and supranational authorities who set the rules for the airspace, grant permission for drone operations and who monitor U-Space.
- Drone manufacturers: Build the drones for different applications corresponding to customer demand and the technical requirements of the regulated airspace (e.g. outfitted with e-identification, geo-fencing and communication capabilities).
- Component suppliers: For UAS as well as for the U-Space infrastructure (communication network supplier).

2.2.3.4 Pre-conditions

- The drone operations rely on an existing Unmanned Traffic Management system (UTM).

2.2.3.5 Triggers

- Business decides to undertake a UAS operation.
- Authorities need to decide, if the conditions of the mission are sufficient for a safe UAV operation based on a risk and impact assessment.

2.2.3.6 Normal Flow

- The drone operator gathers all the necessary information (including geo-fencing data, meteorological data and airspace traffic data) to plan the mission and flight path.
- The mission is submitted to the relevant entities for approval. If necessary, changes to the flight path/flight time are made.
- If approved, the mission is executed accordingly. While airborne, the drone communicates with its surroundings to avoid obstacles (using detect-and-avoid) or restricted areas (via geo-fencing).

2.2.3.7 Alternative Flow

- Redundant and supporting communication channels should be used in case one communication fails. Currently 4G-LTE/5G and 802.11p communication are being tested.

2.2.3.8 Post-conditions

- The drone has completed its mission and is ready for a new assignment.

2.2.3.9 High Level Illustration

The blue and the green lines in Figure 14 represent the Device to everything (D2X) communication that could be based on 5G.

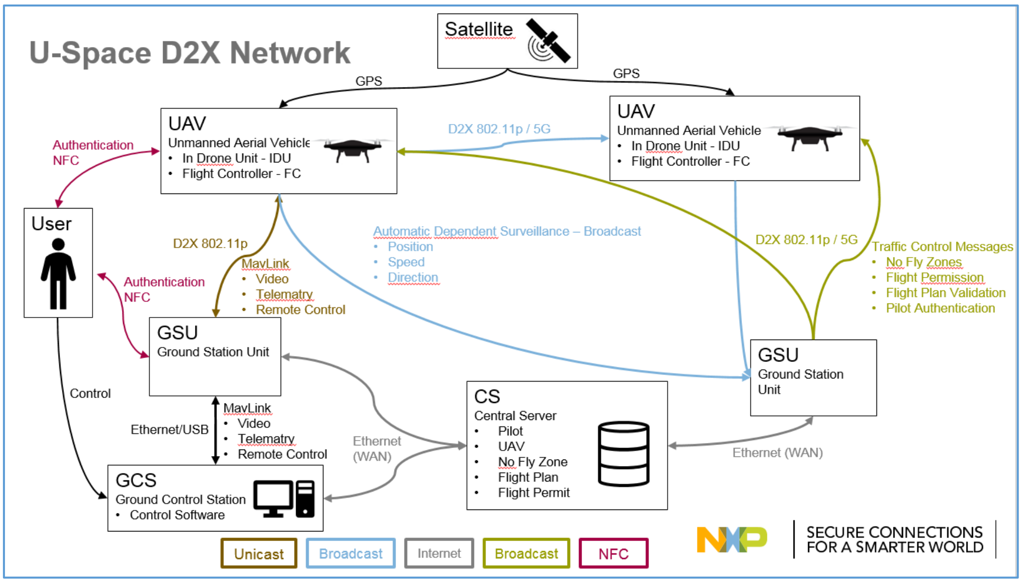

Figure 14: UAS operation in U-Space - High level illustration

2.2.3.10 Potential Requirements

UAS operations in U-Space require reliable, secure and trusted communication. UAS operations always carry a certain risk for accidents and therefore must be secure from outside interference. The system also has to be highly scalable to support many simultaneous operations in the same U-Space.

2.2.3.11 Radio Specific requirements

2.2.3.11.1 Radio Coverage

- UAS operations in U-Space would typically take place as NoLOS. UAV would therefore rely on their technical features to safely and properly execute their missions.
- Operations would take place outside in a public environment. The maximum range would only be limited by battery/fuel capacity and radio cell coverage. A ubiquitous multicell arrangement that covers wide areas of a country, including cities and the countryside, would therefore be essential to enable UAS operations. The handover between cells would need to be seamless to guarantee safe flight operations. While UAVs would be equipped

with detect and avoid systems, a gap or delay in the 5G connection could lead to an increased chance of accidents.

- Additional special coverage challenges arise due to the speed and operating altitude of UAVs of up to several hundred feet.
- Typical ranges would be expected to be several kilometres. There have already been successful long-range NoLOS and Beyond Vision LOS (BVLOS) missions, including one in France where a UAV travelled 50km using a 3G network to guide the UAV.

2.2.3.11.2 Bandwidth requirements

For the exchange of command and control information an up- and downlink data rate of 100 kbps should suffice. Operations that include video-transmission however would necessitate much higher bandwidths of several Mbps.

2.2.3.11.3 URLLC requirements

Safe operations in U-Space require a roundtrip latency as low as possible and a reliability as high as possible. UAVs in U-Space rely on their 5G network connection to transmit their own positional data to others and to receive positional data from other UAVs and about geo-fenced areas to avoid accidents.

2.2.3.11.4 Radio regimens requirements

To reduce possible interferences and to guarantee a low latency a licensed spectrum for UAS operations would be desirable.

2.2.3.11.5 Other requirements

- Power consumption should be as low as possible. Possible UAS operations could last several hours in various environmental and weather conditions. Battery drain due to 5G usage should not be a limiting factor to UAS operations.
- UAVs use GPS to detect their location. Terminal location via 5G is therefore not required, but could be useful to facilitate failsafe redundancy provided that the accuracy is high enough.

2.3 Smart Energy

2.3.1 Future Energy Grids

2.3.1.1 Description

Technological advances - accompanied in some jurisdictions by market liberalisation – along with the emergence of new energy sources often provided by prosumers at the edge of the network are transforming the energy network from a closed, monolithic and highly predictable infrastructure to an open, multi-owned, decentralized ecosystem. This poses significant challenges, both in functional (i.e. stability, resiliency and highly availability) and in non-functional (i.e. sustainability, security, privacy and Capital Expenditure / Operational Expenditure (CAPEX/OPEX)) aspects. Internet of Things and 5G technologies will deliver the technical capability to support the vision of a Smart Energy Grid. The potential prize is significant: to meet rising demand, increase the reliability and quality of power supplies, improve energy efficiency, and integrate highly distributed and low-carbon energy sources into power networks.

In particular, the last mile of smart energy grids will extensively use IoT and 5G technology: while smart energy grids observability and monitoring is already in place in the high and (mostly) in the medium voltage branches of the energy networks, the Low Voltage/Low Pressure branches are much less technologically mature. Currently, no consideration is typically given to real time energy consumption or energy production feedback from prosumers, which would allow finer-grained prediction of demand and improved load balancing of energy networks. Prosumers are considered to be homes/buildings that are able to produce and consume energy. Hence the smart energy "last mile" network represents an ideal application domain for extensive IoT and 5G deployment, where different applications with different ICT requirements have to be flexibly managed:

- Smart Grid applications, such as supervisory monitoring (cyber-monitoring and physical/aerial surveillance), fault localization, isolation/self-healing and energy re-routing;
- Advanced metering applications enabling the massive and lock-in free integration of end-user infrastructure to the grid;
- A combination of the above in areas such as smart EV charging where dispatchable demand response can be used to optimise the use of resources and minimise the possibility of power being unavailable when required.

2.3.1.2 Source

H2020 5G-PPP project NRG5

2.3.1.3 Roles and Actors

- Industrial and residential end users (consumers and prosumers), Energy suppliers, 5G operators, suppliers of Advanced Metering and related hardware.

2.3.1.4 Pre-conditions

- Extensive deployment of standards-based next generation smart meters; power infrastructure necessary to support an energy grid with multiple heterogeneous energy sources; 5G network.

2.3.1.5 Triggers

The supervisory monitoring (cyber-monitoring and physical/aerial surveillance), fault localization, isolation/self-healing and energy re-routing processes will be ongoing continuous processes, triggered only by the continuous requirement for actors to generate and consume energy.

2.3.1.6 Normal Flow

Next generation smart meters measure data at the network edge. Digital twins receive and store this data and answer queries in from applications or aggregation platforms that require the data. Analytics and simulation models are then used to generate a wide variety of key grid measurement predictions such as grid status, weather conditions, near real-time predicted future supply and production, and so on. The data is used by the applications to provide insight to energy users, suppliers and grid operators to help them optimize grid performance.

2.3.1.7 Alternative Flow

2.3.1.8 Post-conditions

The provision of an_open, multi-owned, decentralized energy ecosystem, retaining crucial features from the existing more monolithic approach, both in functional (i.e. stability, resiliency and highly availability) and in non-functional (i.e. sustainability, security, privacy and CAPEX/OPEX) aspects.

2.3.1.9 High Level Illustration

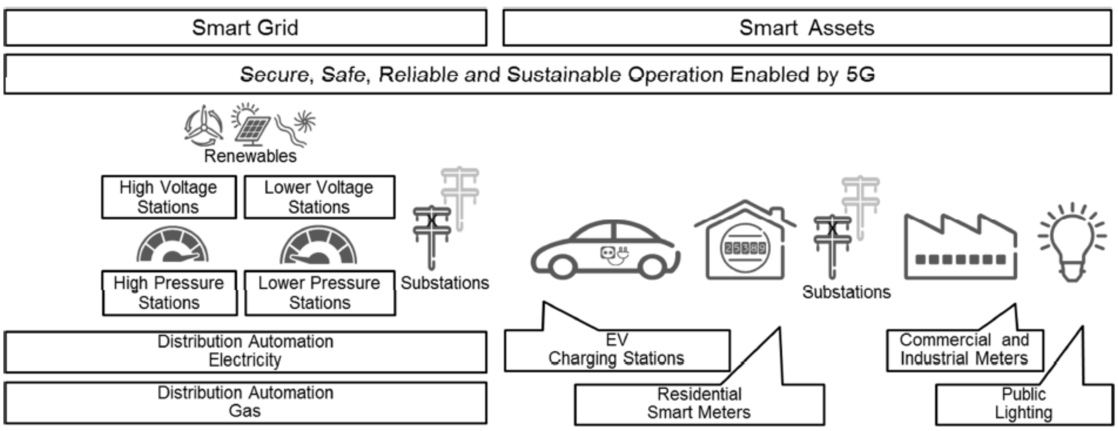

Figure 15: The energy uses cases highlighting the smart assets use cases and the energy, distribution use case from smart grids, copied from [6]

2.3.1.10 Potential Requirements

The frequency of data transmission, the massive number of devices involved and the low latency required make 5G an essential part of any Smart Grid solution. Thus the emergence of the Smart Grid will require availability of 3 of the principal features of 5G:

- Enhanced Mobile Broadband (eMBB),
- Ultra-reliable and Low-latency Communications (uRLLC)
- Massive Machine Type Communications (mMTC)

We exemplify the requirement for these network characteristics by reference to use cases from the NRG-5 European collaborative project[1]:

1. eMBB: in one use case, the project will use semi-autonomous swarms of drones to survey energy network infrastructure for the purposes of security and predictive maintenance from different views/cameras. The UAVs/Drones swarms need to run complex, bandwidth demanding, computationally heavy and time critical applications.
2. uRLLC: NRG-5 will implement the "plug & play vision" in metering resources by realizing a novel and scalable edge computing solution. Advanced Metering Infrastructure will support a 'transactive' energy grid in a highly decentralised and distributed environment with multiple local energy exchanges and prosumers. Accurate data reporting is key in such an environment and phasor measurement requires very low latency to ensure this accuracy.
3. mMTC: in this use case the project is managing energy network stability and resilience in the context of EVs with an open ecosystem of providers and consumers with the goal of optimising usage and minimise cost of energy, as well as ensuring energy availability. A large number of both fixed and mobile sensors will require econnectivity, thus requiring the mMTC capabilities of 5G. In addition, the uRLLC scenario elaborated in bullet (2) above, will also require mMTC with millions of devices being deployed in dense areas.

   The Smart Energy performance requirements listed in Table 4 apply also to this use case.

[1] http://www.nrg5.eu/

2.4 Smart Agriculture

2.4.1 Smart Irrigation

2.4.1.1 Description

The motivation of the use case is the increasing demand and market for smart agriculture that is expected to grow from USD 13.7 billion in 2015 to 26.8 billion by 2020.

Farmers demand IoT-based advanced technologies and solutions to improve operational efficiency, maximize yield, and minimize wastage through real-time field data collection, data analysis, and deployment of control mechanism.

The aim of smart agriculture solutions is to increase productivity, food security, and efficiency of agricultural processes. There are different applications of smart agriculture:

- Precise farming entails the obtaining of real-time data on the conditions of crops, soil, and air.
- Smart irrigation measures various parameters such as humidity, soil moisture, temperature, and light intensity to calculate the precise requirements for water. It has been proved that such mechanism can contribute to higher irrigation efficiency.
- Smart greenhouse allows farmers to cultivate crops with minimal human intervention. Climatic conditions such as temperature, humidity, luminosity, and soil moisture are continuously monitored inside a greenhouse. Variations in these conditions will trigger automated actions. These actions will then evaluate the changes and implement corrective actions to maintain optimal conditions for plant growth.
- Precision Livestock Farming supports real-time monitoring of productions, health, and welfare of livestock to ensuring optimal yield.

In particular, this use case is based on the solution "IrrigNET -Plant-specific model-based irrigation using Internet of Things (IoT)" that is developed in FRACTALS (Future Internet Enabled Agricultural Applications, FP7 project No. 632874. The mathematical models of a specific crop (initially sugar beet) and soil structure are fed with data generated by sensors deployed in the field (soil temperature, humidity), current weather conditions and weather forecast to create an "irrigation recipe", i.e. how much water should be used at a given time.

2.4.1.2 Source

The initial version of the irrigNET solution is developed with the support of FRACTALS (Future Internet Enabled Agricultural Applications, FP7 project No. 632874), under the funding framework of the European Commission. FRACTALS supports innovative ICT SMEs and web-entrepreneurs to develop IoT-based applications with high market potential, addressing the needs of the agricultural sector.

2.4.1.3 Roles and Actors

Below, the main actors and their roles are identified in the use case of smart irrigation using cellular IoT technologies:

- ICT hardware and software suppliers: Suppliers of ICT hardware and software solutions required in Smart Irrigation scenarios.
- Smart Irrigation application developer: Supplier of novel and advanced Smart irrigation applications.
- IoT platform providers: used to deploy and provide the IrrigNET service in the cloud.
- Telecommunication operators: communication network operators that provide access for cellular IoT devices in different deployments.
- End-users are owners of greenhouses or crops in agriculture sector.

2.4.1.4 Pre-conditions

To enable the use case, the pre-condition is 5G connectivity in the crops and farms where IoT devices must be deployed for monitoring the ground and weather conditions and for control the irrigation process.

2.4.1.5 Triggers

For this use case, the trigger is the farmers' demand of solutions to reduce their costs of water and energy consumptions in order to be more competitive.

2.4.1.6 Normal Flow

Each device sends periodically sensor data and waits the answer of the IoT platform. If the platform has new configuration, the platform includes this configuration in the answer message to send toward the device.

2.4.1.7 Alternative Flow

No alternative flows are identified.

2.4.1.8 Post-conditions

The IrrigNET solution defines the exact time of irrigation as well as the exact amount of water to be used, based on the field measurements, soil type and specific needs of the plant, taking into account forecasted temperature and rainfall as well.

The IrrigNET solution provides:

- Efficient irrigation using IoT technologies
- Yields and crop quality improvement
- Rational water consumption
- Reduction of harmful effects on land

IrrigNET is available for many different crops: corn, soybean, sugar beet, potato, onion, cucumber, paprika, vineyards, blueberries. New crops are being added continuously and can be made on request.

2.4.1.9 High Level Illustration

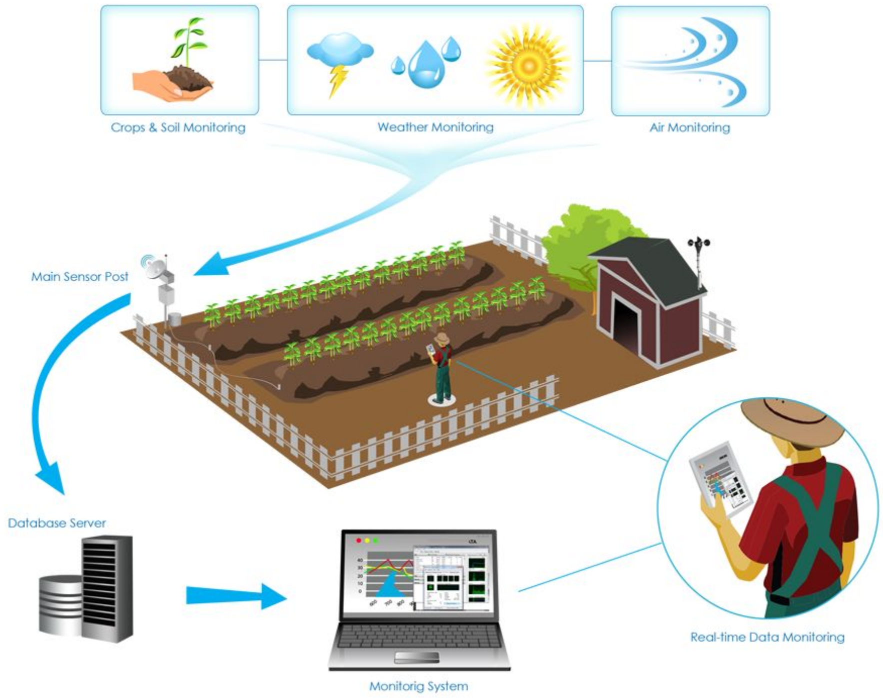

Figure 16: Smart irrigation - High level illustration

2.4.1.10 Potential Requirements

Smart irrigation requires NB-IoT devices with high network coverage, high battery life and low device cost to be deployed in farms and crops where there are not power supply and traditional mobile connectivity. The reliability and security are two main requirements that must be provided by the IoT solutions of smart irrigation based on wireless devices and cloud platforms.

2.4.1.11 Radio Specific requirements

Requirement	Explicit 5G Promises	Smart Irrigation
Real-time capability- Latency	5 ms (e2e)	5 ms (e2e)
Real-time capability- Jitter	-	-
Bandwidth	Peak data 10Gbps	10kbps .. 100kbps
Time period of information loss during failures	-	none (seamless failover)
Availability / coverage	-	ubiquitous
Range (distance between communication neighbours)	-	< 10km
Reliability	99.999%	99.99%
Mobility	500km/h	none
Outdoor terminal location accuracy	<1m	none
Multi-tenant support	yes	yes
Non-standard operating conditions	energy reduction by 10	Battery powered device with >1 year lifetime
Harsh environment (weather)		
Ease of use	-	Plug and Play device (sensor and actuators)
Communication service approach		
SLA Tooling	-	Service Level Agreement (SLA) monitoring
Service deployment time	90min	days
Private 5G infrastructure	-	no
Scalability: Number of devices per km2	1.000.000	1000
Globally harmonized definition of Service Qualities	-	-
Technology availability	-	> 25 years
Globally simplified certification of ICT components	-	Yes
Assured Guarantees	-	mandatory

2.4.1.11.1 Radio Coverage

- Radio cell range
  - o Long range (> 10 Km) under LOS and NoLOS conditions.
- Does the radio link crosses public spaces? Or is it constrained to indoor or customer premises?
  - o The radio link crosses public spaces mainly outdoors, given the monitoring features for smart irrigation.
- Is Multicell required?
  - o Multicell is not required.
- Is handover required? Seamless? Tolerable impact in delay and jitter?
  - o Handover is not required.
- Mobility: maximum relative speed of UE/FP peers
  - o Mobility is not required.
- Special coverage needs: i.e., maritime, aerial
  - o No, only terrestrial.

2.4.1.11.2 Bandwidth requirements

- Peak data rate
  - o 100 Kbps.
- Average data rate
  - o 10 Kbps.
- Is traffic packet mode or circuit mode?
  - o Packet mode

2.4.1.11.3 URLLC requirements

- Required Latency
  - o Usually roundtrip communication with latency tolerance up to 1 second.
- Required Reliability
  - o 99,99% (no tolerant to losses)

2.4.1.11.4 Radio regimens requirements

- Desired and acceptable radio regimens
  - o When possible, it is preferred license – public mobile, in order to improve interoperability support and wide coverage of the service.

2.4.1.11.5 Other requirements

- UE power consumption
  - Rechargeable or primary battery?
    - o When solar panels can be deployed, a rechargeable battery should be used for the IoT device.
  - Acceptable battery life
    - o At least enough to cover a crop lifetime (e.g. one year).
- Is terminal location required? location accuracy?
  - o No, the location is usually not required.

2.5 Cross-vertical

2.5.1 Siemens White Paper "5G communication networks: Vertical industry requirements"

In [4], several 5G requirements were derived by Siemens based on their studies on vertical application domains, such as Smart City, Smart Mobility, Smart Manufacturing, Smart Energy and Smart Building.

Table 3 shows a consolidated view of the 5G requirements, while Table 4 provides more details on the 5G requirements coming from verticals.

Table 3: 5G promises vs. Vertical requirements, copied from [4] with courtesy of Siemens

Category	Requirement	Explicit 5G promises (according to [1], Figure 2)	Consolidated requirements from verticals - Siemens view
Industry-grade Service Quality	Realtime capability – Latency	5 ms (e2e)	1 ms (local) 5 ms (long distance)
	Realtime capability –Jitter	-	1us (local)
	Bandwidth	Peak data 10 Gbps Mobile data volume 10 TB/s/km^2 Number of devices: 1 mio/km^2	kbps ... 10Gbps
	Time period of information loss during failures	-	none (seamless failover)
	Availability/coverage	-	ubiquitous
	Range (distance between communication neighbors)	-	0,1 m ... 200 km
	Reliability (minimum uptime per year [%])	99,999%	99,9999%
	Mobility	500km/h	500km/h
	Outdoor terminal location accuracy	<1m	0,1 m
	Multi-tenant support	yes (Network Slices)	yes
Operation and maintenance	Non-standard operating conditions	Energy consumption reduced by factor 10	• Battery powered devices with >10years lifetime • Harsh environments (weather, vibrations, heat, dust, hazardous gases, etc.)
	Ease of use	-	• Communication services approach • Plug and play device (sensor, actuator, controller) integration
	SLA Tooling	-	Service Level Agreement (SLA) monitoring and management tools for provider and consumer
	Service deployment time (time between service request and service realization)	90 min	hours
	Private 5G infrastructures	-	yes
Non-technical	Scalability: Number of devices per km^2	10^6	10^5
	Globally harmonized definition of Service Qualities	-	yes
	Technology availability	-	>20 years
	Globally simplified certification of ICT components	-	Yes
Assured Guarantees		-	mandatory

Table 4: 5G promises vs. Vertical requirements (details), copied from [4] with courtesy of Siemens

Category	Requirement	Explicit 5G promises (according to [1], Figure 2)	Siemens demand	Smart City	Smart Mobility	Smart Manufacturing		Smart Energy			Smart Building
						Process	Discrete	Low Voltage	Medium Voltage	High Voltage	
Industry-grade Service Quality	Realtime capability – Latency	5 ms (e2e)	1 ms (local) 5 ms (long distance)	-	1ms (local) 10 ms (long distance)	20ms (local) 1s (long distance)	1ms (local) 20ms (long distance)	-	25ms	5ms (long distance)	100ms
	Realtime capability -- Jitter	-	1us (local)	-	-	20ms	1us	-	25ms	1ms	-
	Bandwidth	Peak data 10 Gbps Mobile data volume 10 TB/s/km² Number of devices: 1 mio/km²	kbps ... 10Gbps	kbps (sensors) ... Mbps (video supervision) ... 10 Gbps (data centers)	10 Mbps ... 1 Gbps	100 kbit/s (automaton stream) ... 100 Mbps (remote access, video supervision)	100 kbit/s (automaton stream) ... 100 Mbps (remote access, video supervision)	1 kbps per subscriber	5 Mbps per secondary substation	1Gbps along power lines	100 kbit/s (automaton stream) ... 100 Mbps (remote access, video supervision)
	Time period of information loss during failures	-	none (seamless failover)	1s	100 ms	100 ms	none (seamless failover)	minutes	25ms	none (seamless failover)	100 ms
	Availability/ coverage	-	Ubiquitous	City-level	Ubiquitous	Industrial Plant Areas	Industrial Plant Areas	Ubiquitous	Ubiquitous	Ubiquitous	City-level
	Range (distance between communication neighbors)	-	0,1 m ... 200 km	10 km	1 km (cars) ... 10 km (trains)	0,1m ... 10 km	0,1 m ... 100 m	10 km	20 km	200 km	100m
	Reliability (minimum uptime per year [%])	99,999%	100%	99,9%	100%	100%	100%	98%	99,9%	100%	99,9%
	Mobility	500km/h	500km/h	100km/h	500km/h	50km/h	50km/h	5km/h	-	-	5km/h
	Outdoor terminal location accuracy	<1m	0,1 m	1 m	0,1 m	0,1 m	0,1 m	10 m	10 m	-	0,1 m
	Multi-tenant support	yes (Network Slices)	yes								
Operation and maintenance	Non-standard operating conditions	Energy consumption reduced by factor 10	• Battery powered devices with >10years lifetime • Harsh environments (weather, vibrations, heat, dust, hazardous gases, etc.)								
	Ease of use	-	• Communication Services approach • Plug and Play Device (Sensor, Actuator, Controller) integration								
	SLA Tooling	-	Service Level Agreement (SLA) monitoring and management tools for provider and consumer								
	Service deployment time (time between service request and service realization)	90 min	hours								
	private 5G infrastructures	-	yes	-	yes	yes	yes	-	optional	yes	optional
Non-technical	Scalability: Number of devices per km²	10^6	10^5	10^5	10^4	10^5 (high density of devices)	10^5 (high density of devices)	10^4	10^3	10^3	10^5
	Globally harmonized definition of Service Qualities	-	yes	-	yes	yes (for long distance)	yes (for long distance)	-	yes	yes	-
	Technology availability	-	>20 years								
	Globally simplified certification of ICT components	-	Yes								
Assured Guarantees		-	Mandatory	Relaxed	Mandatory	Mandatory	Mandatory	Relaxed	Mandatory	Mandatory	Relaxed

3 Conclusions

It is expected that 5G systems will extend mobile communication services beyond mobile telephony, mobile broadband, and massive machine-type communication into new application domains, so-called vertical domains.

Issue 1 of this report highlighted specific IoT vertical domain use cases and determined the specific requirements they impose on the network infrastructure. These use cases and requirements can be used by SDOs (Standards Developing Organizations), such as 3GPP requirements for automation in vertical domains focusing on critical communications.

The IoT vertical domain use cases that have been presented in this Issue of this report are being proposed by AIOTI members and are derived from IoT projects where they participated or are currently participating. The presented IoT vertical domains are: Smart Mobility, Smart City, Smart Agriculture and Smart Energy.

Regarding requirements that these use cases are imposing on the underlying communication network infrastructure the following key conclusions have been derived:

- Smart Mobility: Most of the 5G promises on performance capabilities, see [1] can be used to support the requirements imposed by the Smart Mobility use cases presented in this Issue of this report. The following Smart Mobility (Vehicle Monitoring) use case requirements are different than the 5G promises on performance capabilities, see [1]:
    - Range distance between communication neighbours: > 1km (long range)
    - Non standard operating conditions:
        - Possible powered device with > 1 day lifetime
    - Technology availability: > 15 years
    - SLA tooling: SLA monitoring
- Smart Agriculture: Most of the 5G promises on performance capabilities, see [1] can be used to support the requirements imposed by the Smart Agriculture use cases presented in this Issue of this report. The following Smart Agriculture (Smart Irrigation) use case requirements are different than the 5G promises on performance capabilities, see [1]:
    - Range distance between communication neighbours: < 10 km
    - Non standard operating conditions:
        - Possible powered device with > 1 year lifetime
    - SLA tooling: SLA monitoring
    - Technology availability: > 25 years

- Smart City: Most of the 5G promises on performance capabilities, see [1] can be used to support the requirements imposed by the Smart City use cases presented in this

Issue of this report. The following Smart City use cases impose requirements that are different than the 5G promises on performance capabilities, see [1]:

- Public warning system in critical infrastructures use case:
    - Required Reliability 99,99999%
- UAV as MEC nodes for emergency operations support use case:
    - Radio cell range:
        - For cellular based transmissions: over 1 km transmission distances are required
        - For LP-WAN based transmissions: 10 km LOS and 4km NoLOS

- Smart Energy: Most of the 5G promises on performance capabilities, see [1] can be used to support the requirements imposed by the Smart Energy use cases presented in this Issue of this report. The Smart Energy (cross-vertical) requirements are different than the 5G promises on performance capabilities, see [1]:
    - Real time capability latency:
        - Medium voltage: 25ms
        - High Voltage: 5ms (long range)
    - Real time capability jitter:
        - Medium Voltage: 25 ms
        - High voltage: 1 ms
    - Time period information loss during failures:
        - Low voltage: minutes
        - Medium voltage: 25 ms
        - High voltage: seamless failover
    - Reliability:
        - Low voltage: 98%
        - Medium voltage: 99,9%
        - High voltage: 100%

Annex I References

[1] 5G Vision, The 5G Infrastructure Public Private Partnership: the next generation of communication networks and services, 5GPPP, February 2015, to be retrieved via: https://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf

[2] D. Evans, "The Internet of Things: How the Next Evolution of the Internet is Changing Everything," [Online]. Available: https://www.cisco.com/c/dam/en_us/about/ac79/docs/innov/IoT_IBSG_0411FINAL.pdf .

[3] AIOTI WG06 (Smart Farming and Food Security), "Broadband Requirements for farming and rural uses," 2016.

[4] Siemens AG, "5G communication networks: Vertical industry requirements," 11 2016. [Online]. Available: http://www.virtuwind.eu/_docs/Siemens_PositionPaper_5G_2016.pdf.

[5] 5G-PPP, "5G Empowering Vertical Industries," 02 2016. [Online]. Available: https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf.

[6] "5G and Energy", 5G Infrastructure Association, September 2015 (visited in May 018) https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-White_Paper-on-Energy-Vertical-Sector.pdf

[7] Recommendation ITU-T Y.3502, Information technology - Cloud computing - Reference architecture, ITU-T, 2014.

Annex II There are no sources in the current document.Template used for Use Case descriptions

X. Use Case (title)

X.1 Description

- Provide motivation of having this use case, e.g., is it currently applied and successful; what are the business drivers, e.g., several stakeholder types will participate and profit from this use case
- Provide on a high level, the operation of the use case, i.e., which sequence of steps are used in this operation?

X.2 Source

- Provide reference to project, SDO, alliance, etc.

X.3 Roles and Actors

- Roles: Roles relating to/appearing in the use case
  - Roles and responsibilities in this use case, e.g., end user, vertical industry, Communication Network supplier/provider/operator, IoT device manufacturer, IoT platform provider, Insurance company, etc.
  - Relationships between roles
- Actors: Which are the actors with respect to played roles

A detailed definition of the Roles and Actors is provided in [6].

X.4 Pre-conditions

- What are the pre-conditions that must be valid (be in place) before the use case can become operational

X.5 Triggers

- What are the triggers used by this use case

X.6 Normal Flow

- What is the normal flow of exchanged data between the key entities used in this use case: devices, IoT platform, infrastructure, pedestrians, vehicles, etc.

X.7 Alternative Flow

- Is there an alternative flow

X.8 Post-conditions

- What happens after the use case is completed

X.9 High Level Illustration

- High level figure/picture that shows the main entities used in the use case and if possible their interaction on a high level of abstraction

X.10 Potential Requirements

This section should provide the potential requirements and in particular the requirements imposed towards the underlying communication technology
These requirements can be split in:

- Functional requirements
  (to possibly consider them – but not limited to – with respect to the identified functions/capabilities)
- Non-functional requirements – possible consideration includes:
  - Flexibility
  - Scalability
  - Interoperability
  - Reliability
  - Safety
  - Security and privacy
  - Trust

As example of the format of such requirements is provided in Section 2.5.1.

X.11 Radio Specific requirements

X.11.1 Radio Coverage

- Radio cell range
  Specification of expected maximum and typical radio ranges (indicate if LOS/NoLOS)
  - Does the radio link crosses public spaces? Or is it constrained to indoor or customer premises?
- Is Multicell required?
  (If YES, specify the required scope of the multicell arrangement. I.e. "building", "city", "global")
  - Is handover required? Seamless? Tolerable impact in delay and jitter?
- Mobility: maximum relative speed of UE/FP peers
- Special coverage needs: i.e., maritime, aerial

X.11.2 Bandwidth requirements

- Peak data rate
- Average data rate
- Is traffic packet mode or circuit mode?
- If circuit mode, is isochronicity required?

X.11.3 URLLC requirements

- Required Latency

  (specify if it is one way or roundtrip)
- Required Reliability
  (i.e., 99,99999%)
- Maximum tolerable jitter

X.11.4 Radio regimens requirements

- Desired and acceptable radio regimens (describe the desired and acceptable radio regimens: I.e.: licensed - public mobile, licensed – specific license, license-exempt)

X.11.5 Other requirements

- UE power consumption
  - Rechargeable or primary battery?
  - Acceptable battery life
- Is terminal location required? location accuracy?

Annex III Summary table from AIOTI WG06 report "Broadband Requirements for farming and rural uses" copied from [3]

Use case	Relevance	Status	Bandwidth Download/Upload	Latency	Ubiquity / Coverage	Need for fixed/backhaul vs. wireless solutions	Satellite connectivity needed?	Demands a better performing broadband service?
1.a Precision farming: Live mapping of soil moisture	High	Planned	Mbps order	Not critical	Ubiquitous	-	No	Yes
1.b Precision farming: variable rate fertilization (including N-sensing)	High (economy- and environment-wise)	In place / Planned	-	Not critical	Ubiquitous	-	No	Yes
1.c Precision farming: Smart irrigation	High (economy- and environment-wise)	In place / Planned	Kbps order	Not critical	Rural areas where irrigation is used	No	No	No
2. Wirelessly connected agricultural machinery	Medium-high	In place / planned	Kbps-Mbps (depending on application)	Critical / Non-critical, (depending on application)	Ubiquitous	Depending on market evolution	-	Yes (efforts already underway at standardization level)

Use case	Relevance	Status	Bandwidth Download/Upload	Latency	Ubiquity / Coverage	Need for fixed/backhaul vs. wireless solutions	Satellite connectivity needed?	Demands a better performing broadband service?
3. Data- centric farm management	High	In place / planned	Mbps order	10's miliseconds order	Ubiquitous	Depending on aggregated demand in a rural area	Yes, if only affordable solution	Yes
4. Remote video monitoring and videoconferencing in farming	Medium	Planned / Potentially needed	Mbps order	Non-critical (monitoring)	Large area coverage	Depending on aggregated demand in a rural area	Yes, if cost-effective for remote areas with no proper wireless connectivity	Yes
5. Connectivity to wind farms	Medium	In place / planned	Gbps order	Critical	Localized (fiber) connectivity	Fixed	No	Yes
6. General broadband use by rural citizens and businesses	High	In place	Gbps order	Varying (depending on application)	Populated rural areas	Depending on aggregated demand in a rural area	Yes, if only affordable solution	Yes

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