"5G for Drone-based Vertical Applications"

D1.1 – Use case specifications and requirements

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Executive Summary

The goal of the 5G!Drones project is to trial several UAV use cases that cover enhanced mobile broadband (eMBB), ultra-reliable, low-latency communications (uRLLC) and massive machine type communication (mMTC) 5G services, and validate 5G KPIs which apply to support challenging UAV-based use cases. The principal purpose of D1.1 is to introduce the reader to the 5G!Drones project, providing insight on the technologies that will be used to enable the UAV use cases over the 5G test facilities followed by a detailed description of each identified use case scenario.

The 5G!Drones project has identified four broad UAV-based use case categories that would benefit from the large-scale deployment of 5G networks. Within each of these four use cases, the 5G!Drones project has determined twelve scenarios (including three sub-scenarios) seen as candidates to be trialled over the available 5G test facilities to test and validate 5G KPIs. As the name suggests, D1.1 provides a description of each of the use case scenarios detailing all components necessary in enabling the trial. It also provides information on the network and drone requirements required to deploy the trials and also lists the KPIs that need to be achieved while trialling the respective scenarios.

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List of Abbreviations

3GPP	Third Generation Partnership Project
AI	Artificial Intelligence
ANSP	Air Navigation Service Provider (State Civil Airspace Management Authority)
AR	Augmented Reality
ATS	Air Traffic Services
BER	Bit Error Ratio
BVLOS	Beyond Visual Line of Site
C-UAS	Counter Unmanned Aerial System
C2	Command and Control
DL	Downlink
DLN	Drone Logistics Network
eMBB	Enhanced Mobile Broadband
FIMS	Flight Information Management System
FPV	First Person View
g	Gram
GCS	Ground Control Station
gNB	gNodeB, 5G NR, next generation NR eq. of base station
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HAP	High Altitude Platforms
IoT	Internet of Things
kg	Kilogram
KPI	Key Performance Indicator
LOS	Line of Sight
LTE	Long-Term Evolution
MCT	Micro Controller Tower
MEC	Mobile Edge Computing
mMTC	Massive Machine Type Communication
NFZ	No Fly Zone

NLOS	Non-Line Of Sight
NR	New Radio
OEM	Original Equipment Manufacturer
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RCC	Rescue Command Center
RTH	Return to Home
SORA	Specific Operations Risk Assessment
SC	Scenario
UART	Universal Asynchronous Receiver-Transmitter
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UC	Use Case
UE	User Equipment
UL	Uplink
UL-ACE	Unmanned Life Autonomous Control Endpoint
UL-CCP	Unmanned Life Central Command Platform
uRLLC	Ultra-Reliable, Low-Latency Communications
UTM	UAV Traffic Management
UxNB	Radio Access node on-board UAV
VLOS	Visual Line of Sight
VPN	Virtual Private Network
VR	Virtual Reality

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1. INTRODUCTION

1.1. Objective of the document

The main purpose of this deliverable is to summarise the outcomes of the first technical task of 5G!Drones, Task 1.2, targeting the description of the target use cases, the definition of the requirements and the 5G Key Performance Indicators (KPIs) to be validated. However, being the first technical deliverable of the 5G!Drones project, the document also presents a distilled view of the project's scope and objectives, and highlights the innovations and ambitions that are set to be fulfilled. It delves into the technological solutions that are part of 5G!Drones aiming at clarifying how the project will build on the existing technologies. In this context, the deliverable is expected to serve as a fundamental reference guide for specifying the 5G!Drones system architecture and determining the subsequent implementation work.

The core objectives of the D1.1 include:

- **"Analysis of the performance requirements of UAV verticals' applications and business models in 5G**"
  - Detailed workflows for each application scenario, including the intra-component communication, timing, and information flows.
  - Application performance requirements and vertical-service-level KPIs that are critical to be measured during the trials.
- **"Design and implementation of the 5G!Drones system layer and the related hardware and software enabling components to execute UAV trials and operations"**
  - UAV service components that will be included as software and/or hardware on-board the UAVs and at remote infrastructures, as well as the role of each partner in providing or realising them.
  - Enhance the existing UAV software or develop new software to support the use cases. This includes both control functionality and application level software.
  - Types, technical specifications, and numbers of UAVs that will be used for trialling the use case scenario.
- **Define the use case scenarios**
  - Re-evaluate the decided use cases and the trial scenarios, in order to ensure their feasibility and market relevance, and identify potential necessary adjustments following the current state of the vertical market

1.2. Structure of the document

Since the 5G!Drones project is an amalgamation of two different ecosystems, the resulting audience base is wide and can possess different understanding levels of both the 5G and UAV ecosystems. Therefore, it is important to structure the document in a manner that allows the reader to get a glimpse into the two ecosystems before diving deep into the description of the use case scenarios.

To align with this thought, the deliverable first introduces the key aspects of the 5G!Drones project where it describes the main objectives, innovations and impact. This is followed by providing insight into the 5G and UAV ecosystems as well as a background on the technologies that will be used to deploy the trials. This section ends by providing the reader with a high-level system architecture of the 5G!Drones project.

This section is followed by the deep dive into the 5G!Drones use case scenarios where the 3GPP defined UAV use cases and the common requirements for experimentation are introduced at a high-level and followed by a detailed description of each use case scenario.

1.3. Target Audience

This deliverable is mainly addressed to:

- The Project Consortium to validate that the project objectives and proposed technological advancements have been analyzed and to ensure that, through the described Use Cases, identified requirements and target KPIs, the next actions can be concretely derived
- The Research Community and funding EC Organization to: i) summarize the 5G!Drones scope, objectives and intended project innovations, ii) detail the 5G!Drones target use cases that shall be demonstrated and measure provided technological advancements and iii) present the related requirements and associated KPIs that must be tackled to achieve the expected results
- The general public for obtaining a better understanding of the framework and scope of the 5G!Drones project

2. 5G!DRONES KEY ASPECTS

This section addresses the 5G!Drones objectives, ambitions and target innovations that are the fundamental drivers for the appropriate definition of the target use cases, the identification of the related network and application requirements and KPIs, namely the aspects that are in focus of this deliverable. It also provides a concise overview of the 5G and UAV concepts and background that are considered influential for the project's vision and work.

2.1. Main Objectives, Innovations and Impact

The 5G!Drones project aims to trial several UAV use cases that cover eMBB, uRLLC and mMTC 5G services, and validate the relevant 5G KPIs that apply to such challenging use cases. The project will build on top of 2 of the 3 the 5G facilities provided by the ICT-17 projects (namely 5G-EVE and 5GENESIS) as well as 2 others (5G-TN, X-Networks), and shall identify and develop the missing components to trial the UAV use cases. To ease and automate the execution of trials by the verticals, that are the main users of 5G!Drones, the project builds a software layer that exposes a high-level API to be used in order to request the execution of a trial according to the scenario of interest.

In this respect, the main objectives of the project include:

Objective (1)	Analysis of the performance requirements of UAV verticals' applications and business models in 5G.
Objective (2)	Design and implementation of the 5G!Drones software layer (or system) to execute UAV trials
Objective (3)	Design a high-level scenario descriptor language to run and analyze the results of the UAV trials
Objective (4)	Design and implementation of 5G!Drones enablers for UAV trials and operations
Objective (5)	Validate 5G KPIs that demonstrate execution of UAV use cases
Objective (6)	Validate UAV KPIs using 5G
Objective (7)	Advanced data analytics tools to visualize and deeply analyze the trial results, and provide feedback to the 5G and UAV ecosystem
Objective (8)	Dissemination, standardization and exploitation of 5G!Drones

The project plans to offer innovations in the UAV vertical industry through the application scenarios that harness the 5G potential, and in the network and infrastructure domain through the development of the necessary system support. Furthermore, the project sets out to contribute to innovative methodologies and tools for large-scale experimentation. In summary, the main innovations expected by 5G!Drones are:

- **Business and regulatory aspects**, through the definition of a business and financial analysis framework for the UAV ecosystem considering vertical-service-related KPIs and the ongoing regulatory developments
- **Trial Execution,** through the development of automation tools for 5G trials, innovative data management analysis and visualisation tools, and monitoring & management interfaces towards verticals, facility operators and experimenters.
- **5G Infrastructure Support,** through multi-domain slice orchestration, MEC architecture extensions and E2E network slicing security
- **Vertical Services,** through development of new 5G enabled vertical services including public safety, emergency response, situation aware IoT and enhanced connectivity services. Furthermore, innovation in the area of novel UAS traffic management including virtual reality based services and behind visual line of sight (BVLOS) operations is expected.

This deliverable partly addresses the first project objective, by describing the target state-of-the-art UAV use cases, identifying the 5G network functionalities and applications required, relating to the relevant KPIs and detailing the specific requirements that each use case mandates for the appropriate realization. Through this work, and particularly the analysis of the UAV application requirements, it is evident that work on Objective 2 shall be shaped. Also, the work presented in this document sets the cornerstone for the developments towards the Trial Execution, 5G Infrastructure Support and Vertical Services innovations.

On the grounds of the project's expected contribution and impact, the technical analysis presented in this document considers:

- Vertical use cases and deployment scenarios from high to low density regions.
- eMBB, mMTC, uRLLC services for end-to-end slicing and virtualisation.
- Relevant KPIs for validation.

2.2. Actors/Stakeholders and Roles

2.2.1. 5G Ecosystem: Verticals, Services and Stakeholders

Contrary to the legacy network technologies (including 4G), where all activities related to technology development and commercialisation were based on an abstract, application/service agnostic definition of the network QoS requirements, the 5G development activities are based on a more stakeholder/application/service requirements aware approach. Besides the general technical QoS KPIs and target values for 5G technologies, the actual 5G network deployments and operation will be tailored (automatically) to support the requirements of a range of stakeholders and services in a holistic manner. For this purpose, technical activities around 5G are tightly coupled with activities related to the analysis of stakeholders and their service requirements towards mapping them to 5G network capabilities, functionalities, deployment strategies, etc.

To this end, 5G-related activities from 5G-PPP [5], [6] as well as 5G Americas [7] have converged to address the major vertical industries, which have been considered to be the **Automotive, Smart Cities, Media & Entertainment, Industry, Health, Public Safety & Digital Divide Reduction, Energy, Transport and Logistics, Satellite/Non-Terrestrial Networks for Verticals, etc.** It becomes obvious, that these vertical industries involve large service groups, which can be provided

by various business stakeholders depending on the specific market/social environment, and can include many applications/services. It is noteworthy that the public sector is expected to have a major role in 5G adoption as it is envisaged to become an early adopter and promoter of 5G connectivity-based solutions, encouraging the emergence of innovative services, contributing to a critical mass of investment, and addressing issues of importance for society. Migrating public safety and security services from existing proprietary communications platforms to even more secure, resilient and reliable 5G platforms is part of the European Commission's Action Plan of "5G for Europe" [29]. Action 7 of the plan encourages Member States to consider the 5G infrastructure for their advanced broadband public protection and disaster relief systems (PPDR) that typically support services for the police and fire brigades. To this end, in May 2018, a cooperation agreement to foster developments on 5G for public safety stakeholders [30] was signed by the 5G Infrastructure Association, representing the European industry in 5G-PPP Research Programme, and the European Public Safety Association.

At the same time, business and market research reports [26][27][28] clearly state that the UAV technology drives innovation to various other industries, apart from the obvious impact on **military** and **civil government** applications. Considering the Unmanned Aerial Systems (UAS) interest in using cellular connectivity is strong, because the 3GPP ecosystem offers excellent benefits for UAS operation [10], it becomes obvious that these vertical industries and opportunities are also relevant in the 5G perspective. More specifically, and as noted in [27], **Infrastructure**, **Agriculture**, **Transport**, **Insurance**, **Mining** industries shall cumulatively create a market value of $127bn as a result of the drone disruption in their business.

To address this complex, multi-dimensional environment with diverse but strict service assurance expectations, and enable the service-centric transformation through a homogeneous break-down of vertical industry use cases to network services and related prerequisites, the Standards Developing Organisations, mainly ITU and 3GPP, have categorised the 5G services as follows:

- **eMBB (enhanced Mobile Broadband)** [3], that refers to bandwidth intensive services and applications, including Augmented Reality (AR)/Virtual Reality (VR), Ultra-High Definition Video sharing in heavily crowded hotspots, TV programs broadcasting, etc. The bandwidth requirements of this type of services are expected to be about 100 Mbps per user, while in some cases it can be in the order of some Gbps, reaching even 10 Gbps (for broadcast services);
- **mMTC (massive Machine-Type Communications - Massive Internet of Things (mIoT)**)[1], that refers to massive IoT services extending the Long Term Evolution (LTE) IoT (for example, Narrow Band–IoT) to support huge numbers of devices with lower costs, enhanced coverage, and long battery life. With regard to ITU objectives, 5G will support ten times as many devices per area as LTE. This category includes eHealth, wearables, industrial control and factory automation, and sensor networks;
- **uRLLC (Ultra-Reliable, Low-Latency Communications) - Critical Communications** [2], that refers to latency sensitive, wireless applications and services, some of which are impossible to be supported by existing network deployments. These services are referred also as "mission-critical" communications or critical Machine-Type Communications (by 3GPP), and are necessary to enable an autonomous BVLOS drone control. uRLLC is also required to deploy applications in public safety lifeline and situational awareness, industrial automation, new medical applications, autonomous vehicles, etc. The latency requirements for this type of services are expected to range between 1ms-2ms for the radio interface and less than 10ms for the end-to-end data plane;
- **Network Operation Services** [4] are distinguished by 3GPP as a separate class of services addressing the functional system requirements, including aspects such as: flexible functions and capabilities, multi-tenancy, energy efficiency migration and interworking, optimisations and security.

This service-centric approach is expected to trigger changes in the current market stakeholders and their roles and generate opportunities for the creation of new roles and introduction of additional stakeholders. Extensive analysis on the envisaged stakeholders has already been performed through the 5G-PPP initiative, as depicted in Figure 1. Building on this view, the key stakeholders being primarily involved in the 5G!Drones business cases are considered to be:

- **Business Verticals**, from both private and public sectors, which drive the need for 5G services deployments with rigorous demand;
- **Connectivity Providers** (5G Industry), including network operators, hotspot providers, service operators and site owners that own and operate fully or in cooperation the telecommunication infrastructure and services that shall realise the offered services;
- **Technology Providers** (5G Industry, UAV Industry), Technology vendors, SMEs, start-ups, which provide technology solutions, services and applications to be integrated, either to implement the service offerings expected, or even to address the functionality and operation of the platforms themselves;
- **Policy Makers**, the regulation bodies that set the prevailing legal, regulation, and other compliance mandates
- **Research** institutions, academia, and the open source community (others) to ensure the sustainability of the designed solutions through their influence in shaping scientific trends;
- **End Users**, to consume the services offered and provide the end-user experience feedbacks.

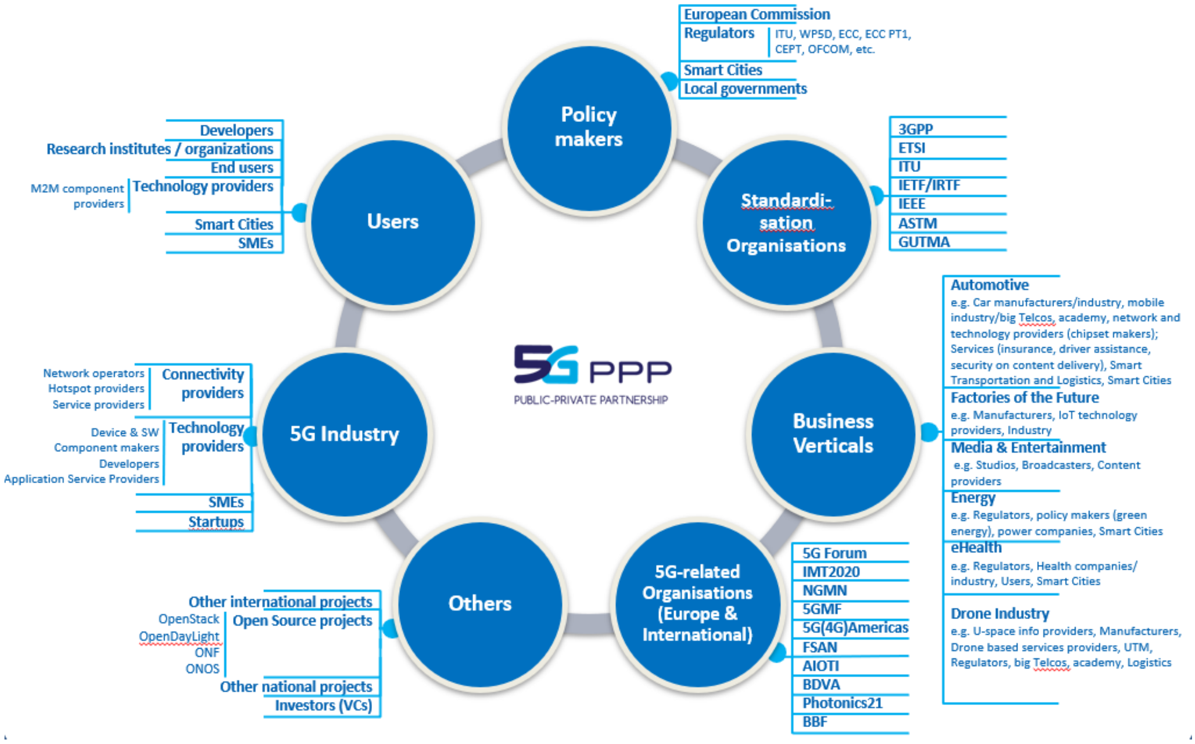

Figure 1: 5G PPP Target Stakeholders

On top of this, 5G!Drones puts the experimentation perspective, as it targets 5G and UAV platforms optimised through a software layer that can accept, execute and analyse UAV trials to validate 5G KPIs. Such deployment, execution and validation, that can be called an Experiment assumes the following roles:

- **Experimenter**: Executes the experiments using the experimenter interface provided by the 5G!Drones platform;

- **Platform Operator**: Hosts, manages and operates the platform's software and infrastructure, including the interface to the experimenters, the telecommunications infrastructure, as well as, the coordination, management, orchestration and monitoring systems;
- **Vertical Industry Technology Provider**: All vendors and research institutions that provide software and hardware components to the 5G!Drones platforms;
- **Testers and End Users**: The users of the services deployed in the 5G!Drones platforms by the Experimenter. They can be either individuals or corporate end-users.

It is worth mentioning that we do not foresee a fixed association of these roles to the 5G-PPP stakeholders, but rather a variety of combinations is expected, leading to interesting exploitation opportunities and business potentials.

2.2.2. UAV Ecosystem: Verticals, Services and Stakeholders

The UAV ecosystem is growing at an enormous pace with interests from small and medium enterprises to large corporations alike. The largest players known from the aviation, telecommunications and IT market are also investing in technologies and software. It is worth to mention, that number of fresh technology and software providers within the UAV ecosystem are also growing rapidly.

At a high level, the drone ecosystem can be divided into:

- Hardware suppliers
    - Drone platforms
        - Agriculture
        - Delivery systems
        - Safety and security
        - Lighter than air
        - Commercial drones / toys / recreational
        - Fixed wing
        - VTOL fixed wing
        - Helicopters
    - Passenger drones / eVTOLs / Air taxis
    - Counter drone solutions
    - Components and systems
    - Cameras, imaging and visions systems
    - Launch and recovery systems
    - Propulsion and power
    - Navigation and guidance systems
    - Data and communication
- Software
    - Flight, fleet operation management
    - Open source, SDK
    - Navigation
    - Artificial Intelligence (AI)
    - VR
    - Unmanned Traffic Management (UTM)
    - Data analytics, workflows
- Services
    - Drone-as-a-service Providers
    - Education, simulation and training
    - System integration, engineering, advisory
    - Maintenance

  - Supplier, retailers
  - Test sites
  - User groups and networks
  - Social media
  - Media, news, blogs and magazines
  - Marketplaces
  - Shows, conferences, events
  - Insurance
  - Organizations, coalitions, initiatives

It is worth mentioning, that the 5G!Drones project keeps in mind the interests of the entire UAV ecosystem. Through regulations and recommendations, it will be possible to effectively influence the functionality and overall safety of the entire ecosystem. On the other hand, the Open Source community plays an important role. Well-known and popular UAV control platforms and autopilots such as PixHawk [43], ArduPilot [44], DJI [45] have a significant role within UAV society. They bring together a programming community and produce brilliant products. However, due to the unknown production processes in conjunction with a lack of supervision on certification process it is difficult to "go in production" in the context of certification, safety, cybersecurity. Regulation & Standardization is ongoing, to keep pace with the fast moving ecosystem accelerated processes & procedures are applied. Still, a mature and proven regulatory framework will be available in a year earliest.

5G!Drones project results should have a positive impact on the UAV ecosystem especially on the following areas:

- Safety of operations
- Speed of service implementation
- Convenience in using 5G network services (time to market)

Thanks to 5G!Drones project, UAV users will have the chance to better utilize the benefits of telecommunications network technology. Based on reliable connectivity, low latency, high bandwidth and edge computing, new categories of services will be created, which have not been possible until now:

- Access to MEC
- Providing better communication for UAV control
- Providing reliable stream of traffic data
- Providing better signal quality for controlling multiple drones and swarms
- Better methods for assessing risk analysis
- Possibility of easier provisioning of services
- UTM operators will be able to create their own virtual networks and guarantee services in selected areas
- Network support in areas with high population density

In the scope of 5G!Drones the UAV Ecosystem is categorized in two main groups of actors, services and systems:

- Operational: Required/enforced by regulation at the time of experiments
- Pre-Operational: Used specifically in 5G!Drones experiments to explore 5G possibilities as well as validate relevant KPIs

Since UAVs/UTM is a new technology/domain, there is still basic regulation work ongoing in many areas. For the 5G!Drones project period it is expected, that the following regulations will be enforced:

- UAV categories

  - Commission Delegated Regulation (EU) 2019/945 of 12 March 2019 on unmanned aircraft systems and on third-country operators of unmanned aircraft systems [31]
  - Commission Implementing Regulation (EU) 2019/947 of 24 May 2019 on the rules and procedures for the operation of unmanned aircraft [32]
  - Standard scenarios [33]
- Registration & Identification [34]
- Risk Assessment [35]
- Flight Approval Processes (not in detailed specified by EASA, however most advanced UTM providers, developed their own specification)

On top, flight regulation and available operational UTM services will be different for the different test facilities in 5G!Drones due to several national ecosystems. At any time, 5G!Drones experiments will follow regulation in the national ecosystem. In parallel, pre-operational systems, services and actors will be a part of 5G!Drones experiments. It is foreseen to establish a UTM system used in all test facilities and all experiments. The system will provide enhanced services on top of the available operational services to validate interfaces and KPIs to/for 5G network.

The enhanced UTM (U-space) services will focus on using 5G network connectivity data for flight planning, risk assessment and approval processes. Additionally, an interface to network operators for requesting and formally agreeing network connectivity data is a major focus area for the pre-operational system.

In order to focus solely on the task, set out in this project, the UTM systems (FIMS) will be allowed to be used remotely. The remote UTM will be able to create a delegated airspace management area for testing purposes in accordance with all requirements set by appropriate supervision in each country.

2.3. Background Technologies and Terminology

2.3.1. 5G Network

There is strong interest in using commercial cellular network to provide support to UAVs for use in flight command and control systems as well as to support communication to payload applications [8]. Considering that the number of UAV cellular users increases, along with a growing focus on the safety and reliability of both commercial and leisure UAV operations, the need to put special focus on the necessary technical improvements to enhance the services provided to UAVs has been identified.

3GPP has already addressed the implications of serving low altitude UAVs using LTE radio in Release 15 [16], that led to the report 36.777 Enhanced LTE Support for Aerial Vehicles [10], approved in January 2018, with the main focus on radio aspects for the support of UAVs to provide the coverage necessary for a growing population of low altitude UAVs in all types of environments. It is perceived that most problems are due to interference caused by the UAVs operating above the normal height of user equipment (UE). New Radio (NR) is expected to make greater use of beamforming antennas to reduce this interference but could introduce new problems. UAVs may also experience “coverage holes in the air” as network planning and design is directed to ground-based users [8]. In terms of support for High Altitude Platforms (HAP) operating at altitudes between 8Km and 50 Km, work reported in TR 38.811 [16] and continued in Release 16, can provide services to either fixed very narrow aperture receivers or to portable hand-held receivers.

In Release 16, system and application layer aspects are put in perspective, through an initial study of service requirements for UAV identification [12] that led to the approved 22.825 report on “Study on Remote Identification of Unmanned Aerial Systems” [13]. As noted in [8], the focus of Release 16 UAV study and normative work [14] has been the concept of UAV identification by control data

that can be transmitted via the 3GPP network between a UAV or UAV controller and a centralised network-based UTM function. The direct communication between UAVs, and UAVs and ground-based personnel (especially law enforcement) has also been considered to support collision avoidance use cases. In 3GPP 22.825 "Study on Remote Identification of Unmanned Aerial Systems" [13] a proposed high-level architecture is introduced, as shown in Figure 2.

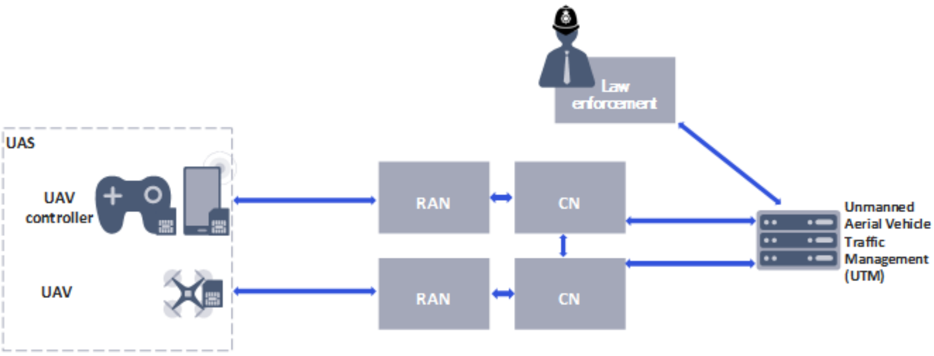

Figure 2: High Level Architecture of 3GPP Release 16 [13]

3GPP release 17, extends the work through a study item on enhanced requirements for UAV services including specific KPIs relevant to UAVs. In TS22.125 [19] the UAS Reference Model is included:

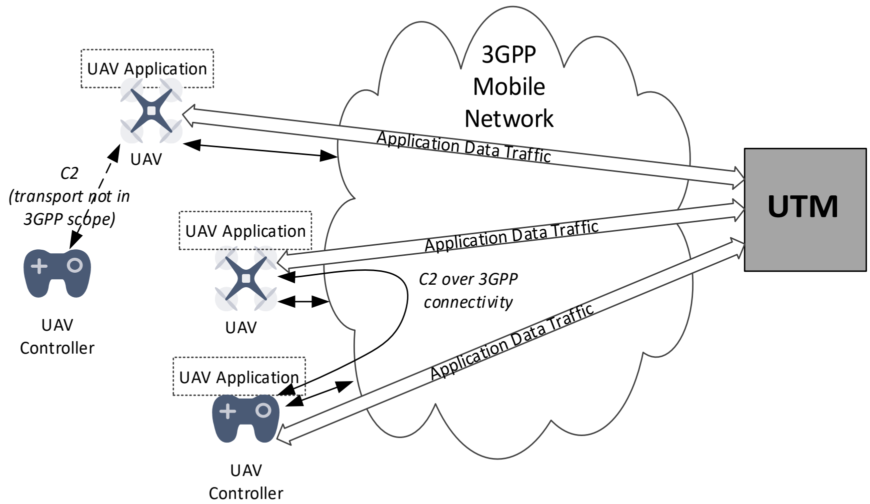

Figure 3: UAS Reference Model in 3GPP ecosystem TS22.125 [19]

Even more, in 3GPP Release 17, through TS22.125 [19] and TR22.829 129 the communication model for command and control (C2) is analysed, as depicted in Figure 3:

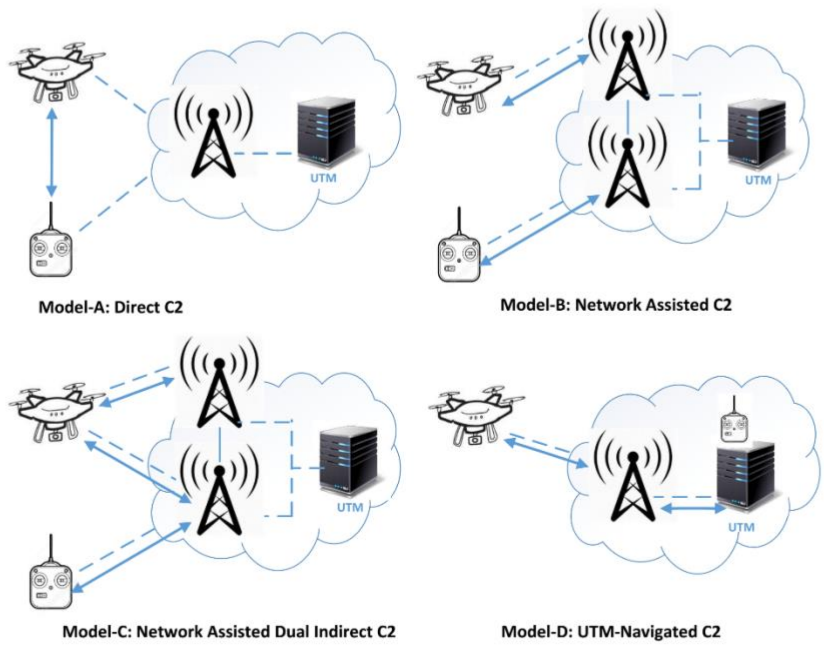

Figure 4: C2 Communication Models (Blue Arrows show C2 communication links)

In TS22.125 [19] the term UxNB is introduced referring to the radio access node on-board UAV, defined to be the radio access node providing connectivity to UEs, which is carried in the air by an UAV. The UxNB can also connect to the 3GPP core network like a normal ground base station [18].

2.3.1.1. Parameters Terminology/Definition

A full set of generic network parameters used in identifying network requirements, together with the related definition can be found in Table 1. Note that this is a reference for the purpose of completeness, and depending on the specific application, some of these may not be relevant.

Table 1: Definition of requirements considered for the use cases/applications analysis

Requirement	Definition	Type of value, unit of measure
Latency (3GPP TS22.261 [20])	End-to-end latency: the time it takes to transfer a given piece of information from a source to a destination, measured at the communication interface, from the moment it is transmitted by the source to the moment it is successfully received at the destination. It might be important as well to define as requirement the user plane latency, with the same definition but different end-points	ms
Packet loss [21]	Frame loss ratio: defined as the percentage of frames that should have been forwarded by a network but were not.	Ratio, no units
BER [22]	The bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unit less performance measure, often expressed as a percentage	Ratio, no units
Energy efficiency	The energy consumed for the end-to-end transport of a byte	J/byte
Security	Level of importance for attack prevention	qualitative
Data rate (DL/UL data rate)	Peak and average values of data rates should be provided (it could be useful or mandatory to provide also the user experienced data rate: the minimum data rate required to achieve a sufficient quality	bit/s

Requirement	Definition	Type of value, unit of measure
	experience (QoE), with the exception of scenarios for broadcast like services, where the given value is the maximum that is needed). The data rate is a time-variable function. It might be important to define some parameters (e.g. peak, burst, average) in order to better describe the data rate	
Jitter [23]	The short-term variations of a digital signal's significant instants from their ideal positions in time	ms
Packet delay variation [24]	Variation in latency as measured in the variability over time of the packet latency across a network. Packet delay variation is expressed as an average of the deviation from the network mean latency	ms
Reliability (3GPP TS22.261 [20])	Percentage value of the amount of sent network layer packets successfully delivered to a given node within the time constraint required by the targeted service, divided by the total number of sent network layer packets. The reliability rate is evaluated only when the network is available	Percentage, no units
Availability (ITU-T G.827 [25]) (3GPP TS22.261 [20])	Connection availability: the percentage of available time (w.r.t. total time) in a generic observation period of volume of airspace (defined as horizontal and vertical borders) the connection across the transport network. A bi-directional path or connection is in the unavailable state if either one or both directions are in the unavailable state. Communication service availability: percentage value of the amount of time the end-to-end communication service in the defined volume of airspace (understood as horizontal and vertical borders) is delivered according to an agreed QoS, divided by the amount of time the system is expected to deliver the end-to-end service according to the specification in a specific area.	Percentage, no units
Mobility	Fixed (no mobility: office, home) or max speed in movement (pedestrian or on a transportation mean: train, road vehicle, airplane, drone,…)	km/h
Traffic density	Traffic in a specific area	Mbit/s / km2
Connection density	Number of devices in a specific area	devices / km2
Coverage	Area of application interest	km2
Battery lifetime	Time of battery duration	Days, years
Data size	Size of the atomic packet or frame (average, max)	bytes

2.3.2. UAV Technology

UAV flights for 5G!Drones can be either fully manual, semi-autonomous, or fully autonomous. As seen in Figure 5 a fully manual flight, a human pilot (per UAV) sends C2 commands to the UAV with a remote control. It is the responsibility of the human pilot(s) to communicate with a UTM via PC for pre-operational flight planning.

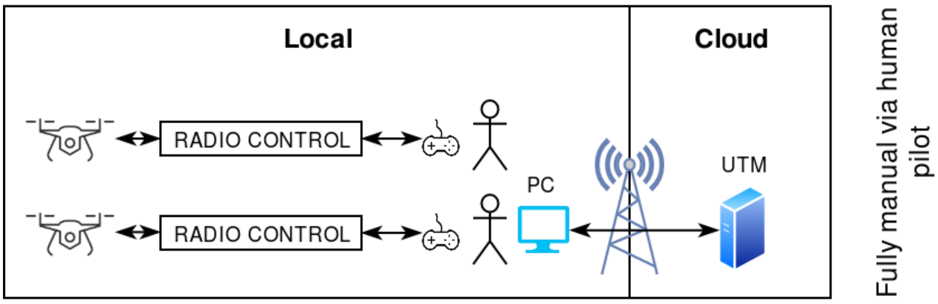

Figure 5: Fully manual flight architecture

In a semi-autonomous flight as visible in Figure 6, UAVs download missions with pre-defined waypoints from a ground control station (GCS). In flight, they stream telemetry data to the GCS. It is the responsibility of the GCS to communicate with the UTM for operational flight tracking. Some GCS support UTM integration, but if not, it is the responsibility of a human operator to communicate with the UTM.

Command and control of a smaller drone (for example DJI Mavic) is done by using a modified UGCS C2 platform [37]. UGCS has been used by many of verticals and also in EU SESAR-JU project [37] and has wide range functions to support fully-autonomous and semi-autonomous UAS flights.

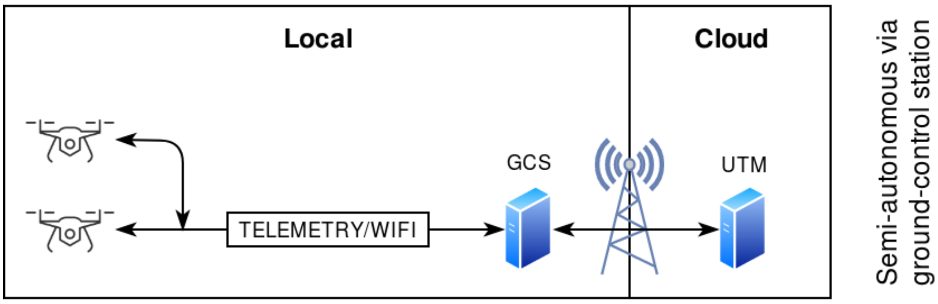

Figure 6: Semi-autonomous flight architecture

For a fully-autonomous flight, an autonomous control endpoint as well as a central command platform are required. Within the 5G!Drones project, for select trials Unmanned Life will provide its proprietary autonomous control endpoint (UL-ACE) which will communicate with the Unmanned Life central command platform (UL-CCP) to execute flights with a higher degree of autonomy. The UL-ACE offloads varying degrees of computation to the UL-CCP as permitted by network performance and sends or forwards C2 commands to the UAV via MAVLINK or the DJI SDK, as required.

5G!Drones use-cases consider two deployment models for fully-autonomous flights, depending on the placement of the UL-CCP. In the edge deployment model, the UL-CCP and UGCS are hosted on an edge server (Figure 7) and communicate with the UL-ACE and command and control center over 3G/4G/5G respectively.

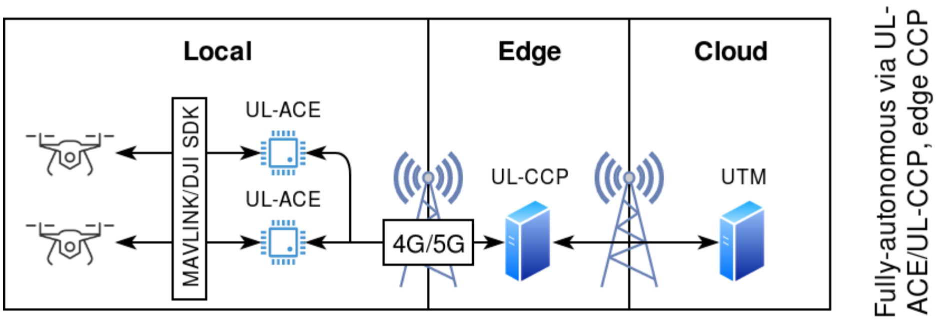

Figure 7: Fully-autonomous flight over edge architecture

In the local deployment model (Figure 8), the UL-CCP and UGCS are hosted on a local server and communicate with the UL-ACE and the UAS remote controller over either 3G/4G/5G, or local Wi-Fi respectively.

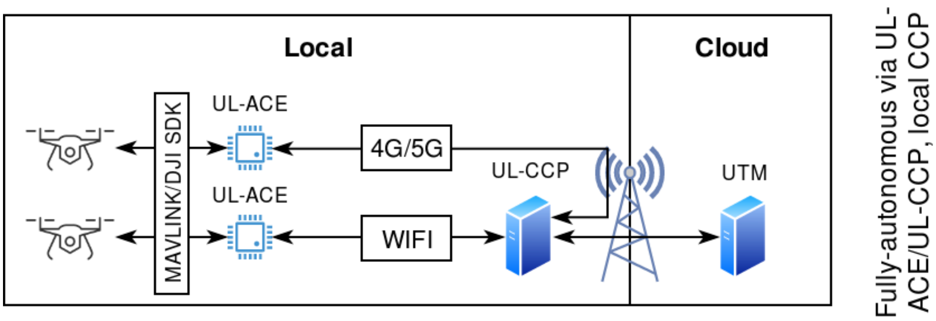

Figure 8: Fully-autonomous flight over Cloud architecture

It is the responsibility of the UL-CCP/ UGCS to communicate with the UTM for both pre-operational and operational flight planning and tracking.

2.3.2.1. UAS Systems

Today UAVs are generally connected to a ground control system via limited range communications over unlicensed spectrum. As a result, they tend to be restricted to visual-line-of-sight (VLOS) applications, limiting their usefulness for enterprises.

This section will differentiate between two types of UAS controllers: flight controllers, which provide basic low-level control for UAVs, and autonomous control endpoints, which provide higher-level autonomous capabilities to UAVs.

2.3.2.1.1. Flight Controller

A flight controller is an embedded system responsible for the low-level control of UAVs. Flight controllers implement control algorithms for:

- Position & velocity control
  - Input: desired position or velocity
  - Output: required attitude
- Attitude (orientation) & rate control
  - Input: desired attitude
  - Output: required motor speeds

Outputs from the position controller are input to the attitude controller. Outputs from the attitude controller are input to motor controllers, which are hardware components outside the purview of the flight controller.

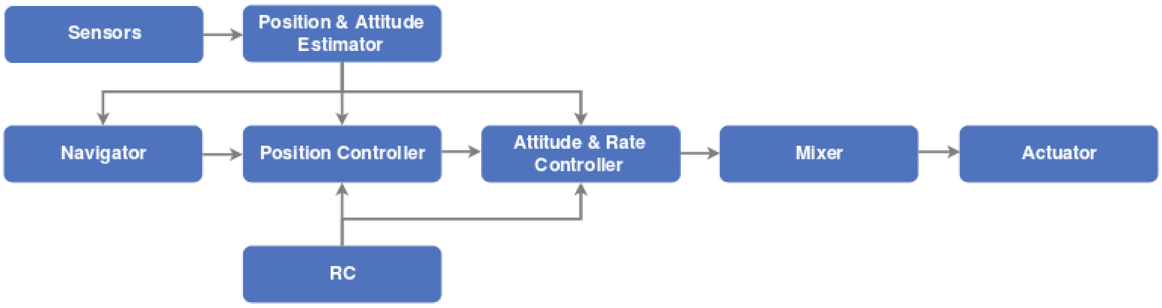

Figure 9: Flight controller input and output flow

During manual flight, a flight controller accepts position or attitude inputs from a human operator via remote control.

Some flight controllers additionally support basic, semi-autonomous use-cases with pre-defined waypoints. These flight controllers, given the appropriate sensor inputs, can generate their own position and velocity commands to navigate to the given waypoints.

2.3.2.1.2. Autonomous Control Endpoint

The autonomous control endpoint is a computing unit installed on a UAV in addition to a flight controller. This computing unit provides higher processing power than the flight controller and enables higher-level autonomous control by sending C2 commands to the flight controller. This communication takes place using a hardwired Universal asynchronous receiver-transmitter (UART) to USB connection directly between the autonomous endpoint and the flight controller.

For smaller drones, an autonomous mission loading system from the UGCS will be used. UGCS system communicates with the drones via remote controllers with 4G/5G smartphone (RC based drone controller) and UTM system. The communication between UGCS system and drone controller takes place over 4G/5G.

The autonomous control endpoint also communicates with a central command platform that coordinates the individual actions of a group of autonomous vehicles. This communication can take place over Wi-Fi, 4G, or 5G. A 5G network extends the capabilities of the system by:

- allowing the autonomous control endpoint to offload latency-critical processing tasks to the central command platform
- facilitating the transfer of real-time, high-bandwidth sensor data like high-quality video streams

2.3.2.1.3. Central Command Platform

For fully-autonomous use-cases using the Unmanned Life or UGCS architecture, it is necessary to host a central command platform (UL-CCP [46] or CAFA UGCS Platform [47]) for the coordination of autonomous control endpoints (UL-ACE or UGCS UAS remote controllers with smartphones). The UL-CCP or CAFA UGCS platform is responsible for managing the current task of managed endpoints and provides information to endpoints about the status of other endpoints in the area.

If network latency and bandwidth performance permit it, the UL-ACE endpoints or UGCS UAS remote controllers with smartphones, may also offload computational tasks such as image processing to the UL-CCP or to the CAFA UGCS platform (CUP). The UL-CCP and CAFA UGCS platform provides four layers of services:

- Data management, e.g.,
  - data caching
  - sensor data fusion
  - real-time data processing
  - integration of external sensor data
- Device management, e.g.,
  - M2M communication
  - swarm control
  - sensor and device status monitoring
  - battery management
- Mission management, e.g.,
  - task allocation to the swarm to achieve common goal
  - run-time replacement or allocation of endpoints to replace e.g., out-of-battery system
- Decision management, e.g.,
  - prediction and decisions driven by AI models
  - object recognition
  - computer vision

2.3.3. NB-IoT Applications

NB-IoT is the new narrowband radio technology developed for the Internet of Things (IoT). It is categorized as one of the licensed Low-Power Wide-Area Networks cellular technologies, which is especially suited for mMTC applications with low data rate that require low module cost, long battery lifetime and increased coverage. In this regard, new features are introduced, such as power saving mode and extended discontinuous reception, to enable massive deployment with limited human intervention. Moreover, NB-IoT inherits basic functionalities from the LTE system. Indeed, a deployed core network of an LTE network can be enabled to support NB-IoT with a software upgrade. As illustrated in Figure 10, NB-IoT is well positioned to address low-power, low-date-rate applications while being closely linked to LTE.

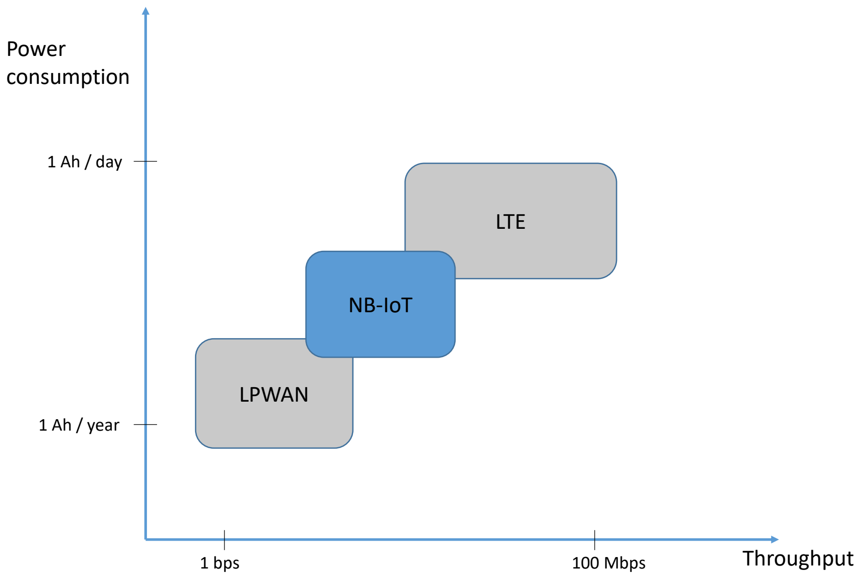

Figure 10: Positioning of NB-IoT in low-power, low-data-rate applications & being closely linked to LTE

3GPP has introduced the first IoT-specific UE in LTE Release 12 (also known as LTE Cat-0 or LTE-M). The underlying features include peak data rate of 1 Mbps over 1.08 MHz bandwidth and enable connecting a large number of devices from a single access point. In its LTE Release 13, 3GPP has standardized NB-IoT and addressed different objectives such as indoor coverage, support of massive number of low throughput devices, delay sensitivity and low-power consumption. Further standardization of NB-IoT is considered by 3GPP in its release 14 by addressing several topics including improved positioning support, multicast downlink transmission, etc. Table 2 provides some features of NB-IoT in the releases 13 and 14 of 3GPP.

Table 2: NB-IoT features as per releases 13 and 14

Parameter	Release 13	Release 14
Downlink Peak Rate	26 kbit/s	127 kbit/s
Uplink Peak Rate	66 kbit/s	159 kbit/s
Device Transmit Power	20 / 23 dBm	14 / 20 / 23 dBm

NB-IoT will provide a huge support for cellular networks and especially for mMTC applications, which reflect one of the service categories of 5G. Indeed, the IoT is in continuous expansion across different fields. It is envisioned that billions of IoT devices will require internet connections by 2020, creating disruptive innovations and transformative economic potentials. Smart metering, smart cities and smart agriculture are just a few examples. In this regard, NB-IoT will play a key role in enabling several use cases requiring a large number of mostly battery-powered devices that seldom transmit or receive small amounts of data.

2.3.4. LTE Cat-M1 IoT Applications

The 5G!Drones project aims to trial several UAV use cases that cover eMBB, uRLLC and mMTC 5G services. Drones are mobile but have a limited working time. Combination of drones and IoT devices would give cost effective solutions. For 5G!Drones project, it is important to note that Oulu University 5GTN and Eurecom 5G-EVE 5G test facilities have LTE-M networks.

LTE-M (LTE-MTC Machine Type Communication) has two standards Cat-M1 and Cat-M2. Specified by 3GPP as Cat-M1 and Cat-M2, the low power technology supports mobility, roaming, moderate data rates, real-time connectivity and voice support. Those devices are expected to substitute existing 2G-GPRS machine-to-machine devices. LTE-M together with NB-IoT will be the main 5G technologies for mMTC use cases and coexist with 5G NR by in-band operation [38].

LTE-M is designed for IoT sensors Machine Type Communication with high data rate and low latency. This standard is particularly effective for transferring photos and video clips from IoT cameras.

Table 3: LTE Cat-M1 v/s LTE Cat-M2 v/s NB-IoT comparison

Parameter	LTE Cat-M1	LTE Cat-M2	NB-IOT
Uplink	1Mbit/s	7Mbit/s	159kbit/s
Latency	10-15ms	10-15ms	1.6-10sec
Bandwidth	1.4MHz	5 MHz	180-700Khz

Notice that the figures are the technology requirements. In practice, maximum uplink data rate of existing CAT-M1 devices is approximately 375kbps.

LTE-M's ability to operate as a full-duplex system over a larger bandwidth also gives it an additional dimension with its capability to offer services of lower latency and higher throughput than EC-GSM-IoT and NB-IoT, qualities which allow LTE-M to support services such as voice over IP [39].

LTE-M can reduce battery consumption and improve indoor coverage compared to LTE. It was initially limited to a bandwidth of 1.4 MHz (Cat M1) in 3GPP release 13 and some coverage enhancements feature like frequency hopping and sub-frame repetitions. The new Cat-M2 was introduced allowing the optional use of 5 MHz bandwidth and voice enhancement in 3GPP Release 14. 3GPP Release 15 (2019) describes Wake Up signal (WUS) in the idle mode, Early Data Transmission and Latency optimization. 3GPP Release 16 (June 2020) describes coexistence with 5G NR and standalone LTE-M.

Compared to NB-IoT, the higher data rates provided by Cat-M1 means that more data can be sent through the network in a given timeframe. This would be hugely beneficial to applications that rely on speed of transition, for example security or mission critical reporting. Cat-M1 also has the advantage of being able to support voice transmissions, unlike NB-IoT, enabling support for a wider range of use cases. Notice that inversely, LTE-M consumes a little bit more energy than NB-IoT. Therefore, it is widely understood that the majority of operators will support both CAT-M1 and NB-IoT within the next couple of years [40][41].

NB-IoT and LTE-M are 3GPP standards that both are set to coexist with other 3GPP 5G technologies, so fulfilling the long term 5G LPWA requirements [42]. Mobile IoT is a GSMA term which refers to the 3GPP standardised Low Power Wide Area (LPWA) technologies using licensed spectrum bands such as NB-IoT and LTE-M [42].

As new 5G components that support 5G use cases in addition to LPWA are specified and rolled out in future, it is envisaged that NB-IoT and LTE-M will continue to coexist alongside these other 5G components [42].

2.4. High-Level 5G!Drones System Architecture

The 5G!Drones system involves three distinct actors, whose interaction allows understanding how the selected UAV use cases will be trialed over the project's 5G facilities. These actors are the UAV verticals, the 5G!Drones Trial Controller and the 5G facility. Figure 11 gives a high-level representation of the 5G!Drones system architecture, and highlights how the aforementioned actors interact.

The UAV vertical is the actor in charge of performing the trials of UAV use cases on top of a 5G infrastructure provided by the project's 5G facilities. To do so, it uses a dedicated set of APIs, referred to as Northbound APIs in this high-level representation, to interact with the second actor in this representation, the 5G!Drones Trial Controller. In addition, the 5G!Drones Trial Controller is in charge of enforcing the trial scenario by interacting with the third actor of this representation, the 5G facility. This interaction is allowed by APIs provided by both the 5G facility and the 5G!Drones Enablers, which are referred to as Southbound APIs.

Moreover, the role of the Trial Controller is to translate the high-level trial scenario description, provided by the UAV Vertical, to a set of 5G network components required to run on top of the 5G facility. It is worth highlighting that the 5G!Drones architecture is designed so that the Trial Controller allows the simultaneous run and control of multiple UAV use cases, demonstrating the capability of 5G to guarantee different service requirements at the same time.

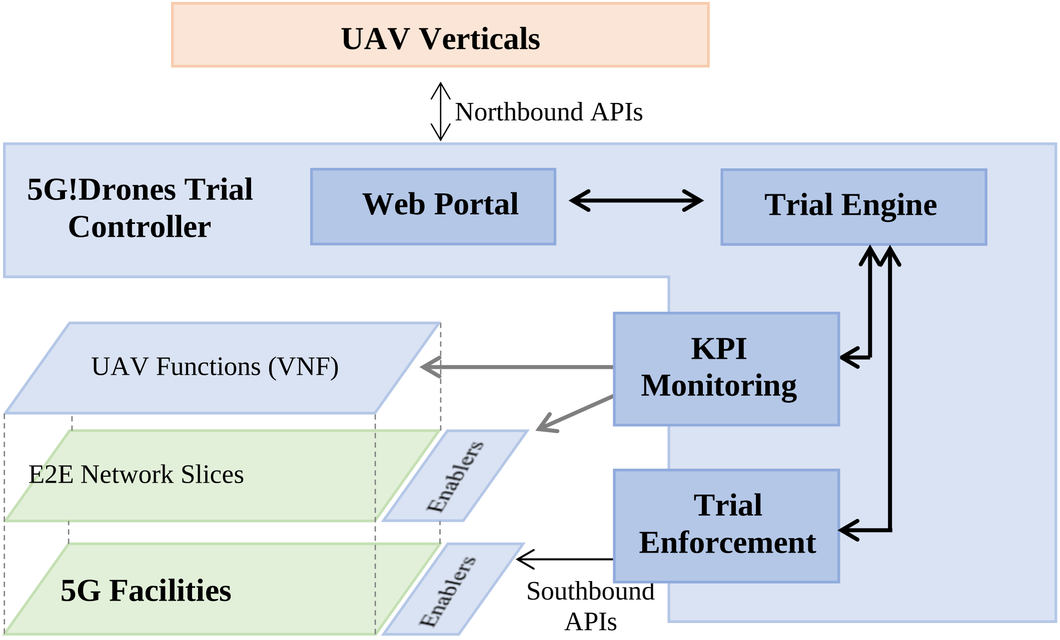

Figure 11: High-level representation of the 5G!Drones architectural components

The Trial Controller represents the main component of the 5G!Drones trial architecture. It includes the following sub-components: the Web Portal, the Trial Engine, the KPI Monitoring component and the Trial Enforcement component.

- The Web Portal is the component in charge of the interaction with the UAV Verticals, through the Northbound APIs. The Web Portal allows a UAV Vertical to describe the desired trial scenarios and to indicate the (5G and UAV) KPIs to measure for the considered scenario to trial.
- The Trial Engine takes as input from the Web Portal the scenario defined by the UAV Vertical. It is in charge of instantiating virtual and physical functions according to this trial scenario. In addition, it implements the lifecycle management of the trial.
- The Trial Enforcement component is in charge of enforcing the trial scenario elements forwarded by the Trial Engine module. To this purpose, it uses the Southbound APIs, which allow accessing the 5G Facility resources. Moreover, this component allows instantiating the network slices needed to run the trial, onboarding the required UAV service components, under the form of VNFs, gathering service-level KPIs, configuring the relevant monitoring information and returning to the Trial Engine the interfaces needed to retrieve monitoring information from the 5G Facility.
- The KPI Monitoring component is in charge to monitor the KPIs defined by the trial scenario, and requested by the Trial Engine.

The UAV Verticals can request to modify the configuration of the slices running the trials, via the Web Portal and APIs. Then, the Trial Engine will update its database and request the new resource allocation via the Trial Enforcement module. Finally, It is worth noting that in Figure 11, the elements highlighted in blue are designed and developed by the 5G!Drones project, whereas those in green are provided by the project's 5G facilities and the 5G!Drones system architecture itself will evolve based on the use case scenarios described below.

A detailed description of the 5G!Drones System Architecture can be found in deliverable D1.3.

3. 5G!DRONES USE CASES

3.1. 3GPP Defined UAV Use Cases, Generic Requirements and KPIs

Interest in using cellular connectivity to support UAS is strong, and the 3GPP ecosystem offers excellent benefits for UAS operation. Starting from meeting the radio access network challenges, 3GPP TSG RAN WG2 in May 2017 [17] has already concluded that the following parameters are important for the proper support of the UAV services, and a set of target values is discussed:

Table 4: TSG RAN Parameters to Support UAV [17]

Parameter	Target Value
Data Type	1. Command and Control (C2) 2. Application Data: including video streaming, images, sensor data, etc
Heights	Target up to 300 m above ground level
Speeds	Target horizontal speeds up to 160 km/h (~100 mph) for all scenarios
Latency	1. C&C: RAN2 understanding is 50 ms (one way from eNB to UAV) 2. Application Data: Latency value similar to LTE ground based users
Data Rates	1. C2: [60-100] kbps for uplink and downlink 2. Application Data: up to 50 Mbps for UL
C&C Reliability	As low as 10^{-3} Packet Error Rate
Position Accuracy	TBD

In 3GPP Release 16 UAV study, work has extended on the radio access to focus towards the identification of requirements to meet the worldwide needs of UAV operators, law enforcement, regulatory bodies and OEMs. The ubiquitous coverage, high reliability and QoS, robust security, seamless mobility and appropriate regulation standards are considered critical factors to supporting UAS functions over cellular networks towards a civil UAS ecosystem which can safely coexist with commercial air traffic, general aviation, public and private infrastructure, and the general population. In 3GPP 22.825 [13], a set of use cases were studied and some service and network requirements were identified and the requirements derived can be found in ANNEX 1: 3GPP Rel.16 22.825 Generic Use Cases Requirements. In summary, use cases under study include:

3GPPr16UC.1. Initial authorization to operate a UAV.

3GPPr16UC.2. Live data acquisition by UTM.

3GPPr16UC.3. Data acquisition from the UTM by law enforcement.

3GPPr16UC.4. Enforcement of no-fly zones.

3GPPr16UC.5. Enforcement of separation between UAVs operating in close proximity.

3GPPr16UC.6. Local broadcast of UAS identity.

3GPPr16UC.7. Differentiation between UAVs with integral cellular capabilities and conventional mobile phones attached to UAVs.

3GPPr16UC.8. Cloud-based Non-Line of Sight (NLOS) UAV operation.

3GPPr16UC.9. UAV based remote inspection of infrastructure.

And requirements are derived from these use cases, such as:

- UAVs and UAV controllers can send identification and personal information to UTM at initial authorization.
- The UTM can restrict authorization to operate a UAV.
- UAVs and UAV controllers can send location continuously to UTM and this may be augmented by network-provided location data.
- When operating beyond line of sight, UAVs must also support the broadcast of identity.
- Law enforcement can query UTM for location and identity information.
- The network can differentiate types of UAVs, such as UAV with integral cellular capabilities and UAVs without integral cellular capabilities (e.g. a UAV carrying a regular ground base smartphone)
- The 3GPP system can help to enforce the authorization for an in-flight UAV to operate basing on UAV subscription information or under the instructions from UTM

In 3GPP release 17, in TS 22.125 [19] an extended list of requirements is provided in order to meet the business, security, and public safety needs for the remote identification and tracking of UAS linked to a 3GPP subscription. Through the Technical Specification “Enhancement for Unmanned Aerial Vehicles [18] more scenarios are proposed:

3GPPr17UC.1. UAV supporting high resolution video live broadcast application

3GPPr17UC.2. Radio access node on-board UAV

3GPPr17UC.3. UAS command and control (C2) communication

3GPPr17UC.4. Simultaneously support data transmission for UAVs and eMBB users

3GPPr17UC.5. Autonomous UAVs controlled by AI

3GPPr17UC.6. Isolated deployment of radio access through UAV

3GPPr17UC.7. Radio access through UAV

3GPPr17UC.8. Separation of UAV service area

3GPPr17UC.9. Service experience assurance

3GPPr17UC.10. Service availability to UAVs needs

3GPPr17UC.11. Swarm of UAVs in logistics

3GPPr17UC.12. Changing UAV Controller

3GPPr17UC.13. Steering KPIs of UAV

As a result of this work, a new set of consolidated requirements is specified, as summarised in ANNEX 2: 3GPP Rel.17 22.829 Generic Use Cases Requirements and specific KPIs are set, discussed per application and use case. The key KPIs that must be considered for future reference are summarised in below tables.

Table 5: Consolidated KPIs for UAV [18]

Services	Uplink data rate (UAV to Net) Note 7	Service control data rate (Net to UAV)	Data latency	Control latency	Positioning accuracy	Altitude	Higher accuracy location latency	Region
8K video live broadcast	100 Mbps	600 Kbps	200 ms	20 ms	0.5 m	<100 m	-	Urban, scenic area
Laser mapping/ HD patrol	120 Mbps Note 1	300 Kbps	200 ms	20 ms	0.5 m	30-300 m	-	Urban, rural area, scenic area
4*4K AI surveillance	120 Mbps	50 Mbps	200 ms	40ms Note 2	0.1m	<200 m	10 ms Note 3	Urban, rural area
Remote UAV controller through HD video	>=25 Mbit/s Note 4	300Kbit/s	100 ms	20 ms	0.5m	<300 m Note 5	-	Urban, rural area
Telemetry	0.012 Mbps w/o video	Note 6	-	Note 6	-	-	-	Urban, rural, countryside
Real-Time Video	0.06 Mbps w/o video	Note 6	100 ms	Note 6	-	-	-	Urban, rural, countryside
Video streaming	4 Mbps for 720p video 9 Mbps for 1080p video	Note 6	100 ms	Note 6	-	-	-	Urban, rural, countryside

NOTE 1: The flight average speed is 60km/h.
NOTE 2: The latency is two-way network delay, i.e., UAV to Net plus Net to UAV.
NOTE 3: The latency is the time of the 5G system provide higher accuracy location information of a UAV to a trusted third party.
NOTE 4: Referring to TS 22.125 clause 5.3, the absolute flying speed of UAV in this service can be up to 160km/h.
NOTE 5: Referring to TR 36.777, the maximum altitude is 300 m.
NOTE 6: Relevant KPIs to be defined in next document revision. The KPIs is also compatible for service 1~4.
NOTE 7: In addition to service data, it is possible to transmit the following UAV management parameters simultaneously.

- Flight time of UAV
- Real-time Position, Height and Moving Speed of UAV
- Vibration Coefficient and Sloshing Coefficient of UAV
- Current pitch angle, heading angle and roll angle of UAV
- Status of Airborne Sensors such as Gyroscope and Barometer of UAV
- Working state of UAV satellite positioning module
- Battery Volume and Working State of Unmanned Aerial Vehicle
- UAV Control Link State

Specifically for the support of high-resolution video application, the 3GPP specification 22.829 considers that the performance requirements of UAV to support VR live broadcast application are as reported in below table:

Table 6: KPIs for High Resolution Video Application [18]

Time	Video resolution	Upload data rate (UL)	Remote control data rate (DL)	Video latency	Control latency	Positioning Accuracy	Altitude	Region
2018	1080P	6 Mbps	300 Kbps	500ms	100 ms	1m	<100 m	City/ Scenic Area
	4K	25 Mbps				1m		
2020	4K	25 Mbps	600 Kbps	200ms	20 ms	0.5 m		
	8K	100 Mbps				0.5 m		

Table 7: KPIs considered for C2 communication Use Cases [18]

Traffic Type for C2	Bandwidth	Latency
Command and Control	0.001 Mbps	VLOS: 10 ms Non-VLOS: 360 ms
Telemetry	0.012 Mbps w/o video	1 sec
Real-Time	0.06 Mbps w/o video	100 ms
Video Streaming	4 Mbps for 720p video 9 Mbps for 1080p video [30 Mbps for 4K Video]: optional	100 ms
Situation Aware report	1 Mbps	10-100 ms

Table 8: KPIs for Changing UAV Controller [18]

Application	Upload data rate (UL)	Remote control data rate (DL)	E2E latency	Control latency	Positioning Accuracy	Altitude	Region
Remote controller through HD video	25Mbps	300Kbps	<200ms	20ms	0.5m	<100m	Urban, Rural, countryside

3.2. Common Requirements with Respect to Experimentation

Apart from the technical requirements driven by the execution of the use cases trials, a number of requirements are derived from the need to exploit existing 5G facilities to execute these trials. In order to formalise the pre-requisites so that to properly support these executions, addressing the metadata that needs to be exchanged, such as use case trial parameters as well as monitoring data and metrics collected, the table below summarises some key generic requirements:

Table 9: Common requirements for Experimentation on 5G Facilities

Requirement	Layer	Priority	Description
Open APIs towards the experimenter	Facility	Essential	The facility should expose open APIs enabling the Vertical experimenter to access the facility, define and conduct experiments as well as retrieve the results
Facility capabilities	Facility	Essential	The facility should provide a list of experimental capabilities.
Experiment execution	Facility	Essential	Need to Support faster and more flexible allocation of network resources (E2E deployment in 90 min or less).
Experiment execution	Facility	Essential	The platforms should provide both commercial and experimental UEs with open APIs to allow flexible configuration.
Experiment execution	Facility	Essential	The network shall allow operators to optimize network behavior (e.g., mobility management support) based on the mobility patterns (e.g., stationary, nomadic, spatially restricted mobility, full mobility) of a UE or group of UEs.
Drone experimentation	Drones	Optional	Need to Support faster and more flexible drone deployment and operation, per needs of the trial demonstration.
Drone operation management	Drones	Essential	For experiments, the drones shall be able to provide sufficient control over the stages of experimentation cycle over the deployed 5G network. A backup control link shall be available at any time to ensure safe operations.
Experiment execution	Drones/Facility	Essential	The drone should provide standard multimedia transmitting capabilities over IP. The transmission should be end-to-end in terms of 5G, involving all new 5G components (UE, NR and packet core).
Experiment execution	Drones	Essential	The UAS operations shall be safe at any time of the experiment.

3.3. Use Case Scenarios Structure

The structure of each use case scenario description has been standardized to ensure coherency and ease-of-readability for the reader. A brief summary of each sub-section within the use case scenario description is provided below.

3.3.1. Detailed Description of Scenario

As the name suggests, this section presents a detailed description of the use case scenario. The goal of this section is to provide the reader an understanding of the motivation behind trialling the scenario as well as a summary of the various components that will be employed to enable a successful trial.

3.3.2. High Level Architecture

The high-level architecture section provides a visual/descriptive overview of all the interactions between the identified components necessary to trial the scenario.

3.3.3. UTM System

A UTM system is one of the key components necessary to trial use case scenarios involving UAVs both within this project and in real-life scenarios. The goal of the 5G!Drones project is to employ a

pre-operational UTM system that will replicate the functions of the operational UTM system. This pre-operational UTM system will be used for each use case scenario and will be deployed on infrastructure provided by the respective partners and connect to the trial facilities via IP network.

It will integrate with the Trial Controller, UAV operator, UAS system, and trial facility systems to:

- Provide basic U-space services
  - Registration
  - E-Identification
- Provide flight planning assistance
  - Geo-awareness & strategic deconfliction
  - Includes network aspects
- Provide tracking & monitoring for UAV operations
- Validate 5G KPIs relevant for UTM systems
- Facilitate operational test execution
  - Including 2-way non-verbal communication between operation center and relevant traffic management services (ATS)

The pre-operational UTM is foreseen to interface with the operational systems in order to meet the relevant regulatory requirements applicable with respect to the test facility.

3.3.4. UAS System

This section provides a short summary of the UAS system that is planned to be used to control and manage the UAVs that will be employed during the trial. As identified in Section 2.3.2, the UAVs can be deployed either manually, semi-autonomously, or full-autonomously.

3.3.5. Drones

This section provides a detailed overview of the UAVs that will be used as a part of the scenario trials.

3.3.6. 5G Radio Access Network

The goal of this section is to provide a glimpse into the current 5G radio access network capabilities of the 5G test facility where the trial is going to be held. Further details regarding this section can be found in D1.2 - “Initial description of the 5G trial facilities”.

3.3.7. 5G Core Network

Similar to the above section, the purpose of this section is to introduce the 5G core network capabilities of the 5G test facility to the reader. A detailed description of this section can be found in D1.2.

3.3.8. Mobile Edge Network

The mobile edge network section also follows the same technique as the above two sections and likewise detailed information about it can be found in D1.2.

3.3.9. Application Servers & Devices

This section describes all the applications that need to be installed on the edge/cloud to enable a successful trial of the use case scenario.

3.3.10. Security and Regulation

Since the scenarios will be trialled at various 5G test facilities across Europe (France, Finland, and Greece), it is critical that the security measures and regulations specific to each use case scenario within those countries are followed before the deployment of the trial. The purpose of this section is to provide the reader with an overview of the identified security measures and regulations.

3.3.11. Scenario Interactions High Level Workflow

There are multiple stages that need to be followed before, during, and after the trial has been conducted in order to ensure a successful trial. This section provides an overview of these identified steps.

(A) Preparation stage: Before it is conducted, each trial must go through a preparation stage to ensure all administrative processes and technical abilities of UAVs have been checked and complied with. These steps are common across all outdoor use case scenarios and need to be fulfilled before moving onto the next stage:

i. Propose specific routes for the scenario
ii. Prepare detailed flight plan
iii. Agree on a date for the validation demonstration
iv. Prepare SORA
v. Obtain necessary authorizations to fly (aviation authority and 5G test facility approval)
vi. Prepare multiple drones with the goal to fly them
vii. Check and agree on their individual capabilities with respect to:
    a. flight plan proposed
    b. connectivity,
    c. flight management,
    d. amount of data to be sent/received,
    e. security
    f. other

(B) Preliminary flight stage: Post the successful completion of the preparation stage, the trials will undergo a preliminary flight stage where the following steps will be followed to ensure that the UAVs are ready to be used for the trials:

i. Prepare trial site & ground teams
ii. Prepare drones
iii. Pre-flight checks of drones
iv. Manual test flight with one drone to test basic capabilities of the system within the 5G test area (applicable only for semi-autonomous and fully-autonomous trials)
v. Use the 5G!Drones Trial Controller to set up the demo trial by providing the information needed through a wizard process

(C) Flight stage: The flight stage is the stage where the proposed scenario will be trialled. The steps within this stage will be specifically tailored to fulfil all the criteria of the use case scenario.

(D) Analysis & reporting: Post the successful completion of the trial, the data gathered will be used to for analysis and reporting purposes. This stage also includes several steps such as:

i. Flight telemetry data and sensor data is shared with and stored on the KPI monitoring module of the Trial Controller
ii. Data is aggregated and analysed

iii. Results and conclusions are consolidated in a trial report

3.3.12. Use Case Network and Drone Critical Parameters

This section outlines that various network and UAV specific parameters that are necessary to implement a trial of the use case scenario.

3.3.13. Target KPIs

The purpose of this section is to describe the various KPIs that need to be met in order to determine the success of a trial.

3.3.14. Use Case Requirements

The use case requirements section is divided into two sub-sections i.e. functional and non-functional requirements. As the name suggests, the functional and non-functional requirements necessary to trial a scenario have been provided in this section.

3.4. Use Case Scenarios

3.4.1. Use Case 1: UAV traffic management

3.4.1.1. Scenario 1: UTM command and control application

C2 application between drone and drone controller will be used for all other scenarios mentioned in this document, regardless if they will require fully autonomous, semi-autonomous or fully manual steering of a drone, and regardless if the flight is in VLOS or BVLOS. The main objective for the project is that C2 is performed using 5G connectivity, which means that each trial will utilise one of the three C2 communications models defined by 3GPP mentioned already in Section **Error! Reference source not found.**, in Figure 4 – model-B, -C or -D and new functionalities offered exclusively by 5G networks, like slicing with customised quality of service.

We can distinguish for our scenario two models of interaction between the drone and GCS, which have significantly different requirements demanded from 5G network in terms of throughput:

- C2 based on telemetry.
- C2 with video stream (telepresence) – video can be used by human operator with VR goggles in FPV. Instead of a human operator, an AI algorithm which is using video streaming to control the drone, can also be imagined.

3.4.1.1.1. Detailed Description of Scenario

The most important driver for this scenario is to enable the BVLOS applications, i.e. long range missions where the drone operator does not have visual contact with the drone: BVLOS operations enable the most promising drone applications with the most added value to businesses such as long-range infrastructure inspection, long range drone delivery, large area mapping etc.

Those exciting applications are currently blocked because it is difficult to ensure that the drone will not collide into another aircraft - helicopter, general aviation, other drones, etc.

The answer to such a challenge to unblock those commercial applications is to ensure:

- The full understanding of air traffic in the proximity of the drone – during the planning phase and during the flight.
- Remote near real-time command and control of the drone – controlled by machine, human or mixed.

- That relevant Air Navigation Service Provider (ANSP) has real-time understanding about current status of the mission and can intervene in case of emergency.
- That in case of foreseen or unforeseen emergency, the drone will act according to the defined scenario or contingency measures in place.

To fulfil these needs during the whole flight, the full telemetry of the drone, in near real-time with a high level of accuracy and precision, is required. Knowing where a drone is compared to the rest of the air traffic is essential for collision avoidance and a general shared airspace is an essential feature for both drone operators and aviation authorities. This entails full and continuous connectivity to the network, with low latency and high reliability, which is expected from 5G, which brings new features, like network slicing mechanisms, introduction of MEC and antenna beamforming.

It will be important to adapt existing UTM functionalities to be able to cooperate with 5G network on different stages of mission:

- Planning – defining the route according to mobile network coverage and what is needed in terms of resources from 5G network.
- Validation – examining the possibility to fulfil drone operator needs, in terms of coverage, existing infrastructure, functionality and capacity.
- Execution – how to resolve risks and emergency situations caused not only by traffic situation, but also related to the radio connection from the 5G network:
    - Supervising the ongoing mission and ensuring that it runs according to the plan.
    - A proper handling of situation, in case of temporary or permanent loss of radio connection between the drone and serving 5G base station.
- Post-flight analysis for constant improvement of the procedures and system.

UC1:SC1 – Deployment 1 - Command and Control (C2) with telemetry

In this case, the C2 will be based on the real-time telemetry data streamed to the controller on the ground (GCS) from the different modules embedded within the drone. As described in Section 2.3.2, the location of GCS will be most likely at the EDGE of 5G network, close to the 5G base station. The streamed data will come from modules like: GNSS, accelerometer, gyroscope, compass, barometer, airspeed sensor, etc.

For reliable reception of such information a 5G network slice with uRLLC will be required, as to ensure the very fast, near real-time two-way communication between drone and GCS.

This scenario will use fully autonomous mode, i.e., the drone will perform a point-to-point pre-defined and pre-approved flight, passing through a number of pre-programmed waypoints. Different flight parameters between waypoints (e.g. height, speed etc.) can be also planned and requested. It is planned to use up to 3 drones flying simultaneously and independently, each on its defined route.

UC1:SC1 – Deployment 2 – Command and Control (C2) with telemetry and video

In this case, in addition to uRLLC slice for deployment 1, a video used for steering the drone will have to be broadcasted from the drone. To ensure the required grade of details, the quality of the video should range from HD to 4K. This means, beside the uRLLC slice for telemetry, it will be required to also have an eMBB slice with appropriate bandwidth in UL and DL. As the video stream is transmitted from drone to GCS, the UL bandwidth requirement is higher than DL bandwidth.

The video will be streamed within a VR device from Nokia, which is presented below. It can also be envisaged that the video stream is sent to an AI device, which can steer the drone based on the received images.

The use of FPV for steering means that at least a part of the flight, between two of the programmed waypoints throughout the drone route, will be performed in fully manual mode, where the pilot wearing goggles will have full control over the drone. The rest of the route will be flown in autonomous mode. Similar to deployment 1, it is planned to use in the same time up to 3 drones flying simultaneously and independently, each on its own defined routes.

Figure 12: Nokia Oculus VR goggles and controllers.

<u>Number of controlled drones and other aerial traffic</u>

This scenario aims to demonstrate a UAV traffic command and control application, which will manage a certain number of flying drones (up to 3 drones). The C2 application should demonstrate features such as automatic collision avoidance, especially in the case of multiple drones flying simultaneously and independently, which requires sending large amounts of data in near real-time to assess the potential risks in the sky and enable an enhanced flight awareness of all types of flying objects. The other flying objects (passenger aircrafts, helicopters and small aircrafts) will be also included in the picture, thanks to the capabilities of INVOLI system which provides comprehensive air traffic awareness even at low altitude for drone flights [48].

3.4.1.1.2. High Level Architecture

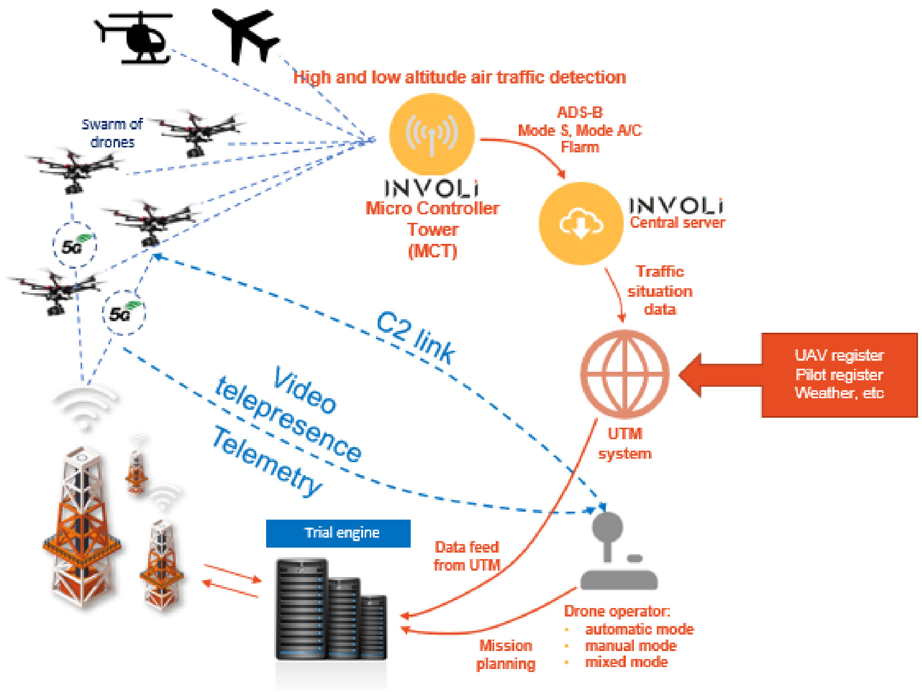

Figure 13: UC1:SC1 - High level architecture.

3.4.1.1.3. UTM System

Please refer to Section 3.3.3.

3.4.1.1.4. UAS System

For deployment 1, the fully autonomous edge deployment is envisaged, whereas for deployment 2, it is planned to use a hybrid mode, where part of the mission will be autonomous and another part will be controlled by human. In this case, to ensure low latency, the human operator should be placed close to the edge computing component.

3.4.1.1.5. Drones

Table 10: UC1:SC1 – Drone Information

Manufacturer	DJI	DJI
Model	Matrice 210	Mavic-2
Number of UAVs	1	2
Tether	No	No
Max Take Off Weight	6 kg	1.1 kg
Max Payload	1.4 kg	190 g
Hovering Time	16 min (1.4 kg payload)	15 min (190 g payload)

	35 min (no payload)	25 min (no payload)
Limitations	Max Wind Resistance 14 m/s	Max Wind Resistance 20 m/s
Resistance to Interferences	Default UAV control is over DJI 2.4 GHz and 5.8 GHz radio link. Different bands compared to 5G but small risk of harmonic frequency interference. Since drone control is over 5G, the risk of interference is larger so separate slice for C2 should be used.	Default UAV control is over DJI 2.4 GHz and 5.8 GHz radio link. Different bands compared to 5G but small risk of harmonic frequency interference. Since drone control is over 5G, the risk of interference is larger so separate slice for C2 should be used.

3.4.1.1.6. 5G Radio Access network

EURECOM site (in Sophia Antipolis, France) which is part of the French site of the 5G-EVE ICT-17 project will be used to conduct this trial.

An OpenAirInterface RAN (OAI-RAN) solution will be provided by EURECOM for this use-case scenario. The initial deployment will be based on Non-Standalone mode (NSA) Option 3. Functionalities offered by this solution include:

- 4G and 5G connectivity (Non-Standalone),
- NB-IoT,
- Functional split: CU, DU and RRU,
- FlexRAN to enable RAN programmability (only for 4G, 5G support in 2021).

The hardware platform, provided by EURECOM, is going to use the ETTUS N300 boards together with a powerful laptop with an 8 core i9 processor. A special adaptor will be used to be able to connect the Thunderbolt 3 interface of the laptop with the 2x10Gbit Ethernet interface of the USRP. An additional RF frontend and antenna will provide enough output power and amplification to operate in an outdoor environment. All the CU, DU components will run in Kubernetes cluster deployed in EURECOM Data Center.

More details describing the EURECOM's infrastructure, current deployment state and plans can be found in deliverable D1.2.

3.4.1.1.7. 5G Core Network

As EURECOM will deploy 5G NSA, then the deployed Core Network is a 4G Evolved Packet Core (EPC) based on OpenAirInterface (OAI). It is composed by a Mobility Management Element (MME), Home Subsriber Server (HSS) and SPGW (Serving and Packet Gateway). The SPGW is CUPS (Contol and User Plan Separation)-ready; i.e. Divided into a SPGW-C (Control Plan) and SPGW-U (Data Plan). All the entities run as Docker container on top of a Kubernetes Cluster, orchestrated by a home-made orchestrator.

3.4.1.1.8. Mobile Edge Network

For the purposes of this use-case scenario, EURECOM will deploy an ETSI-compliant MEC platform (MEP) and orchestration components. This service package includes a minimal-footprint edge VIM developed by EURECOM on top of Kubernetes, offering a REST NBI for onboarding, instantiation and lifecycle management operations of edge application instances.

The Mobile Edge Orchestrator conforms to the ETSI MEC 010 [MEC010] specification for the interface towards the OSS/BSS (Mm1 reference point). It supports traffic redirection/offloading services (Mp1 and Mp2 reference points), and a Radio Network Information Service (Mp1 and Mp2 reference points), using RESTful and publish-subscribe APIs [MEC012]. The MEP will assist in running applications and performing related processing tasks closer to first edge applications, which reduces the latency and the traffic in the microwave link.

3.4.1.1.9. Application Servers & Devices

3.4.1.1.9.1. CAFA Tech UGCS based platform

The CAFA Tech UGCS based platform will be hosted on an edge or local server. This platform is responsible for:

- Planning and Coordinating UAVs missions.
- Task allocation to UAVs for mission management.
- Processing of sensor data for operational decision-making.
- Responding to UTM mission change requests.
- Forwarding of telemetry data to pre-operational UTM systems.
- Providing access to GPS RTK (Real Time Kinematic) corrections.

The CAFA Field software will be used to process sensor data for operational decision making. In addition, the CAFA central server will be used for data storage, coordination and big data analyses.

3.4.1.1.9.2. INVOLI air traffic awareness platform

INVOLI Micro Controller Tower (MCT) is a ground station detecting ADS-B, Mode S & Mode A/C[1], FLARM signals from aircraft and cooperative drones. Its main functions are:

- Allows drone operators to display all surrounding aircraft equipped with ADS-B, Mode-S, Mode A/C, FLARM.
- Enhanced flight awareness for all drone missions - anticipation of any incoming collision
- Alarm on the platform if an aircraft is on a collision course with the drone.

The drone operator and relevant ANSP have the same picture of the traffic situation in the airspace and are able to react and easily coordinate in case safety issues need to be addressed.

3.4.1.1.9.3. Unmanned Life Central Command Platform

The UL-CCP will be hosted on an edge server as described in Section 2.3.2. It is responsible for:

- Coordinating UAVs in a multi-robot environment.
- Task allocation to UAVs for mission management.
- Processing of sensor data for operational decision-making.
- Responding to UTM mission change requests.
- Forwarding of telemetry data to pre-operational UTM systems.

3.4.1.1.10. Security and regulation

The EURECOM site has a corridor of 200m length and 15m of height, where the initial tests in LOS conditions can be performed without any formal permission. For the BVLOS tests, the special

[1] if at least 4 MCTs are installed and if 1030 MHz interrogation is available

request for the flight(s) will be submitted to the relevant French authorities. It will include Specific Operations Risk Assessment (SORA) process, which is a multi-stage process of risk assessment aiming at risk analysis of certain unmanned aircraft operations, as well as defining necessary risk mitigations and robustness levels. For example, due to the particularities of the flights, the proximity of the residential areas, main roads or simply the places with random people might have to be avoided.

In this scenario, a special focus on security and the integrity of the flights will be put, as to avoid the situation where a malicious third party takes control over the operating drones, since such focus is essential to deploying UAS operations in urban and critical environments. The 5G security functions offered by the platform of concerns will be leveraged upon here with focus on E2E network slice security and specific security requirements from each of the targeted slices.

In case the remote controller or CUP software would fail the flight controller is configured to return to home safely and land (RTH). Also Mavic drones will have a safety pilot on standby with a remote control who will be able to take over the autonomous mission at all times.

During the missions the drones will be deployed with a minimal safe distance 30m between them to ensure safety even in case of drops in GPS quality and drifts. DJI Mavic Accuracy (P-Mode, with GPS): Vertical: ±0.5 m, Horizontal: ±1.5 m.

During the trial a human operator who will have the technical capabilities to intervene and take control over the drone will be present on site. As per the French regulations, the human operator will possess a UAV license. In addition to this, other certificates (such as the Certificat de compétences) will be acquired in accordance with the trial being conducted.

3.4.1.1.11. Scenario Interactions High Level Workflow

This is the scenario description for the case, where BVLOS flight is planned, which requires approval form authorities responsible for managing the aerial traffic in the vicinity of EURECOM site. Probably we will make several iterations, starting with one drone, and next testing more complex situation with three drones flying simultaneously.

It's envisaged that BVLOS flights will be preceded by VLOS trials, in the trial corridor close to EURECOM's site, where no approvals are required. The procedure for these trials should be similar to the one of BVLOS, excluding the formal approval process.

(A) Preparation stage: Please refer Section 3.3.11.

(B) Preliminary flight stage: Please refer Section 3.3.11.

(C) Flight stage

i. Use the Trial Controller to initiate the drone trial.
ii. Drones connect to the network and provide feedback once connectivity is established
iii. Autonomous take off of the drones.
iv. Drones follow the agreed flight plan and stream the telemetry data (and video in case of deployment 2), which is used to oversee that the mission is performed as planned.
    a. The drone reports its position periodically.
    b. The drone reports some non-nominal event.
    c. The drone can receive information with regards to redirection due to dynamic conditions (ex: emergency / priority mission, or restrictions imposed by ANSP such as a no-fly zone).
    d. The drone can receive information with regards to re-routing.

e. The control of the drone with video FPV capability is taken over for some time by the human operator, who manually controls the drone on the previously determined (part of the) route. When final waypoint for manual control is reached, the drone continues in autonomous flight mode. In case the drone drifts away from the pre-determined path for the manual flight or in case of emergency, autonomous mode will be restored, and safety procedures applied.

f. The drone shares in real-time airspace-relevant data with other sky stakeholders that may improve overall performance.

v. Once drone arrives to the end point of the mission, it lands autonomously.

vi. End of flight.

(D) Analysis & reporting: Please refer Section 3.3.11.

A summary is presented below:

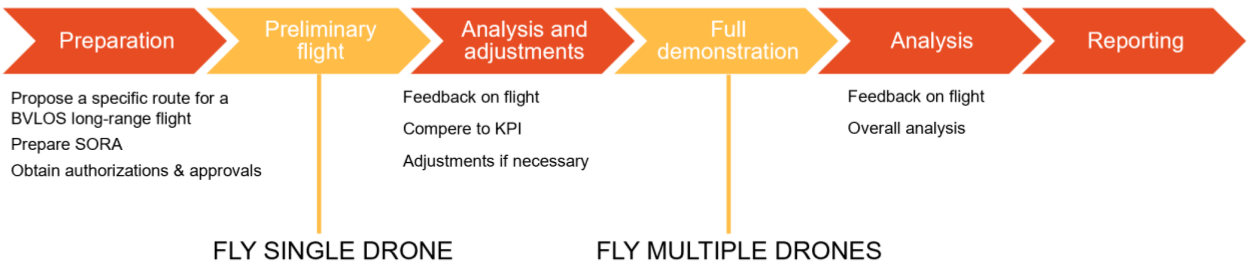

Figure 14: Different stages for test preparation, execution and conclusions

3.4.1.1.12. Use Case Network & Drones Critical Parameters

Table 11: UC1:SC1 – Network critical parameters

Network Critical Parameters	Value
Data Type	**C2** between GCS (5G edge site) and UAVs
	Telemetry from UAV to GCS (5G edge site)
	Video stream for FPV from UAVs to Nokia VR goggle (5G edge site)
Latency	**C2**: <= 10ms one-way between UAV and gNB
	Telemetry: <= 10ms from UAV to GCS (5G edge site)
	Video stream for FPV: <=20ms from UAV camera to Nokia VR goggle (5G edge site)
Data Rate	**C2** (256 kbps) + **Telemetry** (800kbps) between GCS and UAVs with C2 messages having always higher priority over telemetry messages
	Video stream for FPV: in UL 9 Mbps for HD and 30Mbps for 4K
Error Rate	**C2**: less than 10^{-5} block error rate
	Telemetry: less than 10^{-3} block error rate
	Video stream for FPV: usual values for good quality HD or 4K video reception

Table 12: UC1:SC1 – Drone critical parameters

Drone Critical Parameters	Value

Flight Height	Max 120 m AGL. This is the limit for VLL airspace per Eurocontrol definitions.
Speed	Max 70 km/h (~20 m/s) linear velocity
Position accuracy	<1m with GPS RTK system (if available) Around 3 m – An **EGNOS** (European Geostationary Navigation Overlay Service) enabled receiver provides location accuracy to within 3 meters. Without **EGNOS**, a standard GPS receiver only provides **accuracy** to 17 meters.

3.4.1.1.13. Target KPIs

Quantitative KPIs to be measured during execution of this use-case are summarized in the table below.

Table 13: UC1:SC1 – Target KPIs

KPI	Description	Target Value
Service Deployment Time	The time required to provide mobile data service via UAVs, measured from the receipt of a use-case start request from the experimenter	<= 90 min
Service Area	Geographical area over which service is available	>= 4 km^2
C2 Latency	Latency between software pilot and UAV in sending control & command messages – this value has a hard limit of 10ms (one-way) to ensure that software systems have sufficient time to compute and send an appropriate control input with enough regularity to avoid flight instability	<= 10 ms
Video Streaming Data Rate for FPV	Data exchange speeds for streaming video feeds from UAVs to experimenters	>= 9Mbps for HD >= 25Mbps for 4K

3.4.1.1.14. Use Case Requirements

3.4.1.1.14.1. Functional Requirements

UC1.SC1-FUNC1	The mobile network must support 2 concurrent service slices		
Priority	Essential	**Justification**	Use case driven
Description	Two different services shall be supported by the use case: 1. Command and Control of the drone (uRLLC service) 2. Video Streaming for FPV (eMBB Service) – important for deployment 2 test		
Related Component(s)	The 5G core and Access network		

UC1.SC1-FUNC2	Mobile edge capabilities		
Priority	Essential	**Justification**	Use case driven
Description	The provision of the uRLLC service for the drones C2 mandates the existence of a MEC in EURECOM		
Related Component(s)	The 5G core and Access network		

UC1.SC1-FUNC3	Enforcement of separation between UAVs operating in close proximity		
Priority	Optional	**Justification**	3GPP r.16 22.825 UC5
Description	The requirements defined in [13] use case 5 for collision avoidance in cases that drones are flying in close proximity are relevant and should be considered when the technology is made available Drones C2 systems should use GPS RTK solution to improve precision of drone positions.		
Related Component(s)	The 5G core and Access network		

3.4.1.1.14.2. Non Functional Requirements

UC1.SC1-NFUNC1	Safe distance from observers		
Priority	Essential	**Justification**	Regulation
Description	The drone deployment should be in safe distance from observers		
Related Component(s)	All		

UC1.SC1-NFUNC2	Approved Flight Plans		
Priority	Optional	**Justification**	Regulation
Description	If the drones fly below 120 m there is no obligation for approval		
Related Component(s)	All		

UC1.SC1-NFUNC3	Certified Drone operators		
Priority	Essential	**Justification**	Regulation
Description	The drones must be operated by operators certified by the local authorities		
Related Component(s)	All		

UC1.SC1-NFUNC4	Connectivity shall be provided in a secure manner		
Priority	Optional	**Justification**	Security
Description	The network deployed must be protected against denial of service attacks and other malicious attempts to compromise it		
Related Component(s)	5G network		

3.4.1.2. Scenario 2: 3D mapping and supporting visualization/analysis software for UTM

3.4.1.2.1. Detailed Description of Scenario

In this scenario, a set of new technologies are used to visualize the real time operation of drone fleets. Using VR as a visualization platform, multiple source and huge amount of data can be expressed in visual format that is easier for human operators to understand. This use case studies the possibilities of using VR for drone operation and real time visualization.

In this use case, the drone will have a prior map of environment it is about to travel. This includes a structural 3D map, route information from UTM and preliminary map scanned on previous flights. Drone operator defines a goal target position (destination), and when requested, the drone takes

off, follows the given route (while doing local obstacle avoidance, continuous map update, etc.), and lands on given destination. During the flight, a human operator can use VR to observe task progress of multiple drones, showing paths from UTM system, sensor data (from scanners and cameras of each drone, and non-visual information related to 5G performance, including spatial signal strength, bandwidth, etc.

The main objective of this use-case scenario is to help the human operator and flight planners determine the best physical and 5G service condition for flying their drones. Physical condition in terms of area terrains or environmental factors such as temperature, pressure, and 5G services conditions in terms of locations or spots that gives least latency and higher connectivity quality i.e. bandwidth for video transmission.

While the physical conditions are foreseen to be determined using live video streams of the flight path and using onboard sensors for temperature, pressure and other possible measurement to populate the dedicated 3D mapping software or create and update a digital twin world leveraging UTM applications, the 5G service conditions will be achieved by creating a sophisticated 3D reconstruction of various 5G related spatial measurements. Complex shapes of cell tower radiation patterns along with sophisticated signal dissipation (at the buildings, high vegetation areas and uneven terrain) will create a non-trivial signal distribution at urban areas. Getting all these conditions in place will help the human operator or flight planner determine the best possible condition with low latency and high quality of video transmission to fly their drones.

In this use-case scenario, the network needs to provide i) two cross-domain network slices for UAV traffic control and drones' data: a uRLLC slice able to reduce delay and having a high priority for UAV traffic control, and an eMBB slice (no priority) for the data sent by drones; ii) a drone control application and parts of 3D mapping software for the VR world application hosted at the edge. Furthermore, for faster application process at the edge, different MEC slices will be dedicated for various application processing before being transmitted back to the operation center. Even though not all measurements or applications will be processed at the MEC, services such as video processing, 3D map analysis, sensors measurement processing will be done at different MEC slices before further transmission to the operating center. However, live updates from the drone such as location updates, position trackers will be transmitted directed to the control center operator without processing through the MEC server.

3.4.1.2.2. High Level Architecture

The UC1:SC2 is expected to use the existing 5G capability of the Oulu 5GTN for its deployment. It is also proposed that the use case can be deployed on other facilities in future uses. The architecture in Figure 15 is expected to leverage the proposed 5G Trial Controller and a flight control center where parameters regarding flight path, flight map, 5G parameter usage etc. will be set. The Trial Controller is expected to have a web interface (web portal) where the required 5G and UAV parameters are set (at the control center), it should also be connected to the UTM systems for flight path update and finally have an interface to the 5G facility. The experiment is expected to happen within an enclosed location in the University of Oulu, and an initial internal map of the experimental location will be loaded on the UAV, which will be updated as the operation continues. The UAV also forwards data relating to 5G parameters at specific flight location back to the control center. From Figure 15 it can also be seen that all data related to video processing will be done at the 5GTN virtualized MEC facility.

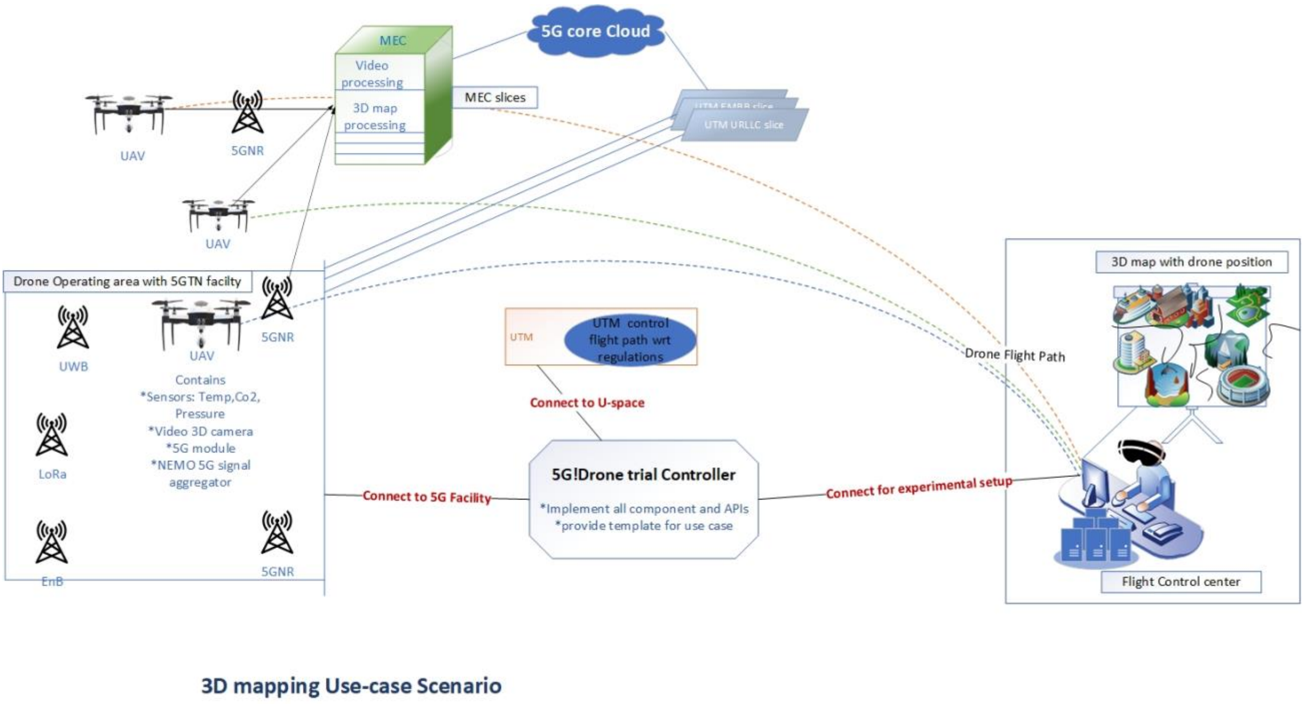

Figure 15: UC1:SC2 - High level architecture

3.4.1.2.3. UTM System

Please refer to Section 3.3.3.

3.4.1.2.4. UAS System

The UAVs in operation in this use case scenario are expected to be deployed using the fully-autonomous deployment model. This is to say the UAV is installed with a UL-ACE as described in section 2.3.2. For this use case, the UL-CCP is hosted at the 5GTN virtualized MEC server (edge) to support the connection to the UL-ACE over the LTE/GT network as seen Figure 16.

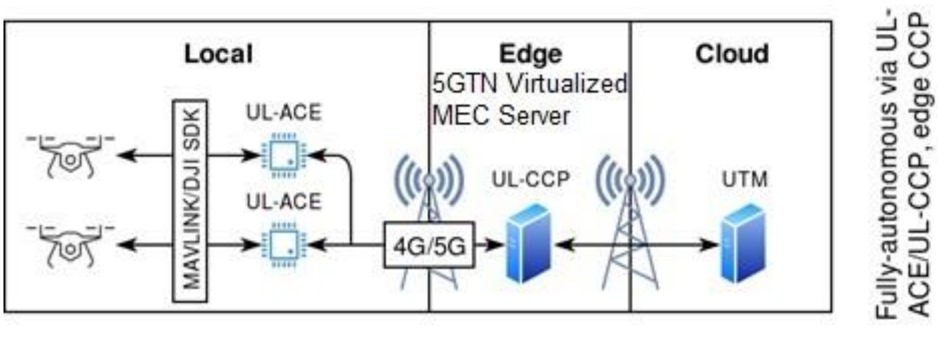

Figure 16: UC1:SC2 - UAS deployment model

3.4.1.2.5. Drones

For indoor test facilities, UO provides a cable drone, a drone that is not actually flying, but moving in 3D space using cables, similarly to so called Spider Cameras used in sports events. This device can be equipped with same sensors as a flying drone and the interface for moving it in the test space is the same as for the flying drones. The advantage of this type of drone replacement is that it can make test series automatically, periodically, and with high precision without human operator

based on the fully-autonomous UAS deployment model. The drone to be used for the experiment has the following properties:

Table 14: UC1:SC2 – Drone Information

Manufacturer	DJI
Model	Matrice M210RTK
Number of UAVs	1
Tether	No
Max Take Off Weight	6.14 kg
Max Payload	2 kg
Hovering time	32 min (No payload with TB55) 24 min (Full payload with TB55)
Limitations	Max Angular Velocity - Pitch: 300°/s, Yaw: 150°/s Max Ascent Speed - 5 m/s Max Descent Speed - 3 m/s Max speed - 64.8 km/h
Resistance to the interferences	Default UAV control is over DJI 2.4 GHz and 5.8 GHz radio link. Different bands compared to 5G but small risk of harmonic frequency interference. Since drone control is over 5G, the risk of interference is larger so separate slice for C2 should be used.

3.4.1.2.6. 5G Radio Access network

The Oulu 5GTN which currently has Option 3 NSA deployment of 5G, (i.e. 5GNR+LTE and EPC core) has two test sites and both sites currently deploy one macrocell and six small cell eNodeBs (eNB). The macrocells are installed outdoors, while the small cells are indoor installed. The eNBs operate in an LTE band 7 (2.6 GHz) and are based on the Frequency Division Duplexing (FDD) scheme.

Interoperability with WLAN networks was specified to 3GPP standards already in Release 8. Integrating WLAN networks both as trusted and un-trusted access into the 5G test network according to the 3GPP specifications have been planned in the near future. However, the transmission resources of WLAN networks can already be exploited in the test network through Layer-3 mobility protocols, such as Mobile IP (MIP), and multi-path protocols, like Multi-Path TCP (MPTCP).

Currently, the test network implements a pre-commercial 2 LTE-M capability (Category-0). Some LTE-M features are already standardized, while some other are still work in progress. However, the overall aim of LTE-M is to connect constrained IoT devices by exploiting the existing LTE infrastructure. Lower resource consumption of LTE-M compared with regular communications is obtained through a narrower bandwidth (1.4 MHz/200 kHz) and advanced power save modes. LTE-M provides also enhanced coverage, reduced hardware costs, and simplified signalling.

3.4.1.2.7. 5G Core Network

The core network entities run on an OpenStack cloud environment. In the first phase of the test network development, System Architecture Evolution Gateway (SAE-GW) and Mobility Management Entity (MME) are installed. The rest of the core network functionality runs from a remote core network, located at Nokia's premises in Tampere, Finland. The remote core network is connected over a Virtual Private Network (VPN) tunnel. However, as SAE-GW and MME run locally in the test network, all data traffic and most of the control traffic stays within the local network.

To support virtualized network, the 5GTN uses OpenEPC and NextEPC for virtual EPC and it utilizes Open Source MANO (OSM), for orchestration. The 5GTN is expected to have 5GCore in the future for support of Option 2 NSA deployment

3.4.1.2.8. Mobile Edge Network

The MEC functionality in the test network will be based on Nokia's MEC solution. The MEC concept is one of the key services in 5G. It allows third-party service providers to bring their services and service-specific functions close to users through standardized interfaces and an open architecture. As the services can be brought to RANs, MEC can result in lower delays and more efficient exploitation of network capacity. Being based on the cloud concept, MEC capabilities can be made dynamic and scalable.

MEC enables a lot more possibilities for application developers in mobile networks. When a service or, for example, a service-specific feedback system is very close to the users, control of service quality can be made efficient. Also, transmission resources for the end users' wireless links, that typically act as bottlenecks in terms of capacity, can be controlled better on application requirement basis. One example could be over-the-top video content providers with CDNs. Instead of using CDN edge servers physically located in a remote cloud system, edge servers could be deployed in a MEC system with a cache containing the most used content in the area covered by base stations driven by the MEC system.

For this use case, the MEC server will have application video processing application, data analysis and map analysis.

3.4.1.2.9. Application Servers & Devices

3.4.1.2.9.1. Unmanned Life Central Command Platform

The UL-CCP will be hosted on an edge server as described in Section 2.3.2. It is responsible for:

- Coordinating UAVs in a multi-robot environment.
- Task allocation to UAVs for mission management.
- Processing of sensor data for operational decision-making.
- Responding to UTM mission change requests.
- Forwarding of telemetry data to operational UTM systems.

3.4.1.2.9.2. Other Applications

The other applications within the edge server include:

i. Video processing application at the MEC server.
ii. Map analysis application.

3.4.1.2.9.3. Devices

Devices include NEMA network measurement device, temperature sensor, pressure sensor, CO2 sensor, and spider camera.

3.4.1.2.10. Security and regulation

Standard safety issues based on SORA. Since the experiment will be carried out at in an indoor facility, safety nets will be installed to prevent drone destruction.

3.4.1.2.11. Scenario Interactions High Level Workflow

(A) Preparation stage:

i. The experimental use case is expected to operate at a predefined indoor location within the 5GTN.
   a. Preliminary testing facility is Indoor 5GTN showroom, a size of 14 m x 18 m x 10 m (W x L x H) lobby with safety nets and required infrastructure.
   b. Several additional indoor and outdoor based drone testing facilities are optionally available with a possibility to install 5G network or have a mobile 5G network during test runs.

ii. As seen in Figure 15, all UAS systems are provided in the test facility which includes the UAV, small cells 5GNR and virtualized MEC facility.

iii. Drones are set up for activity at the control center, with required settings of sensors, required 4K video cameras, and 5G parameters measurement tools.

iv. For ease of connection establishment to the 5G Core Network, a 5G dongle or modem is on-board the drone. the 5G dongle connects automatically to the 5G network at the experimental location.

(B) Preliminary flight stage:

i. The control centre which has access to the Trial Controller web interface (portal) inputs all the required UAV, UTM and 5G parameters on the web interface and locks the drone operation for control and access through the Trial Controller.

(C) Flight stage

i. Based on the provided UTM parameter, the Trial Controller provides the flight path from the control center location to the location of operation (in this case within the 5GTN indoor location).

ii. During the experiment other operations such as parameter update, flight path update etc. are further handled by the Trial Controller.

iii. At the experimental location, the UAV is connected to the 5G facility and allocated specific slices based managed by the slice manager in the 5G Trial Controller.

iv. The UAV takes 4K live video within the location (processed at the MEC), uses the available sensors to measure temperature, CO_2, pressure, etc. and takes the readings or measurement of 5G parameters (data) in terms of bandwidth, throughput and latency at different points within the experimenting location.

v. Live 4K videos taken at the location showing the flight terrain and other views which are processed at the Virtualized MEC server, and with the aid of the eMBB and uRLLC slice, transmit the processed video back to the control center to form an updated 3D map of the location.

vi. Measured data from on-site sensors are also transmitted back to the control center.

vii. And finally, the 5G measurement data via the uRLLC slice are updated and processed to form a visualized 3D graphical display. The 3D display will show locations or points with highest and lowest 5G capabilities in terms of latency, throughput and bandwidth.

viii. After extensive measurement, the drone follows the same flight back to the control center.

ix. The UAVs end their missions.

x. The locked operation of the UAV within the Trial Controller is released and other operation from other UAV use cases can be performed.

(D) Analysis & reporting:

i. Flight telemetry data and sensor data is shared with and stored on the KPI Monitoring module of the Trial Controller.
ii. Data is aggregated and analyzed.
iii. Results and conclusions are consolidated in a trial report.
iv. Live map update of the experimental location collected during the flight phase are analyzed and the 3D map is established.
v. All 5G measurement KPIs at different points of the experimental location are converted into a 3D display, showing different 5G performance metrics such as throughput, bandwidth, latency etc. at these locations in a 3D format.
vi. Sensor data are collected and stored in for data aggregation and for further processing.
vii. All live feed 4K video established during the flight phase are store for further processing.

3.4.1.2.12. Use Case Network & Drones Critical Parameters

Network performance requirement are summarized in table below:

Table 15: UC1:SC2 – Network critical parameters

Network Critical Parameters	Value
Data Type	1. C2 of the drone from the control center to the operation site is max 100 ms latency 2. Application Data: including video streaming, images, sensor data to support event management applications 3. 5G measurement parameters such as bandwidth, throughput, latency etc. are collected at different location to form the 3D mapping
Heights	Preliminary testing facility is Indoor 5GTN showroom, a size of 14 m x 18 m x 10 m (W x L x H) lobby with safety nets and required infrastructure.
Speeds	Target horizontal speeds up to 70 km/h
Latency	1. C2: UAS requirement is 10 ms (one way from eNB to UAV) 2. Application Data: Latency value similar to LTE ground-based users
Data Rates	1. C2: [60-100] kbps for uplink and downlink 2. Application Data: up to 50 Mbps for UL

Table 16: UC1:SC2 – Drone critical parameters

Drones Critical Parameters	Value
Flight Geo Borders	Indoor space: 14 x 18 x 10 m.

Drone Operator Location	Next to fly area, separated with safety nets
Time	It is expected to know provisioning period as the Drone Operator should know how many hours ahead should apply for the service.
No. of Drones	1 tethered, 1 flying
Minimum Separation	5 m In this particular case, drone speed is not important, therefore ensuring separation using 5G networks is also not critical. The minimum separation on the level of 5 m can be ensured by defined flight areas (geofencing via UTM).
Drones Battery Volume	DJI Matrice M210 RTK endurance 24 min (2 kg payload) – 32 min (no payload).
Drone Velocity	DJI Matrice M210 RTK max vertical speed 82.8k m/h, max horizontal speed 64 km/h

3.4.1.2.13. Target KPIs

Table 17: UC1:SC2 – Target KPIs

KPI	Description	Target Values
Capacity	3GPP consolidated KPIs for UAV considers an uplink data rate between 4 Mbps and 9 Mbps for video streaming for the provision of HD video streaming. Considering the case of 4K video, the target value is increased further, reaching 30 Mbps (since 3GPP recommends 120Mbps for a 4*4K surveillance system)	>50 Mbps
Latency	3GPP considers different target values for control latency based on the planned service. The proposed target value is 10ms, which covers a great variety of services, considering that provides an accurate control environment for the UAV.	<= 10 ms
Service Creation Time	The target KPI value proposed by 5G-PPP is the reduction of the average service creation time from 90 days to 90 min. This allows the agile creation	The proposed use case can serve and adapted to a great variety of services. Therefore it is very important the service creation time to be low in order

	and deployment of services, making possible the fast response of the mobile network to the needs of the vertical industries.	to be possible its fast match to different vertical industries.
Video Streaming Data Rate to MEC server for processing	Data exchange speeds for streaming video feeds from UAVs to MEC facility	>= 9 Mbps for HD >= 25 Mbps for 4K Latency <10 ms

3.4.1.2.14. Use Case Requirements

3.4.1.2.14.1. Functional Requirements

UC1.SC2-FUNC1	**The mobile network must support 5 concurrent service slices**		
Priority	Essential	**Justification**	Use case Driven
Description	Four different services shall be supported by the use case: 1. Drone control slice for Control center communications – a uRLLC service 2. Drone data slice for video streaming – an eMBB service 3. Map update slice from drone to control center – a uRLLC service 4. Telemetry slice for UTM – a uRLLC service 5. User data slice for user equipment – an eMBB service		
Related Component(s)	The 5G core and Access network and MEC server Access network (5GNR, EWB, LORA)		

UC1.SC2-FUNC2	**Mobile edge capabilities must be deployed near the UAV trial location**		
Priority	Essential	**Justification**	Use case Driven
Description	The provision of the uRLLC service for the drones command and control mandates the existence of a MEC center near the trial location MEC server will support video processing, map processing at the edge before transmission to the control center		
Related Component(s)	The EPC/5G core and Access network, MEC server		

UC1.SC2-FUNC3	**Enforcement of separation between UAVs operating in close proximity**		
Priority	Optional	**Justification**	3GPP r.16 22.825 UC5
Description	The requirements defined in [13] use case 5 for collision avoidance in cases that drones are flying in close proximity are relevant and should be considered when the technology is made available Drones C2 systems should use GPS RTK solution to improve precision of drone positions. The number of drones for a single operation can range from 1-5		
Related Component(s)	The 5G core and Access network		

UC1.SC2-FUNC4	**Radio Access Node on-board UAV**		
Priority	Essential	**Justification**	3GPP r.17 22.829 UC2
Description	The requirements defined in [18] Use case 2 and summarized in		

	Table **58** as Requirements for UxNB must be considered, and most importantly: The 5G system shall be able to support wireless backhaul with required quality to enable a UxNB. The 3GPP system shall minimize interference among UxNBs in close proximity. Optionally, if the technology is made available, the 3GPP system shall be able to monitor UxNB (e.g. power consumption of the UAV etc.) and provide means to minimize power consumption of the UxNB (e.g. optimizing operation parameter, optimized traffic delivery) without degradation of service provided. Until this is possible, a tethered drone can be used to resolve power consumption concerns. For this scenario, a 5G dongle or modem on-board the drone is proposed.
Related Component(s)	The 5G core and Access network

3.4.1.2.14.2. Non Functional Requirements

UC1.SC2-NFUNC1	**Safe distance from spectators**		
Priority	Essential	**Justification**	Regulation
Description	The drone deployment should be in safe distance from spectators		
Related Component(s)	All		

UC1.SC2-NFUNC2	**Approved Flight Plans**		
Priority	Optional	**Justification**	Regulation
Description	If the drones fly below 120m there is no obligation for approval		
Related Component(s)	All		

UC1.SC2-NFUNC3	**Certified Drone operators**		
Priority	Optional	**Justification**	Regulation
Description	The drones must be operated by operators certified by the local authorities.		
Related Component(s)	All		

UC1.SC2-NFUNC3	**Connectivity shall be provided in a secure manner**		
Priority	Optional	**Justification**	Security
Description	The network deployed must be protected against denial of service attacks and other malicious attempts to compromise it		
Related Component(s)	5G network		

3.4.1.3. Scenario 3: UAV logistics

3.4.1.3.1. Detailed Description of Scenario

The purpose of this scenario is to demonstrate how UAVs through 5G network capabilities can provide logistics solutions. The first scenario is the delivery of a drug to a sick person with a drone. A sick person who cannot go to a pharmacy can receive his/her medicine through a personal delivery by subscribing to a Drone Logistics Network (DLN). The delivery box has IoT (NB-IoT or LTE-CatM1) device which ensures communication with the DLN to coordinate parcel drop-off, landing, etc. Parcel drop off and landing functions need very low latency and therefore DLN Delivery Software (DLN DS) works on MEC.

UC1:SC3 – Deployment 1

A DJI Mavic-2 drone takes one medicine (up to 50 g) from a virtual pharmacy and flies towards the customer delivery box. Approaching the delivery box, the drone has bad GPS signal quality between houses. Drone streams video over 5G and DLN human operator takes over the drone control and uses 5G communication based remote control. For parcel drop-off DLN DS communicates between drone remote controller and delivery box IoT.

UC1:SC3 – Deployment 2

A DJI Matrice 210 drone will deliver a bigger parcel (up to 1 kg) to the delivery box but the entire operation is fully autonomous (drone flight control and communication between the delivery box and the DJI Matrice 210 drone).

The demonstration takes place at Aalto campus.

Flight plans are provided to the 5G!Drones Test Facility UTM system with drone data, flight time, flight area in 3D and operator contacts. The UTM system will approve the flight taking into account different parameters.

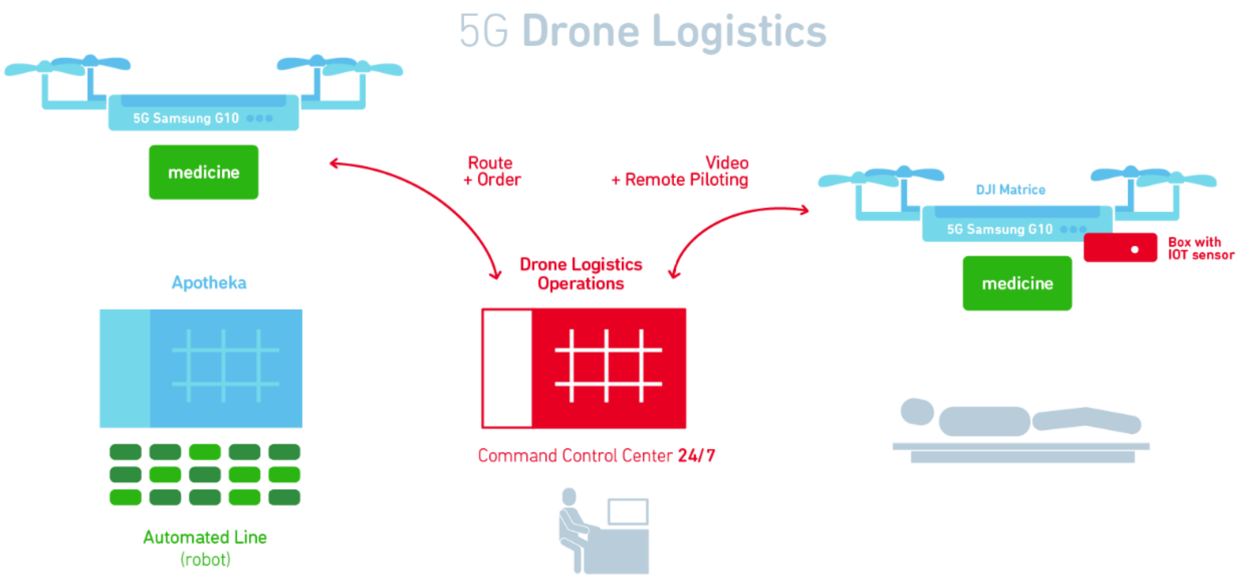

Figure 17: Overview of the Drone Logistics scenario

3.4.1.3.2. High Level Architecture

The use case shall leverage the 5G experimentation capabilities of the Aalto X-network.
This will require a network infrastructure that will provide 3 network slices:

1. Drone C2.
2. Video stream.
3. IoT communication.

The uRLLC slice will reduce delay and give high priority with reliability to the UAV traffic control and, since large amount of data (video streams) will be transmitted by the drone, a dedicated eMBB network slice with no specified priority will also be required for swift data reception. The IoT communication slice will ensure fast and reliable communication with the delivery box IoT sensors. These three network slices (eMBB and uRLLC and NB-IoT or LTE-M IoT) will run in parallel with

enough isolation and reliability to maintain the required performance level. The Aalto X-network will utilize the existing MEC and the upcoming 5G core to support these 3 slices and:

- Basic set-up for measurement within the X-network for drone delivery (UTM 3).
- Low latency between Trial Controller and UAV.
- UAV implementation achieved in the X-Network.
- Aalto MEC server will be used for C2 and video processing.

3.4.1.3.3. UTM System

Please refer to Section 3.3.3.

3.4.1.3.4. UAS System

UAVs in Drone Logistics scenario will be operated using the fully-autonomous edge deployment model and if needed (for example due to bad GPS signal condition) human controlled. UAVs flown in fully-autonomous mode must be controllable by remote controller via a 5G smartphone and communicate with the CAFA UGCS Platform.

3.4.1.3.5. Drones

Table 18: UC1:SC3 – Drone Information

Manufacturer	DJI	DJI
Model	Matrice M210	Mavic
Number of UAVs	1	1
Tether	No	No
Max Take Off Weight	6.1 kg	1.1 kg
Max Payload	1.4 kg	190 g
Flight time	16 min (1.4 kg payload) 35 min (no payload)	15 min (190 g payload) 25 min (no payload)
Limitations	Max Wind Resistance: 8 m/s	Max Wind Resistance: 8m/s
Resistance to Interferences	Default UAV control is over DJI 2.4 GHz and 5.8 GHz radio link. Different bands compared to 5G but small risk of harmonic frequency interference. Since drone control is over 5G, the risk of interference is larger so separate slice for C2 should be used.	Default UAV control is over DJI 2.4 GHz and 5.8 GHz radio link. Different bands compared to 5G but small risk of harmonic frequency interference. Since drone control is over 5G, the risk of interference is larger so separate slice for C2 should be used.

3.4.1.3.6. 5G Radio Access network

For this trial a 5G radio access network coverage for area: 500x500 m with height up to 100 m AGL is needed. Currently, the radio access network deployed at Aalto University includes different

eNB. Moreover, a NB-IoT eNB has been recently deployed in the campus. Furthermore, the trial site also includes a gNB deployed in NSA mode. For further information please refer to D1.2.

3.4.1.3.7. 5G Core Network

The core network includes three different virtualized EPC core network implementations which are Nokia core, Aalto core and CMC core (Cumucore). The latter implements a prototype of 5G core architecture including AMF, SMF, UPF, NSSF and NRF. The core network will be running in a datacenter located at the campus.

3.4.1.3.8. Mobile Edge Network

The connections between eNB/gNB is based on fiber converge in SDN-ready Juniper MX204 edge routing platform with capacity up to 400 Gbs where MEC platforms are available. The current testbed includes two MEC platforms. The first MEC is provided by Nokia which is connected to the switch where all the eNB and gNB are connected directly through fiber. Another MEC platform is based on SDN and Linux based virtualization system to run services and applications. This open MEC platform is using SDN to redirect the connections from selected users to the MEC platform where the applications are running.

3.4.1.3.9. Application Servers & Devices

3.4.1.3.9.1. CAFA UGCS based platform (CUP) for flights C2 and Drone Logistics Network Delivery Software (DLN DS) for delivery

The CAFA Tech CUP platform will be hosted on an edge and local server. This platform is responsible for:

- Planning and coordinating UAVs missions.
- Task allocation to UAVs for mission management.
- Processing of sensor data for operational decision-making.
- Responding to UTM mission change requests.
- Forwarding of telemetry data to operational UTM systems.
- Providing access to CAFA 3D application for delivery routes analyzing in 3D.
- Providing access to GPS RTK (Real Time Kinematic) corrections.

The DLN delivery software coordinates delivery information between a customer's delivery box, the UAVs, and the logistics center. The CAFA central server stores data and videos and provides big data analyses. CAFA IoT software provides communication between IoT sensors and CAFA CUP and DLN delivery software.

3.4.1.3.10. Security and regulation

For this scenario, drones with take-off weights up to 6.1 kg (DJI Matrice 210) and up to 1.1 kg (DJI Mavic) are planned to be used.

In case the remote controller or CUP software would fail, the flight controller is configured to return to home safely and land (RTH). The Mavic drones will have a safety pilot on standby with a remote control who will be able to take over the autonomous mission at all times.

During the missions the drones will be deployed with a minimal safe distance 30 m between them to ensure safety even in case of drops in GPS quality and drifts. DJI Mavic Accuracy (P-Mode, with GPS): Vertical: ±0.5 m, Horizontal: ±1.5 m.

During the trial a human operator who will have the technical capabilities to intervene and take control over the drone will be present on site. As per the Finnish regulations, for BVLOS operations a *'Danger Area'* will be reserved and activated a day before the proposed trial.

3.4.1.3.11. Scenario Interactions High Level Workflow

(A) Preparation stage: Please refer Section 3.3.11.

(B) Preliminary flight stage

i. Prepare trial site, MEC, IoT devices, CUP and PVA software and communication. Including install CUP and PVA and IoT device controlling software to MEC.
ii. Identification of Network coverage area and quality.
iii. Prepare drones and C2 system.
iv. Manual test flight and systems checks.
v. Use the portal of the 5G!Drones Trial Controller and set up the trial by providing the information needed.
vi. Send a request to the slice manager to deploy and configure the network services to the core cloud and the edge cloud. Create three distinct network slices per drone: one for the control flow (preferably uRLLC), one for the data flow (preferably eMBB) and one for IoT sensor (preferably LTE-M1).

(C) Flight stage

i. Use the Trial Controller to initiate the drone trial.
ii. Autonomous take-off of the DJI Mavic drone and medicine delivery.
iii. DLN operator (human) takes over the drone piloting (remotely, thanks to 5G video stream) and deliver the medicine. The drone returns to the starting position and land autonomously.
iv. Semi-autonomous take-off of the Matrice 210 drone which delivers the 1 kg parcel.
v. DLN operator (human) takes over the drone piloting (remotely, thanks to 5G video stream) and deliver the parcel. The drone returns to the starting position and land autonomously.

(D) Analysis & reporting: Please refer Section 3.3.11.

3.4.1.3.12. Use Case Network & Drones Critical Parameters

With respect to the network related characteristics of the use case, the following parameters are considered:

Table 19: UC1:SC3 – Network critical parameters

Network Critical Parameters	Value
Data Type	1. C2 two way communication from human operator to UAS 2. Application Data: including video streaming, images, sensor data to support logistics operation applications
Coverage area	500 x 500 x 120 m AGL (LxWxH).
Latency	1. C2: UAS requirement is 50 ms (one way from eNB to UAV) 2. Application data: Latency value 50 ms 3. Basic connectivity
Data Rates	1. C2: 100 kbps for uplink and downlink 2. Application Data: up to 30 Mbps for UL 3. Basic Connectivity: 0.5 Mbps

C2 Reliability	As low as 10^{-3} Packet Error Rate because then operator can interfere with the flight

With respect to the drone characteristics of the use case, the following parameters are considered:

Table 20: UC1:SC3 – Drone critical parameters

Drones Critical Parameters	Value
Speeds and Flight time and Max TOW	Target horizontal speeds up to 40 km/h for all scenarios Flight time minimum: 15 min Max TOW: DJI Mavic-2: 1.2 kg DJI Matrice 210: 6.2 kg
Airworthiness	Drones are eligible to conduct the trial
Separation	Minimum distance between drones: 30 m
C2 Reliability	Continuous connection between the remote controller and the drone
Drone Position Accuracy by GPS	1 m

3.4.1.3.13. Target KPIs

In the light of the above context, the target KPIs that are considered for validation during the use case execution are listed in below table:

Table 21: UC1:SC3 – Target KPIs

KPI	Description	Target Values
Capacity	3GPP consolidated KPIs for UAV considers an uplink data rate between 4Mbps and 9 Mbps for video streaming for the provision of HD video streaming. Considering the case of 4K video, the target value is increased further, reaching 30 Mbps.	>30 Mbps
Latency of 5G mobile devices	3GPP considers different target values for control latency based on the planned service.	<= 50 ms
IoT device latency	IoT device and base station latency is important for the package drop off	<= 1 s

3.4.1.3.14. Use Case Requirements

3.4.1.3.14.1. Functional Requirements

UC1.SC3-FUNC1	The mobile network must support 3 concurrent service slices		
Priority	Essential	**Justification**	Use case Driven
Description	Three different services shall be supported by the Use case: 1. C2 (Command and Control) for the drone, a uRLLC service 2. Video streaming from the drone for the remote piloting (FPV) by Command Center operator eMBB Service 3. IoT device slice, IoT service		
Related Component(s)	The 5G Core and Access network with IoT network		

UC1.SC3-FUNC2	Mobile edge capabilities must be deployed in the Aalto campus		
Priority	Essential	**Justification**	Use case Driven
Description	The provision of the uRLLC service for the drones' command and control mandates the existence of a MEC cloud of Aalto University.		
Related Component(s)	The 5G Core and Access network		

UC1.SC3-FUNC3	Enforcement of separation between UAVs operating in close proximity		
Priority	Optional	**Justification**	3GPP r.16 22.825 UC5
Description	The requirements defined in [13] Use case 5 for collision avoidance in cases that drones are flying in close proximity are relevant and should be considered when the technology is made available. Drones C2 systems should use GPS RTK solution to improve precision of drone positions.		
Related Component(s)	The 5G Core and Access network		

UC1.SC3-FUNC4	Simultaneously support data transmission for UAVs and eMBB users		
Priority	Essential	**Justification**	3GPP r.17 22.829 UC4
Description	The 5G system shall need to optimize the resource use of the control plane and/or user plane for transfer of continuous uplink data that requires both high data rate and very low end-to-end latency.		
Related Component(s)	The 5G Core and Access network		

UC1.SC3-FUNC5	The mobile network must support prioritization		
Priority	Essential	**Justification**	Use case Driven
Description	The provision of the uRLLC service with required SLA in the volume of airspace is critical for the drones' command and control (C2 link).		
Related Component(s)	The 5G core and Access network and RAN		

UC1.SC3-FUNC6	The network should provide service for the remote operator		
Priority	High	**Justification**	Use case Driven
Description	A transmission link must be provided for the drone operator in a remote location, at least at the same level as provided for the drone.		

Related Component(s)	The 5G core and Access network, RAN,

3.4.1.3.14.2. Non Functional Requirements

UC1.SC3-NFUNC1	**Approved SORA**		
Priority	Essential	**Justification**	Regulation
Description	No objections from Traficom (Finnish CAA).		
Related Component(s)	Operator		

UC1.SC3-NFUNC2	**Connectivity shall be provided in a secure manner**		
Priority	Optional	**Justification**	Security
Description	The network deployed must be protected against denial of service attacks and other malicious attempts to compromise it		
Related Component(s)	5G network		

3.4.2. Use Case 2: Public safety/saving lives

3.4.2.1. Scenario 1: Monitoring a wildfire

3.4.2.1.1. Detailed Description of Scenario

Wildfire breaks out. First, fire fighters must reach the fire scene and suffer from difficult conditions (inadequate road conditions, numerous obstacles hindering progression like fallen trees for example). In order to progress securely, fire fighters rely on their Mission Critical Services platform allowing them to exchange any audio or video data and empowering them with augmented situational awareness. Essential element for situational awareness is real time joint digital field map which reflects real-time geotagged photos and information.

Drones can play significant roles in this type of scenario provided they can be integrated in fire fighters communication system. Drones can be helpful to localize and rescue persons thanks to thermal cameras and profiting by aerial view, or may embed sensors for measuring toxic or hazardous substances. Their main duties would be to gather visual and location information of the fire scene and to allow first responders sharing of augmented situational awareness through their critical collaboration platform. While the firefighting equipment and human firefighters are on their way, fleets of drones can reach the fire scene first as they can travel straight through the airspace. The air fleets can take preparatory measures, such as search for persons to be rescued, and surveillance of dangerous materials to prevent secondary accidents in the near fire area. In addition, the aerial view from high altitudes can also assist the fire engines to take faster actions and firefighters by navigating the optimal route to the area. Such fleets of drones could be intelligently based on firefighter trucks and either be operated manually by specialized fire fighter drone operators, or automatically in order to reach the completion of their tasks/duty (CAF provides special hardware and software for automatic flights and situation analysis). Rescue fire brigade chief normally has no time to operate with drones. Therefore Rescue Command Centre (RCC) needs to be involved.

We consider a scenario that a team of fire fighters performs a coordinated operation in a forest fire scene with the aid of a fleet of drones and IoT sensor/cameras. Drones can support rescue operations in limited time. The best solution is to combine drones with IoT devices (sensors, cameras). Drones can deliver IoT sensors/cameras to crossroads or other strategic viewpoints to

control the spread of wildfire, toxic gases or people's movements. The main requirement of the scenario is that all team members know exactly what to do for the safety and efficiency of the firefighting operations. This needs timely and relevant operational decisions and proper communications through mission critical channels.

At the incident site of fire, a variety of information is necessary for the command center to provide appropriate guidelines to the fire fighters. Each type of information has different set of requirements. VR video of the fire scene should be delivered in real-time with high data rate requirement. On the contrary, information about the surroundings (e.g., traffic situation, potential risk of secondary accidents, etc.) can bear some delay but needs high reliability.

The stakeholders of this scenario are defined below:

- Fire fighters field system users.
- Field commander / dispatcher in the RCC.
- Drones and dock systems hardware and software for UAVs automatic flights.
- IoT sensors/cameras and integrating those to Mission Critical Services platform.
- Mobile network operator.
- Spectrum regulator.

3.4.2.1.2. High Level Architecture

The figure below represents the UC2:SC1 high level architecture:

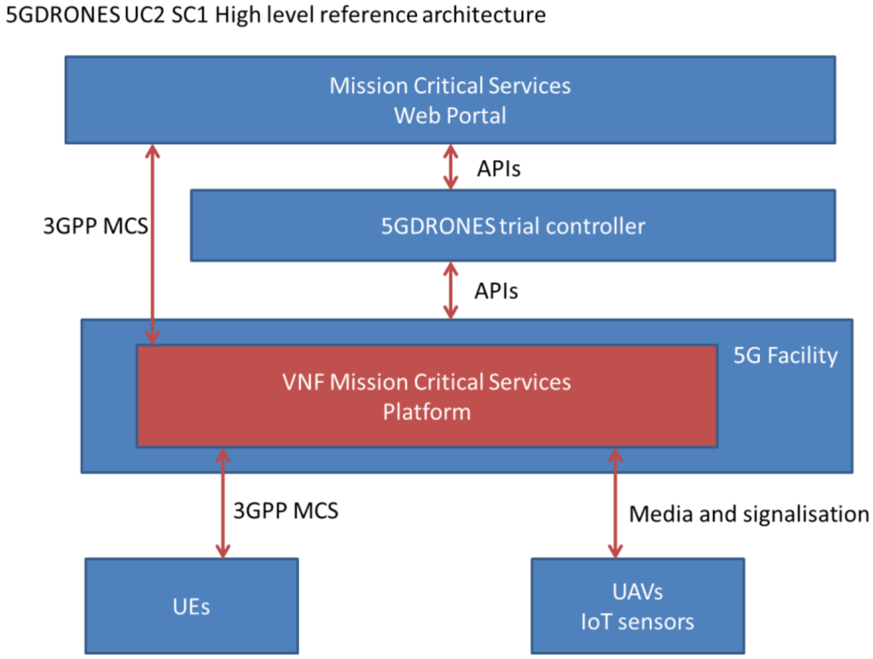

Figure 18: UC2:SC1 - High level architecture

3.4.2.1.3. UTM System

Please refer to Section 3.3.3.

3.4.2.1.4. UAS System

UAVs in wildfire will be operated using the fully-autonomous, semi-autonomous and remotely piloting solutions. CAFA Tech uses CAFA UGCS based platform (CUP) for drones C2.

The CAFA Tech CUP software will be hosted on an edge and local server. This platform is responsible for:

- Planning and coordinating UAVs missions.
- Task allocation to UAVs for mission management.
- Processing of sensor data for operational decision-making.
- Responding to UTM mission change requests.
- Forwarding of telemetry data to operational UTM systems.
- Providing access to IoT sensors viewsheds analysing in 3D.

3.4.2.1.5. Drones

Table 22: UC2:SC1 – Drone Information

Manufacturer	DJI	Nokia
Model	Mavic	NDN Electric Drone
Number of UAVs	2	1
Tether	No	No
Max Take Off Weight	1.1 kg	10 kg
Max Payload	190 g	1.5 kg
Flight time	15 min (190 g payload) 25 min (no payload)	35 min (max payload) 55 min (no payload)
Limitations	8 m/s	Max. speed 80 km/h
Radio Interferences	As drone control is over 5G, there is a risk of interference so separate slice for C2 should be used.	As drone control is over 5G, there is a risk of interference so separate slice for C2 should be used. Back control 868 MHz.

3.4.2.1.6. 5G Radio Access network

This scenario will be trialled at EURECOM 5G-EVE test facility. A description of the facility has been previously provided in Section 3.4.1.1.6 and further information can be found in D1.2.

3.4.2.1.7. 5G Core Network

A description of the facility has been previously provided in Section **Error! Reference source not found.** and further information can be found in D1.2.

3.4.2.1.8. Mobile Edge Network

A description of the facility has been previously provided in Section 3.4.1.1.8 and further information can be found in D1.2.

3.4.2.1.9. Application Servers & Devices

3.4.2.1.9.1. Airbus Multimedia Mission Critical Services

Airbus Multimedia Mission Critical Services provides voice services, instant messaging, video communication and emergency calls.

The Mission Critical Services (MCS) solution allows public safety users to access professional communication in groups and in private calls. The following services are enabled by this solution:

- Group and individual calls.
- Group and individual messaging.
- Group and individual multimedia messaging.
- Group and individual video calls.
- Emergency calls.
- Location and map services.

The following components are deployed as part of the Airbus MCS solution:

- Infrastructure components
  - MCS Server: the MCS Server provides the control and management of voice, video and data communications for both private and group calls. This functionality is divided into Controlling Server(s) and Participating Server(s):
    The MCS Controlling Server is responsible for:
    - Communication control (e.g. policy enforcement for participation in the MCS group communications) towards all the MCS users of group communication (i.e. a group of users capable to communicate with the rest of users at once), as well as and private communication;
    - Managing floor control entity for a group communication and private communication;
    - Managing media handling entity.

    The MCS Participating Server is responsible for:
    - Communication control (e.g. authorization for participation in the MCS communications) to its MCS users for group communication and private communication;
    - Relaying the communication control and floor control messages between the MCS client and the MCS server performing the controlling role;
    - Media handling for its MCS users for unicast media;
    - Management of the quality of service (QoS) by interfacing with the network using the 3GPP Rx interface with a Policy and Charging Rules Function (PCRF) or using the 5G equivalent.
  - Identity Management Server (IdMS): this server is provisioned with the user's MC ID, MCPTT ID and password. The user is also provisioned with its MC ID and credentials. The IdMS authenticates a MCS user by verifying its credentials.
  - Key Management Server (KMS): this server stores and distributes the security information such as encryption keys for private and group calls to the key management client on the UE, to the group management server and to the MCS servers. It enables integrity and confidentiality of the signaling and media flows. The encryption keys are generated by a separate tool and imported to the KMS.
  - Group Management Server (GMS): this server is used to perform the management of communication groups. It manages the group call policy information and media policy information to be used by a given UE.
  - Configuration Management Server (CMS): this server is used to configure the MCS application with non-group management related information and configure data on the configuration management client. The configuration management server manages MCS configurations (e.g. user profile, UE configuration, functional aliases and service configuration).
  - SIP Core: it is the entity responsible for registration, service selection and routing in the SIP signaling control plane.
  - HTTP Proxy: acts as the proxy for all hypertext transactions between the HTTP clients (on the mobile device) and HTTP servers. The HTTP proxy terminates the TLS session with the HTTP client of the MCPTT UE in order to allow the HTTP client to establish a single TLS session for hypertext transactions with multiple HTTP servers.

- MCS Configuration Server: it is used by the MCS system administrators for the management of tactical and technical configuration information.
- Client component:
  - MCS Client application: it runs on the mobile device and implements the MCS protocols, the MCS client entities which are communicating with the servers mentioned above, and the graphical user interface.

3.4.2.1.9.2. CAFA Tech Field Map, CUP Platform, and Video Analysing Software

CAFA Tech will provide a field map which works on tablets, smartphones and laptops. The field map creates a common operational picture because it connects geotagged information, photos and UAV positions.

The CAFA Tech CUP and Video Analysing software will be hosted on an edge and local server. These platforms are responsible for:

- Planning and coordinating UAVs missions.
- Task allocation to UAVs for mission management.
- Processing of sensor data for operational decision-making.
- Responding to UTM mission change requests.
- Forwarding of telemetry data to operational UTM systems.
- Providing access to CAFA Field map for understanding situation and drone positions and IoT sensors viewsheds.

3.4.2.1.9.3. Nokia Sensors

The sensors provided by Nokia include a gimbal HD camera which is capable of clicking full HD images and has a 30x optical zoom and image stabilizer. In addition, it will provide a thermal camera which has a digital display format of 640x480 pixels. Finally, it will also provide a 3-axis gimbal with optimized dampening.

3.4.2.1.10. Security and regulation

The security and regulations described in Section 3.4.1.1.10 will be followed here.

3.4.2.1.11. Scenario Interactions High Level Workflow

(A) Preparation stage: In addition to the steps mentioned in Section 3.3.11, the following steps will be followed:

i. Integration between Airbus Multimedia Mission Critical Services (MMCS) and CAFA CUP system and IoT sensors/cameras.
ii. Prepare detailed trial plan and coordinate with 5G test facility the facility technical status.
iii. Prepare flights documentation and coordinate with French CAA and municipality.

(B) Technical set up stage

i. Prepare trial site, MEC, IoT devices, MMCS, CUP and video analysing software and communication.
ii. Prepare drones and C2 system.
iii. Manual test flight and systems checks.
iv. Use the portal of the 5G!Drones Trial Controller and set up the demo trial by providing the information needed through a wizard process:
   a. Install CUP and VA software to MEC.
   b. Send a request to the slice manager to deploy and configure the network services to the core cloud and the edge cloud.
   c. Create two distinct network slices per drone: one for the control flow (preferably uRLLC) and one for the data flow (preferably eMBB).

d. Create IoT network and sensor/camera.
e. Provide the information needed to perform waypoint flights into the 5G!Drones Test Facility UTS system which will later control the drones with preloaded missions.

(C) Flight stage

i. Use the Trial Controller to initiate the drone trial.
ii. Fully-autonomous flight when Drone No.1 (Mavic) starting and patrolling and streams video from operation area.
iii. Semi-autonomous flight when drone No.2 deliver IoT camera to crossroad.
iv. VA software analysing IoT camera info and video from drone and indicates critical incident (people approaching to danger area).
v. Rescue Command Center sends drone No.1 to detect incident and to alert people by voice (loudspeaker).
vi. Drone no.2 fulfil special task from RCC and firefighters (stream video from center of fire).
vii. Once finished the missions the drones return to the home base and land autonomously.

(D) Analysis & reporting: Please refer Section 3.3.11.

3.4.2.1.12. Use Case Network & Drones Critical Parameters

Network performance requirements are summarized in the table below:

Table 23: UC2:SC1 – Network critical parameters

Parameter	Value
Height	Maximum 120 m AGL. This is the limit for VLL airspace per Eurocontrol definitions.
Speed	Maximum 70 km/h (~20 m/s) linear velocity
Data Type	**C2** from CUP to UAVs
	Telemetry from CUP to UTM
	Application Data from UAVs to Trial Controller via CUP
	End-User Data between ground users & UAVs
Latency	**C2**: <= 10ms one-way from eNB to UAV
	Telemetry: <= 100 ms from CUP to UTM
	Application Data: ~200 ms from UAV to Trial Controller Dashboard
	End-User Data: ~50 ms for user-experienced data exchange
Data Rate	**C2**: 256 kbps from CUP to UAV
	Telemetry: 800 kbps from CUP to UTM
	Application Data: 50 Mbps uplink
	End-User: 10 Mbps up/down
Error Rate	**C2**: less than 10^{-5} block error rate
	Telemetry: less than 10^{-3} block error rate
	Application Data: typical values in LTE
	End-User: typical values in LTE

Drone performance requirements are summarized in the table below:

Table 24: UC2:SC1 – Drone critical parameters

Parameter	Value
Flight Height	Maximum 100 m AGL
Flight Speed	Maximum 70 km/h (~20 m/s) linear velocity
Payload weight	190 g (depends on available camera)

Flight Time	15 min
Resistance to Radio Interference	Radio interference cannot interfere with C2 or KPI collection

3.4.2.1.13. Target KPIs

Below target KPIs are indicative and will have to be assessed with regards to the final demonstrator capacities:

Table 25: UC2:SC1 – Target KPIs

KPI	Description	Target Value
Capacity	3GPP consolidated KPIs for UAV considers an uplink data rate between 4 MBps and 9 MBps for video streaming for the provision of HD video streaming. Considering the case of 4K video, the target value is increased further, reaching 30 Mbps (since 3GPPP recommends 120 Mbps for a 4*4K surveillance system)	>50 Mbps
Latency	3GPP considers different target values for control latency based on the planned service. The proposed target value is 10 ms, which covers a great variety of services, considering that provides an accurate control environment for the UAV.	<= 10 ms
Service Deployment Time	The target KPI value proposed by 5G-PPP is the reduction of the average service creation time from 90 days to 90 min. This allows the agile creation and deployment of services, making possible the fast response of the mobile network to the needs of the vertical industries.	The proposed use case can serve and adapted to a great variety of services. Therefore it is very important the service creation time to be low in order to be possible its fast match to different vertical industries. Considering the proposal made by 5G-PPP, in our use case we aim at decreasing the service creation time by at least one order of magnitude, compared to 4G. Clear improvement of the level of automation of service related processes (i.e. activating group communications in MCS, patrolling etc.)
E2E reliability	Maximum tolerable packet loss rate at the application layer within the maximum tolerable E2E latency for that application.	< 3%
Security	Public safety systems have high demands in security. Different aspects of security are privacy, confidentiality, integrity and authentication.	All security aspects taken into account: True or false.

3.4.2.1.14. Use Case Requirements

3.4.2.1.14.1. Functional Requirements

UC2.SC1-FUNC1	**Real-time video**		
Priority	Essential	**Justification**	Use case Driven
Description	Real-time VR/AR video: the main role of a fleet of UAVs is to collect real-time images of the incidental site. Not only the broad view but also the detailed images, are required for the fire fighters and the command center. At different geological locations, UAVs observe the incident site at different angles and directions and transmit the images to the command center. The center collects and processes those images to realize the real-time VR video for understanding of the overall disaster situation. Some firefighters can receive real-time AR videos which significantly improve the sight of the firefighters when the visibility is impaired by smokes and obstacles. Sometimes, owing to battery issue, UAVs would not be able to provide the high-definition images. Then, AI-assisted image processing algorithm may be implemented to enhance the image quality.		
Related Component(s)	The 5G core and Access network		

UC2.SC1-FUNC2	**Command messages to control Drones**		
Priority	Optional	**Justification**	Use case Driven
Description	Command messages to control UAVs: a messaging scheme must be defined for the control center to send command messages to UAVs. The control center needs to be able to give commands to each component of UAV separately. For example, there could be command messages to control the movement of a drone (e.g. go forward at 1 m/s), to control the camera (e.g., take a still shot), or to control the camera gimbal. Command messages usually take the form of on-demand remote procedure calls, whereas sensory data delivery being periodic data streams. The command messages require very high reliability and low latency, although data rates may not need to be high. The firefighting UAVs receive timely commands from the field commander and field users.		
Related Component(s)	The 5G core and Access network		

UC2.SC1-FUNC3	**Mission critical communications system**		
Priority	Essential	**Justification**	Use case Driven
Description	Mission critical communications the firefighters and the field commander and UAVs: voice is traditional, yet one of the most effective means of communications. UAV needs machine type data communication. Voice connections are much less demanding compared to the real-time videos command messages.		
Related Component(s)	The 5G core, Access network and Mission Critical System		

UC2.SC1-FUNC4	Sensory/cameras information		
Priority	Optional	**Justification**	Use case Driven
Description	Sensory information delivered to the incident commander and the control center: sensory information includes the data of the fire scene measured by the UAVs and IoT sensors/cameras, and the fire fighters (e.g. temperature, wind speed, gases, toxic substances, etc.) and the data of the surroundings (e.g. traffic, people's locations, etc.). In most of the cases, the sensory information can be delivered in a periodic manner, and it can tolerate more latency than other services. However, some measurement data, such as an indication of collapse or explosion and a detection of toxic substances, requires the highest priority to be delivered to the command center. The firefighting UAVs have the ability to detect sensory information around it.		
Related Component(s)	The 5G core and Access network		

UC2.SC1-FUNC5	Upstreaming and processing video		
Priority	Essential	**Justification**	Use case Driven
Description	The field commander should have the capability to receive and process real-time streamed video of the fire scene through critical collaboration platform.		
Related Component(s)	The 5G core and Access network		

UC2.SC1-FUNC6	VR situational awareness		
Priority	Optional	**Justification**	Use case Driven
Description	Field commander has real-time VR video of the fire scene.		
Related Component(s)	The 5G core and Access network		

UC2.SC1-FUNC7	AR situational awareness		
Priority	Optional	**Justification**	Use case Driven
Description	Fire fighters have real-time AR video for visibility enhancement.		
Related Component(s)	The 5G core and Access network		

UC2.SC1-FUNC8	Organization and surroundings location		
Priority	Essential	**Justification**	Use case Driven
Description	Location of all nodes is available in the network. The firefighting UAVs are aware of their location and their surroundings.		
Related Component(s)	The 5G core and Access network + Mission Critical Services		

UC2.SC1-FUNC9	Slicing		
Priority	Essential	**Justification**	Use case Driven
Description	The network switches between the gNBs and the mobile core support SDN to activate network slices.		
Related Component(s)	The 5G core and Access network		

UC2.SC1-FUNC10	MEC		
Priority	Optional	**Justification**	Use case Driven
Description	The task of visual information processing is allocated to the MEC because MEC has more computing power. MEC can perform intensive image and videos processing to provide conclusions for next steps.		
Related Component(s)	The 5G core and Access network		

UC2.SC1-FUNC11	Communications 1		
Priority	Essential	**Justification**	Use case Driven
Description	Communication between the drones for fleet control and visual crowd-sensing.		
Related Component(s)	MCS platform		

UC2.SC1-FUNC12	Communications 2		
Priority	Essential	**Justification**	Use case Driven
Description	Communication between the drones for the awareness of fire scene and command messages (forward link), and for local information obtained from the drones (reverse link).		
Related Component(s)	MCS platform		

UC2.SC1-FUNC13	Communications 3		
Priority	Essential	**Justification**	Use case Driven
Description	Communication between the drones and the field command center for the video taken from the drones and the relaying of local information (reverse link), and the relaying of command messages for the drones (forward link).		
Related Component(s)	MCS platform		

UC2.SC1-FUNC14	Communications 4		
Priority	Essential	**Justification**	Use case Driven
Description	Communication between the drones and the field command center for the video taken from the drones and the relaying of local information (reverse link), and the relaying of command messages for the drones (forward link).		
Related Component(s)	MCS platform		

3.4.2.1.14.2. Non Functional Requirements

UC2.SC1-NFUNC1	Safe distance from spectators		
Priority	Essential	**Justification**	Regulation
Description	The drone deployment should be in safe distance from spectators.		
Related Component(s)	All		

UC2.SC1-NFUNC2	Approved Flight Plans		
Priority	Optional	**Justification**	Regulation
Description	If the drones fly below 120 m there is no obligation for approval.		

Related Component(s)	All

UC2.SC1-NFUNC3	**Certified Drone operators**		
Priority	Essential	**Justification**	Regulation
Description	The drones must be operated by operators certified by the local authorities.		
Related Component(s)	All		

UC2.SC1-NFUNC4	**Connectivity shall be provided in a secure manner**		
Priority	Optional	**Justification**	Security
Description	The network deployed must be protected against denial of service attacks and other malicious attempts to compromise it		
Related Component(s)	5G network		

3.4.2.2. Scenario 2: Disaster recovery

3.4.2.2.1. Detailed Description of Scenario

The purpose of this scenario is to demonstrate how UAVs through 5G network capabilities can help first response teams during disaster situations such as fires, earthquakes, flooding among others. During disaster situations cellular services are often unavailable due to damage to the network infrastructure or due to sudden peaks in the network demands overwhelming the network resources leading to congestion and service unavailability.

The first hour for first responders is often referred to as the “golden hour” to highlight the impact and importance of fast medical care for victims with the eye on a positive outcome, therefore it is important for first response teams to effectively plan their rescue efforts and it is also critical that they obtain a full contextual overview based on data collected from the disaster site and communication among first responders. Since networks are congested, this line of communication is severely affected which results in a gap between the expected and the actual knowledge that first response organizations possess of the current situation. Today handheld two-way radio transceivers allow first responders to communicate in disaster situation, but this medium is limited to basic vocal communication.

Currently drones are also used by first responders to help them in assessing the situation of a disaster site from the sky, which allows them to act in a more efficient and safer way. Today these drones are controlled by a human pilot and are limited in the data they can stream between the base station and the drone due to the restrictions in the network. Autonomous UAV swarms through 5G network capabilities eliminate the need for pilots on-site and allow real real-time data collection.

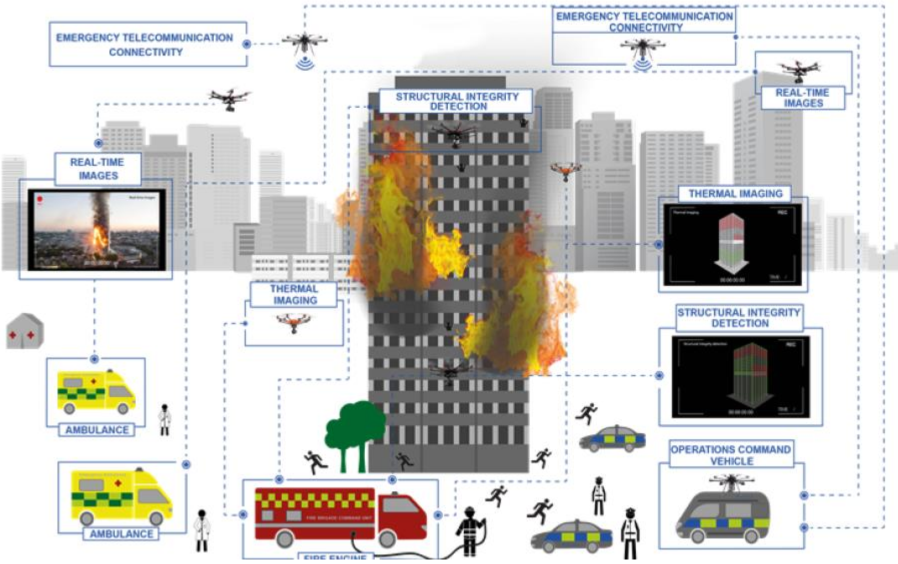

Figure 19: Example of UAVs used in disaster situations

With UC2:SC2 we demonstrate disaster recovery using a swarm of three UAVs, both tethered and untethered, through 5G. The tethered drone is fitted with 5G small cell and serves as a temporary antenna providing the crucial line of connectivity. This temporary network can provide connectivity to the UAV swarm for C2 communication, telemetry and sensor data, the first responders to collection and share situational data as well as to allow citizens to use this connectivity to contact emergency services (112) and ensure that first responders have a greater awareness of the exact situation.

The two other UAVs are installed respectively with a video camera and a thermal imaging camera for real-time video streaming to the GCS for video analysis.

To effectively showcase that a swarm of UAVs combined with 5G connectively are critical for disaster response activities, 5G!Drones will simulate a disaster scenario at EURECOM's 5G-EVE trial facility.

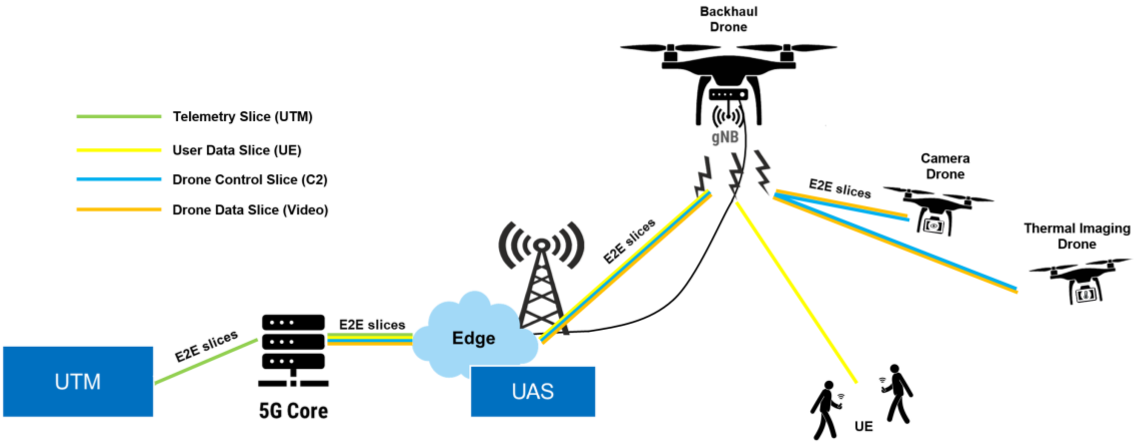

Figure 20: Overview of the disaster recovery scenario

The system will consist of UAVs with system integration boxes (UL-ACE) on board that will be deployed on top of the current infrastructure. The UL-ACE on board of the tethered drone will be connected via the tether to the edge and the 5G network, while the UL-ACE on-board of the camera and thermal imaging UAVs will connect with the gNodeB on the tethered UAV via Android 5G devices.

Drone operators start their mission after performing a risk assessment, as part of the flight planning. Flight plans are provided to the UTM provider with pilot information, mission type, mission purpose, drone data, flight time and duration, flight area and connectivity requirements. The UTM system will approve the flight taking into account different parameters, including the available and agreed connectivity (in operations connectivity should meet the requested level).

In operations, the backhaul drone will be autonomously deployed to provide a local 5G network using a small cell serving as gNodeB connected to the ground station via the tether. The two camera UAVs as well as the UE of the first responders will connect to the gNodeB for the data and C2 communications. The network will be sliced in 4 different slices to optimize the requirements and availability per individual slice. The 4 slices required for this scenario are:

1. Drone control slice for C2 communications (uRLLC).
2. Drone data slice for video streaming (eMBB).
3. Telemetry slice for UTM (uRLLC).
4. User data slice for UE (eMBB).

The drone control slice is used for the C2 communication between the UAS application running on the edge which takes care of the autonomous mission control of the UAVs while the drone data slice will take care of the sensor data communication. This scenario is mainly focused on real time video streaming between the UAV and UAS application on the edge. The video data is processed on the edge using AI for image recognition and object or anomality detection.

The telemetry slice is used to communicate telemetry data e.g. altitude and GPS position from the UAVs to the UTM and for the UTM to send updates on e.g. geofences and weather which might require changes to the mission and flight plan. The user data slice is used by first responders to connect their UE for data sharing and communication.

The scenario will provide a benchmark insight on both the network and UAV KPIs for disaster recovery situations via a scalable and extendible architecture for both autonomous UAV swarm control and communications.

3.4.2.2.2. High Level Architecture

The core components considered for this scenario are depicted in the below architecture:

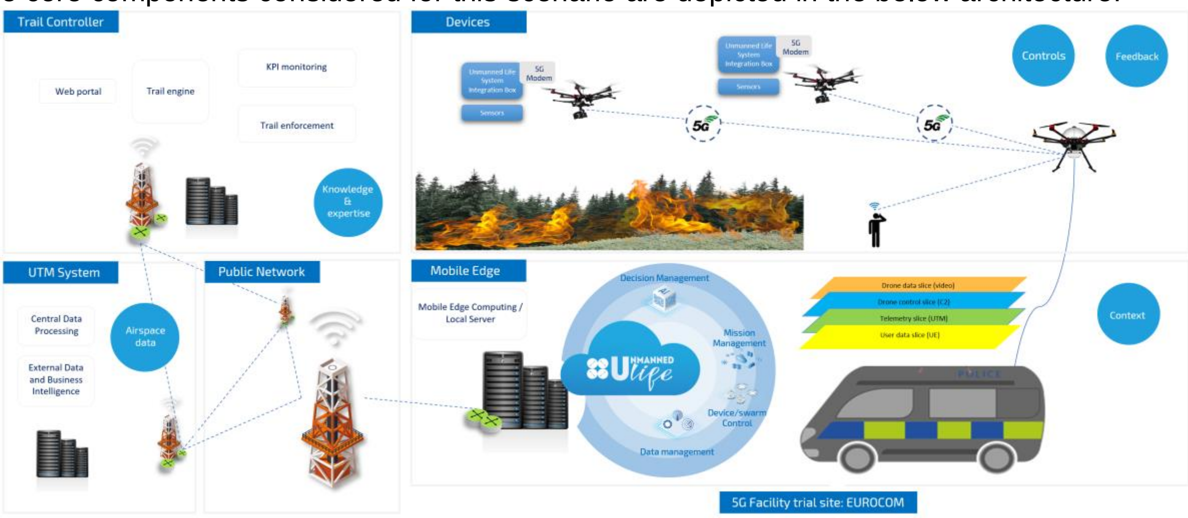

Figure 21: UC2:SC2 - High level architecture

3.4.2.2.3. UTM System

Please refer to Section 3.3.3.

3.4.2.2.4. UAS System

UAVs in UC2:SC2 will be operated using the fully-autonomous edge deployment model.

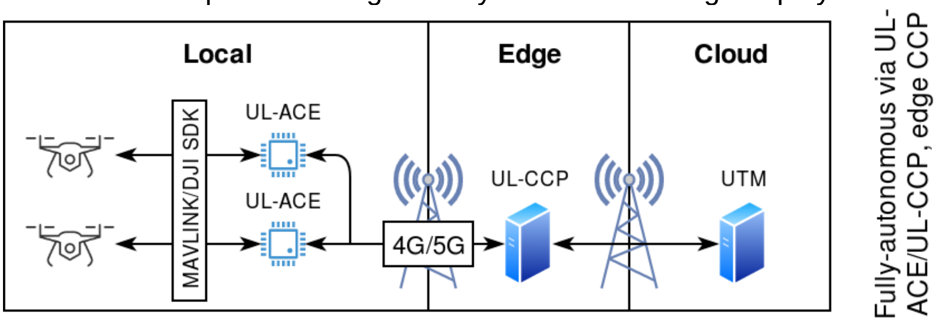

Figure 22: UC2:SC2 - UAS deployment model

UAVs flown in this mode must be augmented with the Unmanned Life autonomous control endpoint (UL-ACE) and communicate with the Unmanned Life central command platform (UL-CCP) for co-ordination in multi-UAS environments and run-time offloading of computation.

3.4.2.2.5. Drones

Table 26: UC2:SC2 – Drone Information

Manufacturer	DJI	Hepta
Model	Matrice M600	HTR-10
Number of UAVs	2	1
Tether	No	Yes, up to 100 m
Max Take Off Weight	15.1 kg	35 kg
Max Payload	6 kg	10 kg
Hovering time	16 min (6 kg payload) – 35 min (no payload)	Tethered 120 min
Limitations	Max Wind Resistance 8 m/s	Max Wind Resistance 12 m/s
Resistance to the interferences	Default UAV control is over DJI 2.4 GHz and 5.8 GHz radio link. Different bands compared to 5G but small risk of harmonic frequency interference. If drone control is over 5G then risk of interference is larger so separate slice for C2 should be used.	UAV control will probably be over fiber optic cable. Risk of radio-interference is minimum.

3.4.2.2.6. 5G Radio Access network

This scenario will be trialled at EURECOM 5G-EVE test facility. A description of the facility has been previously provided in Section 3.4.1.1.6 and further information can be found in D1.2.

3.4.2.2.7. 5G Core Network

A description of the facility has been previously provided in Section **Error! Reference source not found.** and further information can be found in D1.2.

3.4.2.2.8. Mobile Edge Network

A description of the facility has been previously provided in Section 3.4.1.1.8 and further information can be found in D1.2.

3.4.2.2.9. Application Servers & Devices

3.4.2.2.9.1. Unmanned Life Central Command Platform

The Unmanned Life central command platform (UL-CCP) will be hosted on edge facilities provided by EURECOM. It is responsible for:

- Coordinating UAVs in a multi-robot environment.
- Task allocation to UAVs for mission management.
- Processing of sensor data for operational decision-making.
- Responding to UTM mission change requests.
- Forwarding of telemetry data to pre-operational UTM systems.
- Forwarding of telemetry and other UAV KPI data to the Trial Controller.

The UL-CCP will expose interfaces that allow the Unmanned Life technical team to dictate the behaviour of the UAVs per the use-case requirements. All inputs from the Trial Controller that seek to modify the behaviour of the UAVs must be validated or originate from the Unmanned Life technical team.

3.4.2.2.9.2. Frequentis 3020 LifeX Solution

The Frequentis solution is a mission-critical communications solution to manage emergency conversations in the public safety domain. The solution follows a free-seating concept. It will be installed centrally on Frequentis premises and will be accessed remotely through WAN by the control room operator. It is responsible of being the GUI of the control room operator, hence:

- Managing emergency calls
- Presenting emergency calls to the control room operator
  Presenting sensor and drone data to the control room operator

3020 LifeX has an HTML5 GUI an open API that will be used to interface the necessary 3rd party applications.

3.4.2.2.10. Security and regulation

CAA has to approve all commercial flights, hence a detailed risk analysis will be made in preparation of the trial and will together with the use case scenario description provided to CAA in order to obtain the approval or a waiver to execute the trials. Based on the feedback of CAA changes might have to be made to the trial to ensure the safety of the trial or to comply with the regulation or waiver requirements.

For this scenario large drones with take-off weights of 15kg and above will be used, hence no flights will take place over people.

Safety checks will be performed on the drones before deploying the missions and the drones will be deployed with triple safety redundancy:

1. Primary the drones will be installed with the UL-ACE software which will connect the drone to the network and enable the autonomous control of the UAV. The embedded software will also be configured with safety mitigation mission which make the drone self-sustained in case of network or platform failure. This will ensure the UAV can land, loiter or return to home safely.
2. Secondary in case the onboard software would fail or wiring problems occur to the onboard flight controller, the flight controller will be configured to return to home safely and land.
3. Finally each drone will have a safety pilot on standby with a remote control who will be able to take over the autonomous mission at all times.

During the missions the drones will be deployed with a minimal safe distance between them to ensure safety even in case of drops in GPS quality and drifts.

3.4.2.2.11. Scenario Interactions High Level Workflow

(A) Preparation stage: Please refer Section 3.3.11.

(B) Preliminary flight stage: Please refer Section 3.3.11.

(C) Flight stage

i. Use the Trial Controller to initiate the drone trial.
ii. Autonomous take off of the tethered drone to provide local 5G connectivity.
iii. Camera drones connect to the network and provide feedback once connectivity is established.
iv. Autonomous take off of the camera drones.
v. Drones follow the agreed flight plan to scan the area and stream the data for analysis and logging to the edge.
    a. The drone reports its position periodically.
    b. The drone reports some non-nominal event.
    c. The drone can receive information with regards to redirection due to dynamic conditions (ex: emergency / priority mission, or restrictions imposed by ANSP such as a no-fly zone).
    d. The drone can receive information with regards to re-routing.
    e. The drone share in real-time airspace-relevant data with other sky stakeholders that may improve overall performance.
vi. Once finished the missions the camera drones return to the home base and land autonomously.
vii. After landing and disarming of the camera drones the tether drone also lands and disarms.
viii. End of flight.

(D) Analysis & reporting: Please refer Section 3.3.11.

3.4.2.2.12. Use Case Network & Drones Critical Parameters

Network performance requirements are summarized in the table below:

Table 27: UC2:SC2 – Network critical parameters

Network Critical Parameters	Value
Height	Maximum 120 m AGL. This is the limit for VLL airspace per Eurocontrol definitions.
Speed	Maximum 70 km/h (~20 m/s) linear velocity
Data Type	**C2** from UL-CCP to UAVs
	Telemetry from UL-CCP to UTM
	Application Data from UAVs to Trial Controller via UL-CCP
	End-User Data between ground users & UAVs
Latency	**C2**: <= 10 ms one-way from eNB to UAV
	Telemetry: <= 100 ms from UL-CCP to UTM
	Application Data: ~200 ms from UAV to Trial Controller Dashboard
	End-User Data: ~50 ms for user-experienced data exchange
Data Rate	**C2**: 256 kbps from UL-CCP to UAV
	Telemetry: 800 kbps from UL-CCP to UTM
	Application Data: 50 Mbps uplink
	End-User: 10 Mbps up/down
Error Rate	**C2**: less than 10-5 block error rate
	Telemetry: less than 10-3 block error rate
	Application Data: typical values in LTE
	End-User: typical values in LTE

Drone performance requirements are summarized in the table below:

Table 28: UC2:SC2 – Drone performance requirements

Drone Critical Parameters	Value
Flight Height	Maximum 100 m AGL
Flight Speed	Maximum 70 km/h (~20m/s) linear velocity
Payload Weight	**Backhaul Drone**: gNB (7-8 kg est.)
	Video Drone: 550 g (depends on available camera)
Flight Time	**Backhaul Drone**: 120 min (tethered)
	Video Drone: 16 min (non-tethered)
Resistance to Radio Interference	Radio interference cannot interfere with C2 or KPI collection

3.4.2.2.13. Target KPIs

Quantitative KPIs to be measured during execution of this use-case are summarized in the table below:

Table 29: UC2:SC2 – Target KPIs

KPI	Description	Target Value
Service Deployment Time	The time required to provide mobile data service via UAVs, measured from the receipt of a use-case start request from the experimenter	<= 90 min
Service Data Density	Mobile data volume per geographical area	>= 8 Tbps / km$_2$
Service Area	Geographical area over which service is available	>= 0.25 km$_2$
Service Latency	User-experienced data exchange latency	<= 50 ms
Service Data Rate	User-experienced data exchange speeds	>= 10 Mbps
C2 Latency	Latency between software pilot and UAV in sending control & command messages – this value has a hard limit of 10 ms (one-way) to ensure that software systems have sufficient time to compute and send an appropriate control input with enough regularity to avoid flight instability	<= 10 ms
Video Streaming Data Rate	Data exchange speeds for streaming video feeds from UAVs to experimenters	>= 50 Mbps

3.4.2.2.14. Use Case Requirements

3.4.2.2.14.1. Functional Requirements

UC2.SC2-FUNC1	The mobile network must support 4 concurrent service slices		
Priority	Essential	**Justification**	Use case Driven
Description	Four different services shall be supported by the Use case: 1. Drone control slice for C2 communications – a uRLLC service 2. Drone data slice for video streaming - an eMBB service 3. Telemetry slice for UTM - a uRLLC service 4. User data slice for user equipment - an eMBB service		
Related Component(s)	The 5G core and Access network		

UC2.SC2-FUNC2	Mobile edge capabilities must be deployed near the UAV trial location		
Priority	Essential	**Justification**	Use case Driven
Description	The provision of the uRLLC service for the drones command and control mandates the existence of a MEC center near the trial location.		
Related Component(s)	The 5G core and Access network		

UC2.SC2-FUNC3	Enforcement of separation between UAVs operating in close proximity		
Priority	Optional	**Justification**	3GPP r.16 22.825 UC5
Description	The requirements defined in [13] use case 5 for collision avoidance in cases that drones are flying in close proximity are relevant and should be considered when the technology is made available. Drones C2 systems should use GPS RTK solution to improve precision of drone positions.		
Related Component(s)	The 5G core and Access network		

UC2.SC2-FUNC4	Radio Access Node on-board UAV		
Priority	Essential	**Justification**	3GPP r.17 22.829 UC2
Description	The requirements defined in [18] Use case 2 and summarized in Table **58** as Requirements for UxNB must be considered, and most importantly: The 5G system shall be able to support wireless backhaul with required quality to enable a UxNB. The 3GPP system shall minimize interference among UxNBs in close proximity. Optionally, if the technology is made available, the 3GPP system shall be able to monitor UxNB (e.g. power consumption of the UAV etc.) and provide means to minimize power consumption of the UxNB (e.g. optimizing operation parameter, optimized traffic delivery) without degradation of service provided. Until this is possible, a tethered drone can be used to resolve power consumption concerns.		
Related Component(s)	The 5G core and Access network		

UC2.SC2-FUNC5	The drone serving as UxNB should be capable to lift gNodeB equipment		
Priority	Essential	**Justification**	Use Case Specific
Description	The drone that shall lift radio access components should make sure that can lift the gNodeB provided as part of the experiment.		
Related Component(s)	Drone		

3.4.2.2.14.2. Non Functional Requirements

UC2.SC2-NFUNC1	Safe distance from observers		
Priority	Essential	**Justification**	Regulation
Description	The drone deployment should be in safe distance from observers.		
Related Component(s)	All		

UC2.SC2-NFUNC2	Approved flight plans		
Priority	Optional	**Justification**	Regulation
Description	If the drones fly below 120 m there is no obligation for approval.		
Related Component(s)	All		

UC2.SC2-NFUNC3	Certified Drone operators		
Priority	Essential	**Justification**	Regulation
Description	The drones must be operated by operators certified by the local authorities.		

Related Component(s)	All

UC2.SC2-NFUNC4	Connectivity shall be provided in a secure manner		
Priority	Essential	**Justification**	Security
Description	The network deployed must be protected against denial of service attacks and other malicious attempts to compromise it.		
Related Component(s)	5G network		

3.4.2.3. Scenario 3: Police, incl. counter-UAS

3.4.2.3.1. Detailed Description of Scenario

The purpose of this scenario is to demonstrate how a remotely piloted UAV and video analytics can be used for police tasks, including C-UAS activities using 5G communication.

The police are preparing for a VIP visit. The police drone delivers an area scanning IoT camera to the roof of a building which is located at the center of the risky area (hereinafter main building). The camera based on IoT LTE Cat-M1 technology sends photos and video clips of any suspicious movements to police video analyser software.

The police also use a drone that automatically flies and streams 4K video to the video analyser software and the command center. The video analysing software installed on the MEC uses videos and photos provided by the IoT cameras and drone. It also sends the gathered data to the central servers of the police.

As a part of the VIP visit, a temporary No Fly Zone (NFZ) is established. During the visit, the police drone detects an intruder drone in the NFZ. To stop the intruder drone, a human operator in the police control center starts a remotely piloted flight of the police drone. At the same time, AI (computer vision software) notices a suspicious person with a drone remote controller near the main building. The remotely pilot drone then flies near the suspicious person and affects the pilot to stop the illegal activity.

Flight plans for regular flights are provided to the 5G!Drones Test Facility UTM system with drone data, flight time, flight area in 3D and operator contacts. The police drone(s) have privileged rights in UTM system as long as it is not dangerous to other aircrafts.

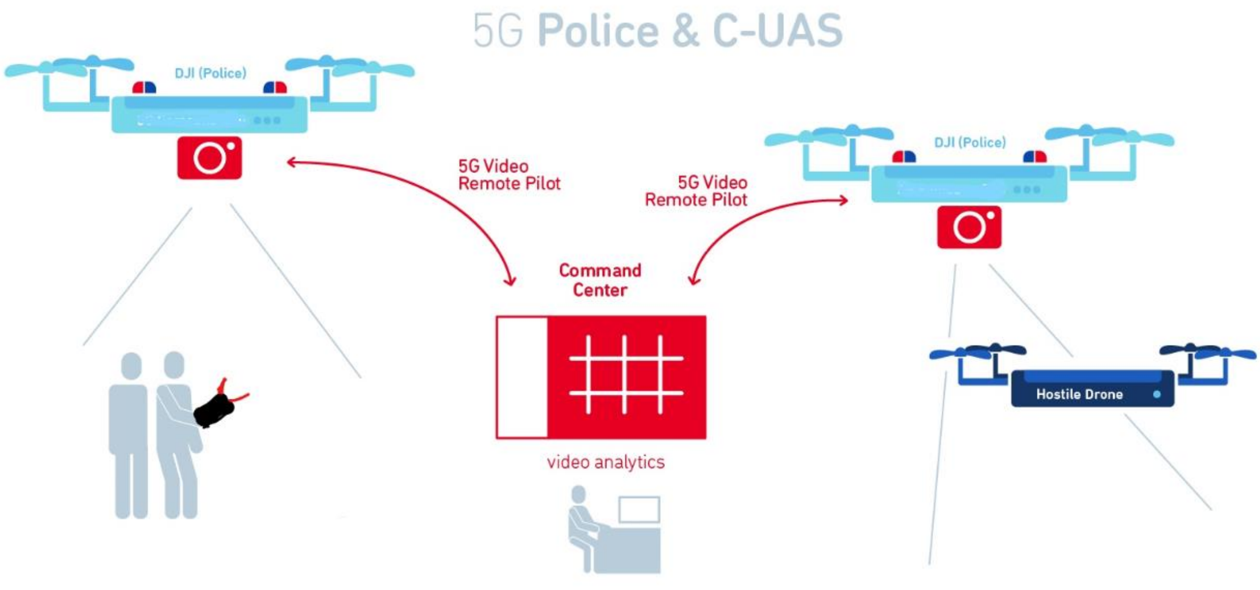

Figure 23: Overview of UC2:SC3

3.4.2.3.2. High Level Architecture

The use case shall leverage the 5G experimentation capabilities of 5GTN. This will require a network infrastructure that will provide 3 network slices:

1. Drone C2.
2. Video stream.
3. IoT communication.

This scenario involves monitoring real time events, hence it needs a dedicated uRLLC slice. It also involves the data transmission of large video data, hence will require a dedicated eMBB slice. Finally it will need a dedicated mMTC slice since the drones uses IoT telemetry from local IoT devices, which involves ultra-reliable machine type communication. The video processing will be achieved at the edge using MEC capabilities. To achieve this trial, a network infrastructure that supports the necessary slices and functionalities in this use case is required. The Oulu 5GTN will provide a dedicated MEC server for video processing before forwarding data to the cloud which will reduce the latency extensively.

3.4.2.3.3. UTM System

Please refer to Section 3.3.3.

3.4.2.3.4. UAS System

UAVs in Police scenario will be operated using the fully-autonomous, semi-autonomous and remotely piloting solutions. CAFA uses CAFA UGCS based platform (CUP) for drones C2.

The CAFA Tech CUP software will be hosted on an edge and local server. This platform is responsible for:

- Planning and coordinating UAVs missions.
- Task allocation to UAVs for mission management.
- Processing of sensor data for operational decision-making..
- Responding to UTM mission change requests.
- Forwarding of telemetry data to operational UTM systems.

Providing access to CAFA 3D application for flight routes and IoT sensors viewsheds analysing in 3D.

3.4.2.3.5. Drones

Table 30: UC2:SC3 – Drone Information

Manufacturer	DJI	DJI
Model	Matrice M210	Mavic
Number of UAVs	1	1
Tether	No	No
Max Take Off Weight	6.1 kg	1.1 kg
Max Payload	1.4 kg	190 g
Flight time	16 min (1.4 kg payload) 35 min (no payload)	15 min (190 g payload) 25 min (no payload)
Limitations	Max Wind Resistance 8m/s	8 m/s
Resistance to the interferences	Default UAV control is over DJI 2.4 GHz and 5.8 GHz radio link. Different bands compared to 5G but small risk of harmonic frequency interference. Since drone control is over 5G, the risk of interference is larger so separate slice for C2 should be used.	Default UAV control is over DJI 2.4 GHz and 5.8 GHz radio link. Different bands compared to 5G but small risk of harmonic frequency interference. Since drone control is over 5G, the risk of interference is larger so separate slice for C2 should be used.

3.4.2.3.6. 5G Radio Access network

This scenario will be trialled at University of Oulu's 5GTN test facility. A description of the facility has been previously provided in Section 3.4.1.2.6 and further information can be found in D1.2.

3.4.2.3.7. 5G Core Network

A description of the facility has been previously provided in Section **Error! Reference source not found.** and further information can be found in D1.2.

3.4.2.3.8. Mobile Edge Network and IoT Gateway

A description of the facility has been previously provided in Section 3.4.1.2.8 and further information can be found in D1.2.

3.4.2.3.9. Application Servers & Devices

3.4.2.3.9.1. CAFA Tech CUP Platform

CAFA uses CAFA UGCS CUP platform for C2 of drones. To analyse videos and photos, CAFA uses a police video analysing software. To control IoT sensors, CAFA uses its IoT software.

These software will be hosted on an edge and local server. These platforms are responsible for:

- Planning and coordinating UAVs missions.
- Task allocation to UAVs for mission management.
- Processing of sensor data for operational decision-making.
- Responding to UTM mission change requests.
- Forwarding of telemetry data to operational UTM systems.

Providing access to CAFA 3D application for flight routes and IoT sensors viewsheds analysing in 3D. The CAFA police video analyser and streaming software analyses videos from UAV and from IoT sensors/cameras and streams videos to field officers and to the police command center and to Operator. IoT camera based on LTE-M Cat1/2 technology provides video from hotspots. CAFA central server (which imitates the police command center) provides situational awareness from the UAVs video feed and IoT cameras.

3.4.2.3.10. Security and regulation

For this scenario, drones with take-off weights up to 6.1 kg (DJI Matrice 210) and up to 1.1 kg (DJI Mavic) are planned to be used.

In case the remote controller or CUP software would fail, the flight controller is configured to return to home safely and land (RTH). The Mavic drones will have a safety pilot on standby with a remote control who will be able to take over the autonomous mission at all times.

During the missions the drones will be deployed with a minimal safe distance 30 m between them to ensure safety even in case of drops in GPS quality and drifts. DJI Mavic Accuracy (P-Mode, with GPS): Vertical: ±0.5 m, Horizontal: ±1.5 m.

During the trial a human operator who will have the technical capabilities to intervene and take control over the drone will be present on site. As per the Finnish regulations, for BVLOS operations a *'Danger Area'* will be reserved and activated a day before the proposed trial.

3.4.2.3.11. Scenario Interactions High Level Workflow

(A) Preparation stage: Please refer Section 3.3.11.

(B) Preliminary flight stage

i. Prepare trial site, MEC, IoT devices, CUP, police video analysing software and communication, including installing CUP, police video analysing and IoT device controlling software to MEC.
ii. Identification of network coverage area and quality.
iii. Prepare drones and C2 system.
iv. Manual test flight and systems checks.
v. Use the portal of the 5G!Drones Trial Controller and set up the trial by providing the information needed.
vi. Send a request to the slice manager to deploy and configure the network services to the core cloud and the edge cloud. Create three distinct network slices per drone: one for the control flow (preferably uRLLC), one for the data flow (preferably eMBB) and one for IoT sensor (preferably LTE-M1).

(C) Flight stage

i. Use the Trial Controller to initiate the drone trial.

ii. Temporary NFZ is established for the upcoming VIP visit.
iii. A semi-autonomous flight is conducted with DJI Matrice to deliver the IoT camera to the main building.
iv. A fully-autonomous flight is conducted with DJI Mavic-2 which patrols and streams video from operation area.
v. Police video analysing software analyses IoT camera feed and video from drone and indicates suspicious activity (man with remote controller).
vi. Police sends the DJI Matrice to detect and stop the offender.
vii. The police drone detects intruder drone in NFZ. The police command center takes over the control of DJI Mavic-2 (remotely using 5G video stream) and starts remotely piloted flight to stop the intruder drone.
viii. Both the drones stop the intruder drone and offender (pilot with remote controller) effectively. The police patrol then arrive at the scene and resolve the situation.
ix. Once finished with the missions the drones return to the home base and land autonomously.

(D) Analysis & reporting: Please refer Section 3.3.11.

3.4.2.3.12. Use Case Network & Drones Critical Parameters

In respect to the network affecting characteristics of the use case, the following parameters are considered:

Table 31: UC2:SC3 – Network critical parameters

Network Critical Parameters	Value
Data Type	1. C2 two way communication from human operator to UAS 2. Application data: including video streaming, images, sensor data to support logistics operation applications
Coverage area	500x500x120 m AGL (LxWxH)
Latency	1. C2: UAS requirement is 50ms (one way from eNB to UAV) 2. Application data: Latency value 50 ms 3. Basic connectivity
Data Rates	1. C2:100 kbps for uplink and downlink 2. Application data: up to 30 Mbps for UL 3. Basic connectivity: 0.5 Mbps
C2 Reliability	As low as 10^{-3} Packet Error Rate because then operator can interfere with the flight

In respect to the drone characteristics of the use case, the following parameters are considered:

Table 32: UC2:SC3 – Drone critical parameters

Drones Critical Parameters	Value
Speeds and Flight time and Max TOW	Target horizontal speeds up to 40 km/h for all scenarios Flight time minimum: 15 min Max TOW: Mavic: 1.2 kg Matrice 210: 6.2 kg
Airworthiness	Drones are eligible to conduct the trial

Separation	Minimum distance between drones: 30 m
C2 Reliability	Continuous connection between the remote controller and the drone
Drone Position Accuracy by GPS	5 m

3.4.2.3.13. Target KPIs

In the light of the above context, the target KPIs that are considered for validation during the use case execution are listed in below table:

Table 33: UC2:SC3 – Target KPIs

KPI	Description	Target Values
Capacity	3GPP consolidated KPIs for UAV considers an uplink data rate between 4Mbps and 9 Mbps for video streaming for the provision of HD video streaming. Considering the case of 4K video, the target value is increased further, reaching 30 Mbps.	>30 Mbps
Latency of 5G mobile devices	Latency is important for the accurate control of the UAV in the case controlling it over the 5G network.	<= 40 ms
IoT device latency	IoT device latency is important to get online information from hotspot	<= 2 s

The total time taken to respond	The total time taken to respond from the time an intruder drone/pilot has been detected, to the time the offender (pilot) and intruder drone has been effectively stopped so that he can no longer continue the offense. This would essentially convey how much time it takes to neutralize the threat situation, also, it would also give a good idea of how well all the different systems (police video analyzing software, 5G transmission, etc.) work together. Also a tracking of independent time stamps could be done to analyze the performance for each unit systems. This would account for the system efficiency.	<= 15 min.

3.4.2.3.14. Use Case Requirements

3.4.2.3.14.1. Functional Requirements

UC2.SC3-FUNC1	**The mobile network must support 3 concurrent service slices on trial area (500x500x120 m)**		
Priority	Essential	**Justification**	Use case Driven
Description	Three different services shall be supported by the Use case: 1. C2 (Command and Contro)l for the drones, a uRLLC service 2. Video streaming from the drone for the remote piloting (FPV) by command center operator eMBB Service. 3. IoT device slice, IoT service.		
Related Component(s)	The 5G Core and Access network with IoT network		

UC2.SC3-FUNC2	**Mobile edge capabilities must be deployed in the UO test area**		
Priority	Essential	**Justification**	Use case Driven
Description	The provision of the uRLLC service for the drones command and control mandates the existence of a MEC cloud of University of Oulu.		
Related Component(s)	The 5G Core and Access network		

UC2.SC3-FUNC3	**Simultaneously support data transmission for UAVs and eMBB users**		
Priority	Essential	**Justification**	3GPP r.17 22.829 UC4
Description	The 5G system shall need to optimize the resource use of the control plane and/or user plane for transfer of continuous uplink data that requires both high data rate and very low end-to-end latency.		
Related Component(s)	The 5G Core and Access network		

UC2.SC3-FUNC4	**The mobile network must support prioritization**		
Priority	Essential	**Justification**	Use case Driven

Description	The provision of the uRLLC service with required SLA in the volume of airspace is critical for the drones C2 link.		
Related Component(s)	The 5G core and Access network and RAN		

UC2.SC3-FUNC5	**The network should provide service for the remote operator**		
Priority	High	**Justification**	Use case Driven
Description	A transmission link must be provided for the drone operator in a remote location, at least at the same level as provided for the drones.		
Related Component(s)	The 5G core and Access network, RAN		

3.4.2.3.14.2. Non Functional Requirements

UC2.SC3-NFUNC1	**Approved SORA**		
Priority	Essential	**Justification**	Regulation
Description	No objections from Traficom (Finnish CAA).		
Related Component(s)	Operator		

UC2.SC3-NFUNC2	**Connectivity shall be provided in a secure manner**		
Priority	Optional	**Justification**	Security
Description	The network deployed must be protected against denial of service attacks and other malicious attempts to compromise it		
Related Component(s)	5G network		

3.4.3. Use Case 3: Situation awareness

3.4.3.1. Scenario 1: Infrastructure inspection

3.4.3.1.1. Sub-scenario 1: 3D Mapping of 5G QoS

3.4.3.1.1.1. Detailed Description of Scenario

The 5G signal quality drops significantly when it is obstructed by various objects. Therefore, it is necessary to plan base stations in 3D for best 5G coverage. Because buildings and other objects have different materials, modelling does not provide a complete answer to the quality of 5G signal propagation.

5G signal propagation is usually measured on the ground by the car. However, it is equally important to control the propagation of the 5G signal at the height of the windows of the apartment buildings (i.e. up to 50 m). For measuring signal propagation at such heights and over, drones are a very effective tool. The results can be used to decide how to move the 5G base station or change beamforming.

For measuring 5G QoS the communication company ordered from drone company the 3D mapping of 5G QoS. At first, the drone (DJI Mavic) take photos which are then processed into a 3D map. This is followed by placing the 5G base stations on the 3D map.

The drone then carries 5G communications equipment to measure the quality of 5G coverage from various positions with 3D coordinates (x,y,z). During the measuring process radio base station

signal parameters (directions and strength etc.) will be changed. Measuring results are transferred to the server and then results visualised on the 3D Map.

3.4.3.1.1.2. High Level Architecture

The use case shall leverage the 5G experimentation capabilities of 5GTN. This will require a network infrastructure that will provide 2 network slices:

1. Drone C2.
2. 5G signal measuring results real time transfer.

This scenario involves monitoring real time quality of signal, hence it needs a dedicated uRLLC slice. It also involves the C2 data transmission.

For 3D measuring there are 2 critical elements:

a) Accurate real time positioning.
b) Same timestamps for measuring and drone positions data.

The data processing will be achieved at the edge using MEC capabilities. To achieve this trial, a network infrastructure that supports the necessary slices and functionalities in this use case is required. The Oulu 5GTN will provide a dedicated MEC server for process this data.

3.4.3.1.1.3. UTM System

Please refer to Section 3.3.3.

3.4.3.1.1.4. UAS System

UAV in this scenario will be operated using the fully-autonomous solution. CAFA uses CAFA UGCS CUP platform for drones C2.

The CAFA Tech CUP software will be hosted on an edge and local server. This platform is responsible for:

- Planning and coordinating UAVs missions.
- Task allocation to UAVs for mission management.
- Processing of sensor data for operational decision-making.
- Responding to UTM mission change requests.
- Forwarding of telemetry data to operational UTM systems.
- Providing access to CAFA 3D application for flight routes and base stations viewsheds analysing in 3D.

3.4.3.1.1.5. Drones

Table 34: UC3:SC1:sub-SC1 – Drone Information

Manufacturer	DJI
Model	Mavic
Number of UAVs	1
Tether	No
Max Take Off Weight	1.1 kg
Max Payload	190 g
Flight time	15 min (190 g payload)

	25 min (no payload)
Limitations	8 m/s
Resistance to the interferences	Default UAV control is over DJI 2.4 GHz and 5.8 GHz radio link. Different bands compared to 5G but small risk of harmonic frequency interference. Since drone control is over 5G, the risk of interference is larger so separate slice for C2 should be used.

3.4.3.1.1.6. 5G Radio Access network

This scenario will be trialled at University of Oulu's 5GTN test facility. A description of the facility has been previously provided in Section 3.4.1.2.6 and further information can be found in D1.2.

3.4.3.1.1.7. 5G Core Network

A description of the facility has been previously provided in Section **Error! Reference source not found.** and further information can be found in D1.2.

3.4.3.1.1.8. Mobile Edge Network

A description of the facility has been previously provided in Section 3.4.1.2.8 and further information can be found in D1.2.

3.4.3.1.1.9. Application Servers & Devices

3.4.3.1.1.9.1. CAFA Tech CUP Platform

CAFA uses CAFA UGCS CUP platform for drone C2 on automated fully autonomous flights. Producing 3D map CAFA uses Agisoft or relevant software. QoS visualising on 3D map is done by CAFA Analyzer.

The CAFA Tech CUP and CAFA Analyzer will be hosted on an edge and local server. These platforms are responsible for:

- Planning and coordinating UAVs missions.
- Task allocation to UAVs for mission management.
- Processing of sensor data for operational decision-making.
- Responding to UTM mission change requests.
- Forwarding of telemetry data to operational UTM systems.
- Providing QoS visualisation on 3D map.

3.4.3.1.1.10. Security and regulation

For this scenario, a drone with take-off weights up to 1.1 kg (DJI Mavic) is planned to be used.

In case the remote controller or CUP software would fail, the flight controller is configured to return to home safely and land (RTH). The Mavic drones will have a safety pilot on standby with a remote control who will be able to take over the autonomous mission at all times.

During the missions the drones will be deployed with a minimal safe distance 30 m between them to ensure safety even in case of drops in GPS quality and drifts. DJI Mavic Accuracy (P-Mode, with GPS): Vertical: ±0.5 m, Horizontal: ±1.5 m.

During the trial a human operator who will have the technical capabilities to intervene and take control over the drone will be present on site. As per the Finnish regulations, for BVLOS operations a *'Danger Area'* will be reserved and activated a day before the proposed trial.

3.4.3.1.1.11. Scenario Interactions High Level Workflow

(A) Preparation stage: Please refer Section 3.3.11.

(B) Preliminary flight stage

i. Prepare trial site, MEC, CUP and 3D map and QoS Analyzer software and communication
ii. Prepare drones and C2 system.
iii. Manual test flight and systems checks.
iv. Use the portal of the 5G!Drones Trial Controller and set up the trial by providing the information needed.
v. Send a request to the slice manager to deploy and configure the network services to the core cloud and the edge cloud. Create two distinct network slices per drone: one for the control flow (preferably uRLLC), one for the data flow (preferably eMBB).

(C) Flight stage

i. Use the Trial Controller to initiate the drone trial.
ii. A fully-autonomous flight is deployed when the DJI Mavic collects photos and videos for creation of 3D map.
iii. The drone lands autonomously.
iv. 3D map creation (approximately 2 hours).
v. Planning route for measuring 5G signal QoS.
vi. A fully-autonomous flight is deployed when the DJI Mavic measures 5G signal QoS.
vii. Once the missions are completed, the drone return to the home base and land autonomously.

(D) Analysis & reporting: Please refer Section 3.3.11.

3.4.3.1.1.12. Use Case Network & Drones Critical Parameters

In respect to the network related characteristics of the use case, the following parameters are considered:

Table 35: UC3:SC1:sub-SC1 – Network critical parameters

Network Critical Parameters	Value
Data Type	1. C2 two way communication from human operator to UAS 2. Application Data: including video streaming, images, sensor data to support logistics operation applications
Coverage area	500x500x120 m AGL (LxWxH)
Latency	1. C2: UAS requirement is 50 ms (one way from eNB to UAV) 2. Application data: Latency value 50 ms 3. Basic connectivity
Data Rates	1. C2:100 kbps for uplink and downlink 2. Application data: up to 30 Mbps for UL 3. Basic connectivity: 0.5 Mbps

C2 Reliability	As low as 10^{-3} packet error rate because then operator can interfere with the flight

In respect to the drone characteristics of the use case, the following parameters are considered:

Table 36: UC3:SC1:sub-SC1 – Drone critical parameters

Drone Critical Parameters	Target Value
Speeds and Flight time and Max TOW	Target horizontal speeds up to 40 km/h for all scenarios Flight time minimum 15 min Max TOW: Mavic: 1.2 kg
Airworthiness	Drones are eligible to conduct the trial
Separation	Minimum distance between drones: 30 m
C2 Reliability	Continuous connection between the remote controller and the drone
Drone Position Accuracy by GPS	1 m

3.4.3.1.1.13. Target KPIs

In the light of the above context, the target KPIs that are considered for validation during the use case execution are listed in below table:

Table 37: UC3:SC1:sub-SC1 – Target KPIs

KPI	Description	Target Values
Capacity	3GPP consolidated KPIs for UAV considers an uplink data rate between 4 Mbps and 9 Mbps for video streaming for the provision of HD video streaming. Considering the case of 4K video, the target value is increased further, reaching 30 Mbps.	>30 Mbps
Latency of 5G mobile devices	3GPP considers different target values for control latency based on the planned service.	<= 50 ms

3.4.3.1.1.14. Use Case Requirements

3.4.3.1.1.14.1.Functional Requirements

UC3.SC1-FUNC1	The mobile network must support 2 concurrent service slices		
Priority	Essential	**Justification**	Use case Driven
Description	Two different services shall be supported by the Use case: 1. C2 for the drones, a uRLLC service 2. Signal measuring data transferring, a uRLLC service		
Related Component(s)	The 5G core and Access network		

UC3.SC1-FUNC2	Mobile edge capabilities must be deployed in the UO test area		
Priority	Essential	**Justification**	Use case Driven
Description	The provision of the uRLLC service for the drones command and control mandates the existence of a MEC cloud of University of Oulu.		
Related Component(s)	The 5G Core and Access network		

UC3.SC1-FUNC3	Simultaneously support data transmission for UAVs and users		
Priority	Essential	**Justification**	3GPP r.17 22.829 UC4
Description	The 5G system shall need to optimize the resource use of the control plane and/or user plane for transfer of continuous uplink data that requires both high data rate and very low end-to-end latency.		
Related Component(s)	The 5G Core and Access network		

UC3.SC1-FUNC4	The mobile network must support prioriterisation		
Priority	Essential	**Justification**	Use case Driven
Description	The provision of the uRLLC service with required SLA in the volume of airspace is critical for the drones' command and control (C2 link).		
Related Component(s)	The 5G core and Access network and RAN		

UC3.SC1-FUNC5	The network should provide service for the remote operator		
Priority	High	**Justification**	Use case Driven
Description	A transmission link must be provided for the drone operator in a remote location, at least at the same level as provided for the drones.		
Related Component(s)	The 5G core and Access network, RAN		

3.4.3.1.1.14.2.Non Functional Requirements

UC3.SC1-NFUNC1	Approved SORA		
Priority	Essential	**Justification**	Regulation
Description	No objections from Traficom (Finnish CAA).		
Related Component(s)	Operator		

UC3.SC1-NFUNC2	Connectivity shall be provided in a secure manner		
Priority	Essential	**Justification**	Security
Description	The network deployed must be protected against denial of service attacks and other malicious attempts to compromise it		
Related Component(s)	5G network		

3.4.3.1.2. Sub-scenario 2: Long range power line inspection

3.4.3.1.2.1. Detailed Description of Scenario

The purpose of this sub-scenario is to demonstrate how UAVs could be used in well-connected 5G urban areas for power line inspection and fault detection. This is an essential and time critical service, which can greatly benefit from the advantages of 5G networks. For example, there is a power outage because of a strong storm. Currently, drones are used in VLOS operations where the UAV collects large amounts of data using LIDAR and cameras which is later analyzed. This kind of operation has two limiting factors, firstly the drone operator has to maintain VLOS which means all kinds of physical obstacles on the ground limit the operator’s movement which in turn limits the UAV’s use. Secondly large amounts of data is saved and later processed, which takes time. 5G networks with low latency and high bandwidth will help UAV operators carry out BVLOS operations transmitting the LIDAR and camera payload data in real time, giving quicker and more efficient results.

The planned trial will focus on BVLOS operations in different weather conditions and data intensive payload transmitting. We will make a mock-up course were the UAV will be connected to a 5G network and be flying semi-autonomously. The UAV is equipped with one LIDAR for collision avoidance, one LIDAR for infrastructure inspection, one camera for 4k video streaming and one sensitive camera for night image processing. The operator will be connected to Hepta’s on-the-cloud software and monitoring the data stream. The operator can also modify the flight plan and change the camera gimbal angles.

In the mockup course there will be a power line insulator which the UAV and operator have to find using LIDAR and camera data. The insulator symbolizes the fault in the power lines and the whole process is similar to real life power line inspection. For regulatory and safety purposes there will also be an official safety pilot to comply with VLOS regulations. They will be on-site and have the ability to manually override the UAV if the need arises. The UAV will utilize MEC capabilities for more efficient data analysis, consisting of image recognition, decision making and using the SLAM algorithm for LIDAR data. In addition, we will simulate different weather conditions for example night and fog to see if this changes the operation.

3.4.3.1.2.2. High Level Architecture

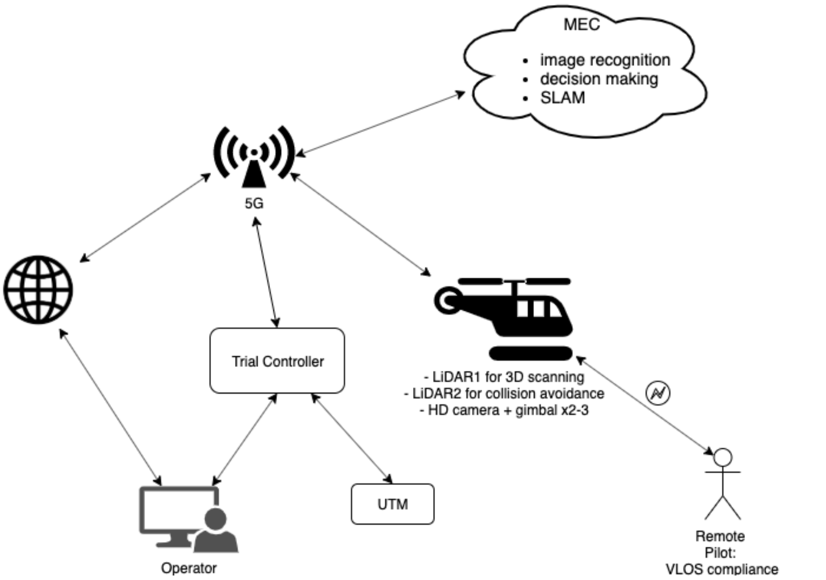

Figure 24: UC3:SC1:sub-SC2 – High level architecture 1

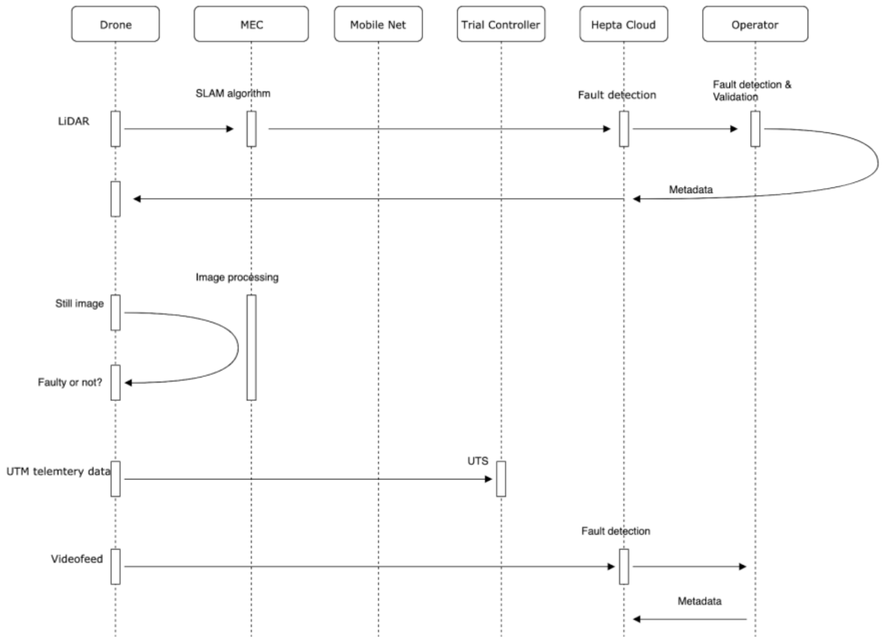

Figure 25: UC3:SC1:sub-SC2 – High level architecture 2

3.4.3.1.2.3. UTM System

Please refer to Section 3.3.3.

3.4.3.1.2.4. UAS System

Hepta's UAS setup has been described in Section 2.3.2.1.2. UAV will be operated by uploading a predefined mission file to the autopilot. The UAV is connected to the 5G network and the operator shall have the opportunity to intervene the semi-autonomous flight process by either pausing, cancelling or modifying the flight. The operator can do this remotely by utilizing Hepta's online GCS. To make it easier to understand when we reference the operator, we also mean the GCS software the operator is using. For example, during the flight, telemetry data will be streamed to the operator which is connected to UTM (actually data is streamed to GCS which is controlled by the operator). The setup uses a separate computing unit in addition to flight controller. Mission

preparation, upload and telemetry stream for the operator will be through QGroundControl utilizing the Mavlink protocol. Computing units can be added according to the payload configuration achieving separation of C2 commands, collision avoidance and high-bandwidth sensor data streams if needed.

3.4.3.1.2.5. Drones

Table 38: UC3:SC1:sub-SC2 – Drone Information

Manufacturer	Hepta
Model	FX-20 Hybrid
Number of UAVs	1
Tether	No
Max Take Off Weight	25 kg
Max Payload	7 kg
Hovering time	60 min
Limitations	Max Wind Resistance 15 m/s
Resistance to the interferences	Safety pilot UAV control is over 868 Mhz radio control. Different bands compared to 5G but small risk of harmonic frequency interference. When drone control is over 5G, the risk of interference larger so separate slice for C2 should be used. Return home and land function programmed to UAV in case of connectivity problems.
Equipped sensors	1 LIDAR for collision avoidance 1 LIDAR for infrastructure inspection 1 Sony A7S for night vision video with gimbal 1 Sony A7R for 4k video streaming with gimbal

3.4.3.1.2.6. 5G Radio Access network

This scenario will be trialled at University of Oulu's 5GTN test facility. A description of the facility has been previously provided in Section 3.4.1.2.6 and further information can be found in D1.2.

3.4.3.1.2.7. 5G Core Network

A description of the facility has been previously provided in Section **Error! Reference source not found.** and further information can be found in D1.2.

3.4.3.1.2.8. Mobile Edge Network

A description of the facility has been previously provided in Section 3.4.1.2.8 and further information can be found in D1.2.

3.4.3.1.2.9. Application Servers & Devices

The operator will be connected to Hepta's Ground Control Station software via Hepta's data cloud. The MEC will be running image processing and LIDAR data SLAM software.

3.4.3.1.2.10. Security and regulation

CAA has to approve all commercial flights; hence a detailed risk analysis will be made in preparation of the trial and will together with the use case scenario description provided to CAA in order to obtain the approval or a waiver to execute the trials. Based on the feedback of CAA changes might have to be made to the trial to ensure the safety of the trial or to comply with the regulation or waiver requirements.

For this scenario on large drones with take-off weight of 25 kg will be used, hence no flights will take place over people.

Safety checks will be performed on the drone before deploying the mission and the drone will be deployed with safety redundancy. In case the on-board software or connectivity problems the drone will be programmed for return to home and land safely instructions. In addition, we will also have an onsite safety pilot who can take over manual control if it is necessary.

3.4.3.1.2.11. Scenario Interactions High Level Workflow

(A) Preparation stage: Please refer Section 3.3.11.

(B) Preliminary flight stage: Please refer Section 3.3.11.

(C) Flight stage

i. Use the Trial Controller to initiate the drone trial.
ii. The drone connects to the network and provides feedback once connectivity is established.
iii. Autonomous take off of the drone.
iv. The drone follows the agreed flight plan to scan the area and stream the data for analysis.
    a. The drone reports its position periodically.
    b. Real time Image recognition over MEC.
    c. LIDAR data is processed over MEC.
    d. Full sensor data is streamed to the operator.
    e. The drone can receive information with regards to re-routing from the operator.
v. Once finished the mission the drone returns to the home base and land autonomously.
vi. The process is repeated for different simulated weather conditions.
vii. End of trial.

(D) Analysis & reporting: Please refer Section 3.3.11.

3.4.3.1.2.12. Use Case Network & Drones Critical Parameters

Network performance requirements are summarized in the table below:

Table 39: UC3:SC1:sub-SC2 – Network critical parameters

Parameter	Value
Height	Maximum 120 m AGL. This is the limit for VLL airspace per Eurocontrol definitions.
Speed	Maximum 70 km/h (ca 20 m/s) linear velocity

Data Type	**C2** from operator to UAV. Including pause, cancel, modify flight plan commands and also camera gimbal control commands.
	LIDAR mapping (for collision avoidance) from UAV to operator
	Telemetry from UAV to operator
	Payload Data between UAV and operator
Latency	**C2**: <= 10 ms one-way from eNB to UAV
	LIDAR mapping (for collision avoidance): <= 10 ms from UAV to operator
	Telemetry: <= 50 ms from UAV to operator
	Payload Data: ~50 ms from UAV to operator
Data Rate	**C2**: 256 kbps from operator to UAV
	LIDAR mapping (for collision avoidance): 120 Mbps from UAV to operator
	Telemetry: 800 kbps from UAV to operator
	Payload data: 120 Mbps up/down
Error Rate	**C2**: less than 10^{-5} block error rate
	LIDAR mapping (for collision avoidance): less than 10^{-3} block error rate
	Telemetry: less than 10^{-3} block error rate
	End-User: typical values in LTE

Drone performance requirements are summarized in the table below:

Table 40: UC3:SC1:sub-SC2 – Drone critical parameters

Parameter	Value
Flight Height	Maximum 120 m AGL
Flight Speed	Maximum 70 km/h (20 m/s) linear velocity
Min Payload Weight	3 kg
Min Endurance	30 min
Resistance to Radio Interference	Radio interference cannot interfere with C2 or KPI collection
Sensor control	UAV has to be equipped with controllable gimbals for camera control

3.4.3.1.2.13. Target KPIs

Quantitative KPIs to be measured during execution of this use-case are summarized in the table below.

Table 41: UC3:SC1:sub-SC2 – Target KPIs

KPI	Description	Target Value
C2 Latency	Latency between operator and UAV in sending control & command messages – this value has a hard limit of 10ms (one-way) to ensure that software systems have sufficient time to compute and send an appropriate control input with enough regularity to avoid flight instability	<= 10 ms
Collision Avoidance LIDAR Data rate and latency	The collision avoidance LIDAR is an essential data stream the operator. Latency and Data rate from the UAV to operator.	<= 10 ms >= 120 Mbps
Payload Video Streaming Data Rate	Data exchange speeds for streaming video feeds from 2 cameras from UAV to operator	>= 100 Mbps
Payload LIDAR streaming Data rate	Data exchange speed for streaming LIDAR laser mapping from UAV to operator	>= 120Mbps

3.4.3.1.2.14. Use Case Requirements

3.4.3.1.2.14.1.Functional Requirements

UC3.SC1-FUNC1	The mobile network must support 4 concurrent service slices		
Priority	Essential	**Justification**	Use case Driven
Description	Four different services shall be supported by the Use case: 1. Drone control slice for C2 communications – a uRLLC service. 2. Drone data slice for LIDAR mapping for collision avoidance - an eMBB and uRLLC service. 3. Telemetry slice for GCS and UTM - a uRLLC service. 4. Payload data - an eMBB service (LIDAR + 2 camera data stream).		
Related Component(s)	The 5G core and Access network		

3.4.3.1.2.14.2.Non Functional Requirements

UC3.SC1-NFUNC1	Safe distance from observers		
Priority	Essential	**Justification**	Regulation
Description	The drone deployment should be in safe distance from observers.		
Related Component(s)	All		

UC3.SC1-NFUNC2	Approved Flight Plans		
Priority	Optional	**Justification**	Regulation
Description	If the drone flies below 120 m there is no obligation for approval.		
Related Component(s)	All		

UC3.SC1-NFUNC3	Certified Drone operators		
Priority	Optional	**Justification**	Regulation
Description	The drone must be operated by operators certified by the local authorities.		

Related Component(s)	All

UC3.SC1-NFUNC4	**Connectivity shall be provided in a secure manner**		
Priority	Optional	**Justification**	Security
Description	The network deployed must be protected against denial of service attacks and other malicious attempts to compromise it.		
Related Component(s)	5G network		

3.4.3.1.3. Sub-scenario 3: Inspection and search & recovery operations in large body of water

3.4.3.1.3.1. Detailed Description of Scenario

This sub-scenario aims at demonstrating how 5G can support and greatly enhance the efficiency of daily UAV inspection operations. More specifically, the operations that this sub-scenario will demonstrate are water survey operations using a hybrid air and water drone.

The goal of the operation is to monitor the state and the evolution of water bodies such as rivers, streams and lakes. For this purpose, a hybrid drone equipped with the required sensors (water quality probes, sonar/lidar…) patrols on the water and gathers data. This data is then post-processed to produce a report on the water quality and a map of underwater depth (bathymetry).

Currently, the control range of the UAV and the lack of embedded processing power are preventing this scenario to be performed in an efficient manner.

With the ability to provide reliable communications and processing power at the edge, 5G has the potential to make this scenario reach its full efficiency enabling reliable long-distance missions and real-time processing of the data for instant insights of a situation.

In the case of a Search & Recovery mission, where teams of divers must inspect the depths of the water, the instant resulting map will help divers to know their working environment and help ensure safer operations.

3.4.3.1.3.2. High Level Architecture

The use case shall leverage the 5G experimentation capabilities of the 5GTN platform in University of Oulu. The core components of the use case considered for this use case are depicted in the picture below:

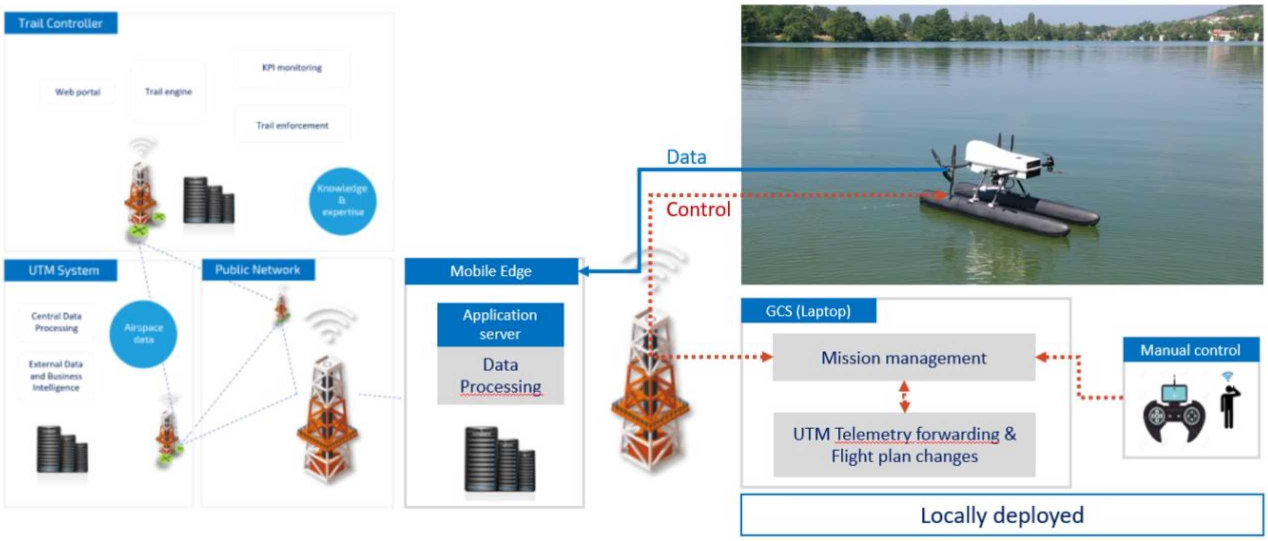

Figure 26: UC3:SC1:sub-SC3 – High level architecture

The main components envisaged to have an active role in the use case execution and interact to ensure the proper operation are discussed below.

3.4.3.1.3.3. UTM System

Please refer to Section 3.3.3.

3.4.3.1.3.4. UAS System

The UAV in this scenario will be operated using the fully-autonomous local deployment model described in Section 2.3.2.

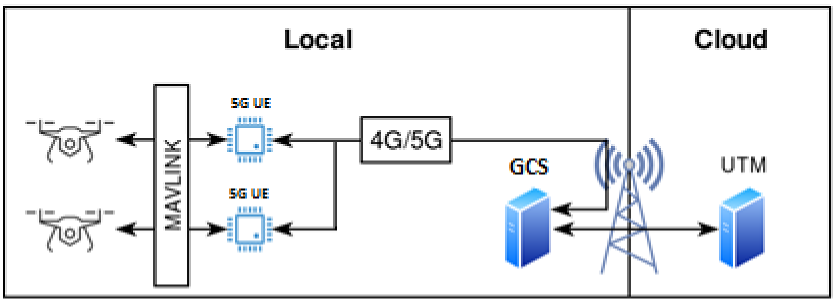

Figure 27: UC3:SC1:sub-SC3 – UAS deployment model

Alerion deploys its GCS on a laptop on-site. The GCS communicates with the UAV through the 5G network and manages the missions. It is the responsibility of the GCS to interface with the UTM.

3.4.3.1.3.5. Drones

The drone will be a customised version of Alerion's hybrid air and water drone (Hydradrone). The drone has the capacity to fly but can also navigate on water due to its rotating rear arm and floats. Once on the water, the embedded probes and sensors start gathering data. Below are the Hydradrone's specifications:

Table 42: UC3:SC1:sub-SC3 – Drone Information

Manufacturer	Alerion
Number	1
Configuration	Multirotor X8
MTOW	8 kg when fully loaded
Payload	• Capacity: currently up to 1.5 kg (can be enhanced with a custom Hydradrone) • Type: water quality sensor, bathymetric sensor
Hovering time	12-15 min
Max altitude for this scenario	30 m AGL
Max. speed	10 m/s (36 km/h)
Operation	Autonomous (the UAV works autonomously but is supervised by an operator with the capacity to take the manual control)

3.4.3.1.3.6. 5G Radio Access Network

This scenario will be trialled at University of Oulu's 5GTN test facility. A description of the facility has been previously provided in Section 3.4.1.2.6 and further information can be found in D1.2.

3.4.3.1.3.7. 5G Core Network

A description of the facility has been previously provided in Section **Error! Reference source not found.** and further information can be found in D1.2.

3.4.3.1.3.8. Mobile Edge Network

A description of the facility has been previously provided in Section 3.4.1.2.8 and further information can be found in D1.2.

3.4.3.1.3.9. Application Servers & Devices

3.4.3.1.3.9.1. Alerion's GCS

The GCS will be hosted on a laptop deployed on site. It is responsible for:

- Managing the Hydradrone's mission through 5G network.
- Allowing the pilot to control the UAV manually when/if needed.
- Responding to UTM mission change requests.
- Forwarding of telemetry data to pre-operational UTM systems.

3.4.3.1.3.9.2. Alerion's post-processing application

Alerion's post-processing application will be hosted on an edge server. It is responsible for:

- Receiving the Hydradrone's specific sensors's data.
- Reconstituting 2D/3D map with the data.
- Provide a report on the situation.

3.4.3.1.3.10. Security and regulation

Since the flights will take place in a populated area, special restrictions apply to the UAV. Flights will be performed in VLOS for the trials and its mass should not be over 7 kg according to Finnish regulation. Description of operation, Safety assessment and Operating procedures documents will be written and transmitted to Finnish CAA in order to have the permission of performing the flights.

The following additional safety measures will be taken:

- The UAV's autopilot will be able to safely return to home and land in case of a loss on connection.
- The UAV is equipped with a termination system composed of a parachute, an engine cutter and a buzzer. The system has its own independent battery.
- At all time, a pilot will be on standby with a remote control and will have the possibility to take over the autonomous mission.

3.4.3.1.3.11. Scenario Interactions High Level Workflow

(A) Preparation stage: Please refer Section 3.3.11.

(B) Preliminary flight stage: Please refer Section 3.3.11.

(C) Flight stage

i. Use the Trial Controller to initiate the drone trial.
ii. Autonomous take off of the drone.
iii. The drone follows the agreed flight plan to perform the scanning and water quality survey:
    a. The drone reports its position periodically.
    b. The drone reports some non-nominal event.
    c. The drone can receive information with regards to re-routing.
    d. The drone feeds the measured data to the data processing application running at the edge in order to have instant insights on the situation.
iv. Once finished the mission, the drone returns to the home base and lands autonomously.
v. End of flight.

(D) Analysis & reporting: Please refer Section 3.3.11.

3.4.3.1.3.12. Use Case Network & Drones Critical Parameters

Network performance requirements are summarized in the table below:

Table 43: UC3:SC1:sub-SC3 – Network critical parameters

Network Critical Parameters	Value
Height	Maximum 30 m AGL
Speed	Maximum 30 km/h (~8.3 m/s) linear velocity
Data Type	**C2** from GCS to UAVs
	Telemetry from GCS to UTM
	Mission Data from UAV to MEC
Latency	**C2**: <= 10 ms one-way from GCS to UAV
	Telemetry: <= 100 ms from GCS to UTM
	Mission Data: ~200 ms from UAV to MEC
Data Rate	**C2**: 256 kbps from GCS to UAV
	Telemetry: 256 kbps from GCS to UTM
	Mission Data: 50 Mbps uplink
Error Rate	**C2**: less than 10^{-5} block error rate
	Telemetry: less than 10^{-3} block error rate

	Mission Data: typical values in LTE

Drone performance requirements are summarized in the table below.

Table 44: UC3:SC1:sub-SC3 – Drone critical parameters

Drone Critical Parameters	Value
Flight Height	Maximum 30 m AGL
Flight Speed	Maximum 30 km/h (~8.3 m/s) linear velocity
Payload Weight	1.5 kg for sonar and water quality sensors
Flight Time	Hovering : ~15 min
	Navigating: ~2 hours
Resistance to Radio Interference	Radio interference cannot interfere with C2 or KPI collection

3.4.3.1.3.13. Target KPIs

Quantitative KPIs to be measured during execution of this use-case are summarized in the table below.

Table 45: UC3:SC1:sub-SC3 – Target KPIs

KPI	Description	Target Value
Service Deployment Time	The time required to start performing the mission, measured from the receipt of a use-case start request from the experimenter	<= 60 min
C2 Latency	Latency between software pilot and UAV in sending control & command messages – this value has a hard limit of 10ms (one-way) to ensure that software systems have sufficient time to compute and send an appropriate control input with enough regularity to avoid flight instability	<= 10 ms
Sensor Data Rate	Data exchange speed for sending sensor data from UAV to data processing application on edge server.	>= 50 Mbps
Hourly inspected area	The maximum area that can be inspected in one hour of time from the beginning on the mission to the reception of the results.	>= 50 000 m² / hour

3.4.3.1.3.14. Use Case Requirements

3.4.3.1.3.14.1.Functional Requirements

UC3.SC1-FUNC1	The mobile network must support 2 concurrent service slices		
Priority	Essential	**Justification**	Use case Driven
Description	Two different services shall be supported by the Use case: Command and Control of the drone and an eMBB Service Sending measurement data.		
Related Component(s)	The 5G core and Access network		

UC3.SC1-FUNC2	Mobile edge capabilities		
Priority	Essential	**Justification**	Use case Driven
Description	Alerion's post-processing software needs to be run on the edge in order to perform direct post-processing of the measurement data.		
Related Component(s)	The 5G core and Access network		

UC3.SC1-FUNC3	Coverage		
Priority	Essential	**Justification**	Use case Driven
Description	The targeted flight location should be covered or at least partially covered.		
Related Component(s)	The 5G core and Access network		

3.4.3.1.3.14.2.Non Functional Requirements

UC3.SC1-NFUNC1	Safe distance from observers		
Priority	Essential	**Justification**	Regulation
Description	The drone deployment should be in safe distance from observers.		
Related Component(s)	All		

UC3.SC1-NFUNC2	Approved Flights		
Priority	Optional	**Justification**	Regulation
Description	For flights in densely populated areas, the required flight preparation documents must be transmitted to the Finnish CAA.		
Related Component(s)	All		

UC3.SC1-NFUNC3	Certified Drone operators		
Priority	Essential	**Justification**	Regulation
Description	The drones must be operated from certified operators (certified by the local authorities)		
Related Component(s)	All		

UC3.SC1-NFUNC4	Connectivity shall be provided in a secure manner		
Priority	Optional	**Justification**	Security
Description	The network deployed must be protected against denial of service attacks and other malicious attempts to compromise it.		
Related Component(s)	5G network		

3.4.3.2. Scenario 2: UAV-based IoT data collection

3.4.3.2.1. Detailed Description of Scenario

The following story is provided to describe the scenario "UAV-based IoT data collection". Thomas from France is interested in setting up a construction business in a site located in the area of Helsinki, Finland. While he is in a meeting with his stockholders, he wanted to show them the site and provide them with real-time data related to this location. Thomas is interested in getting pictures, videos, but also measurements such as temperature and humidity, etc. Such services require on-demand deployment of IoT devices, which can be achieved using drones equipped with IoT sensors, and directing them to the target site. The data collected by each of the drones are streamed to an edge server situated near the target site. In order to provide advanced insights, the collected data are aggregated and analyzed at the level of the edge server. In case of video streaming, Thomas changes the format and the quality of the video according to his preferences.

3.4.3.2.2. High Level Architecture

In the scenario 'UAV-based IoT data collection', drones will be used to collect IoT data from height. This will be performed by the IoT devices which are on-board of the drones (a general overview is depicted in the below figure). The moving ability of the drones will be exploited to direct them to the target location in order to provide on-demand services. The UAV controller deployed at the cloud level performs the command and the control of the drones. Virtual flight controllers are also

instantiated at the edge server near the trial site. As for the data collected by the UAVs, a dedicated module hosted at the edge server is used for aggregation and analysis, which communicates with a central data module deployed at the central cloud.

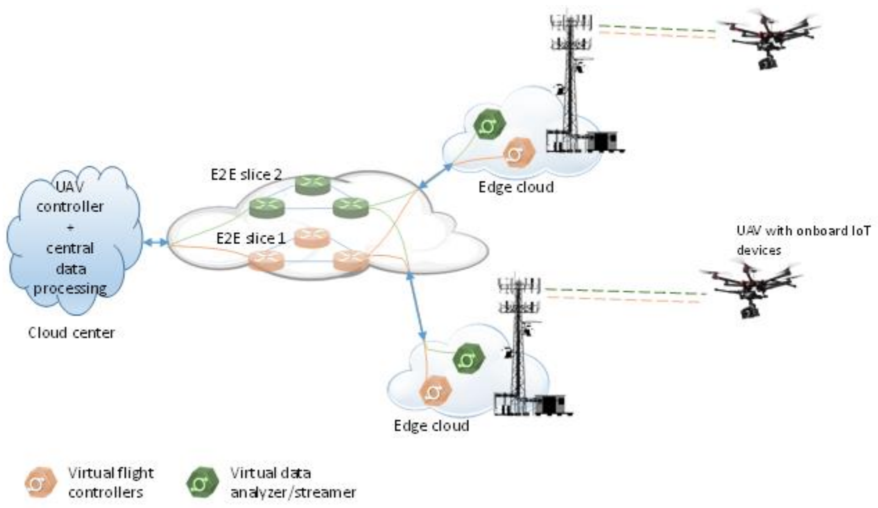

Figure 28: UC3:SC2 - High level architecture

3.4.3.2.3. UTM System

Please refer to Section 3.3.3.

3.4.3.2.4. UAS System

The flying drones will be controlled using the control software developed by Aalto University. This includes the module running at the UAVs, the virtual flight controller instantiated in the edge or running at the cloud.

3.4.3.2.5. Drones

The supporting drones for the scenario "UAV-based IoT data collection" will be provided by Aalto University. The drone platform compromises H frame and X frame models. The underlying specifications are provided in the following table.

Table 46: UC3:SC2 – Drone Information

Key features	H frame	X frame
Weight (w/ battery)	2.5 kg	2.5 kg
Max Takeoff Weight	3 kg	3 kg
Max Speed (no wind)	15 m/s	20 m/s
Hovering time	Around 20 min	Around 20 min
Flight controller	Pixracer	Pixhawk
On-board IoT devices	Gas sensor, Humidity & Temperature sensor, camera	Gas sensor, Humidity & Temperature sensor, camera
Quantity	2	2

3.4.3.2.6. 5G Radio Access network

This scenario will be trialled at Aalto University's X-Network 5G test facility. A description of the facility has been previously provided in Section 3.4.1.3.6 and further information can be found in D1.2.

3.4.3.2.7. 5G Core Network

A description of the facility has been previously provided in Section **Error! Reference source not found.** and further information can be found in D1.2.

3.4.3.2.8. Mobile Edge Network

A description of the facility has been previously provided in Section 3.4.1.3.8 and further information can be found in D1.2.

3.4.3.2.9. Application Servers & Devices

Aalto University will make use of its developed software that includes the module running at the UAVs, the virtual flight controller instantiated in the edge or running at the cloud. The enabled functionalities are:

- Mission planning and management.
- Dynamic and in-flight management of the mission.
- Collection of the telemetry data from the UAVs.
- Collecting IoT data from the sensors on-board of the UAVs.

3.4.3.2.10. Security and regulation

The scenario will take place in the campus of Aalto University. The latter has already made several UAV trials in compliance with the regulations. The maximum allowed altitude is 120 m. In addition, the flight must not disturb people or cause danger for them. Different non-crowded area are available in the campus of Aalto University where the trials are used to take place. Furthermore, a book record of the all performed flight must be maintained and constantly updated. For risk assessment, the Finnish CAA accepts SORA documentation when needed.

3.4.3.2.11. Scenario Interactions High Level Workflow

(A) Preparation stage: Please refer Section 3.3.11.

(B) Preliminary flight stage: Please refer Section 3.3.11.

(C) Flight stage:

i. The 5G test facility gets prepared for the scenario by making the required 5G resources available.
i. Deploying UAVs equipped with IoT devices and connecting them to the test network.
ii. Eventually, perform manual test flights of some drones and test the network connectivity.
iii. The experimenter connects to the system through the web portal.
iv. The experimenter introduces the specifications of the scenario. This includes the area of interest, the IoT parameters to be collected, the target KPIs, the network parameters, etc.
v. The introduced scenario will be evaluated by the Trial Controller on whether it can be performed or not (the target facility has the enough resources, the flight is approved by the UTM, etc.).
vi. In case the scenario is rejected, the experimenter will be informed about the reason and asked to make changed in the introduced scenario.
vii. In case the scenario is validated, the target facility will be prepared to accommodate the trial (e.g., deploying and configuring network services, on boarding vertical specific

VNFs, etc.). This also includes the communication with the UAS system for performing the flight.

viii. The experiment gets started.
ix. The experimenter can see the ongoing evolution of the trial (e.g., followed path by the UAVs, resource usage, etc.).
x. The different KPIs and metrics for both 5G and UAV services are collected and analysed.
xi. The results are visualised to the experimenter.
xii. End of the trial.

(D) Analysis & reporting: Please refer Section 3.3.11.

3.4.3.2.12. Use Case Network & Drones Critical Parameters

The below table summarizes the considered network parameters for the scenario “UAV-based IoT data collection”.

Table 47: UC3:SC2 – Network critical parameters

Network Critical Parameters	Value
Data Type	1. Command and Control (C2) data. 2. Payload data, represented by the data sent by the IoT devices on-board of the UAVs (e.g., video streaming, images, temperature data, etc.).
Heights	Max 120 m, as per the regulation.
Speeds	Max 20 m/s
Latency	10 ms for C2 latency
Data Rates	1. C2: [60-100] kbps for uplink and downlink 2. Application data: up to 50 Mbps for UL
C2 Reliability	As low as 10^{-3} Packet Error Rate

As for the drone specific parameters, they are provided in the below table:

Table 48: UC3:SC2 – Drone critical parameters

Drones Critical Parameters	Value
Flight height	Max 120 m, as per the regulation.
Flight time	20 min
Drone velocity	15 to 20 m/s

3.4.3.2.13. Target KPIs

The target KPIs of the scenario ‘UAV-based IoT data collection’ are listed in the below table.

Table 49: UC3:SC2 – Target KPIs

KPI	Description	Target value
Capacity	Data exchange speed for streaming data	>50 Mbps
Latency	Latency for UAV command and control (from UAS system to UAV).	<= 10 ms.
Service Creation Time	The time required for deploying and configuring network services.	<= 90 min

3.4.3.2.14. Use Case Requirements

3.4.3.2.14.1. Functional Requirements

UC3.SC2-FUNC1	The mobile network must support 2 concurrent service slices		
Priority	Essential	**Justification**	Use case Driven
Description	Two cross domain network slices are required: • one network slice supports uRLLC for UAV command and control; • the second one supports mMTC (or eMBB) for the data sent by the UAVs.		
Related Component(s)	The 5G core and Access network		

UC3.SC2-FUNC2	Consideration of MEC capabilities		
Priority	Essential	**Justification**	Use case Driven
Description	MEC capability: to host the flight controller services of the UAVs as well as data analysis and aggregation services.		
Related Component(s)	MEC		

UC3.SC2-FUNC3	IoT devices onboard of the UAVs		
Priority	Essential	**Justification**	Use case Driven
Description	The flying UAVs must be equipped with onboard IoT device enabling them to collect data from height.		
Related Component(s)	Drones		

3.4.3.2.14.2. Non Functional Requirements

UC3.SC2-NFUNC1	Safe distance from observers on the field		
Priority	Essential	**Justification**	Regulation
Description	The drone deployment should be in safe distance from spectators.		
Related Component(s)	All		

UC3.SC2-NFUNC2	Approved Flight Plans		
Priority	Optional	**Justification**	Regulation
Description	Should be aligned with the regulations.		
Related Component(s)	All		

UC3.SC2-NFUNC3	Certified Drone operators

Priority	Essential	**Justification**	Regulation
Description	The drones must be operated by operators certified by the local authorities.		
Related Component(s)	All		

UC3.SC2-NFUNC4	**Connectivity shall be provided in a secure manner**		
Priority	Optional	**Justification**	Security
Description	The network deployed must be protected against denial of service attacks and other malicious attempts to compromise it.		
Related Component(s)	5G network		

3.4.3.3. Scenario 3: Location of UE in non-GPS environments

3.4.3.3.1. Detailed Description of Scenario

This scenario is created for the UAV positioning needs when the GPS or Global Navigation Satellite System (GNSS) is not available or there is some interference due to nearby high buildings etc. The practical use cases could be, for example, a metro tunnel bridge substructure visual inspection or different indoor applications like storage inventory in a logistics center.

The main objective of this use-case scenario is to give for drone operator and GCS the possibility to know where the UAV is when the flying UAV is in VLOS or BVLOS mode. The same information is needed by UTM. A secondary objective is to create a database for future positioning algorithms development as during the scenario deployment plenty of different sensory information will be collected in a synchronized manner and stored to a database.

This scenario is co-created with following scenarios from Use Case 1: UAV traffic management "Scenario 1: UTM command and control application", "Scenario 2: 3D mapping and supporting visualization/analysis software for UTM" and Use Case 3: Situation awareness "Scenario 1: Infrastructure inspection Sub-scenario 1: 3D Mapping of 5G QoS". The highest similarity in this scenario compared to above listed is related to data collection and processing:

(A) Use well-defined environment with same sensors.

(B) Collect data in same databases from measurement rounds.

(C) Use created 3D reconstructions of various the 5G service conditions. Please refer Section 3.4.1.2.1. and 3.4.3.1.1.

(D) Same 5G gNBs, MEC setups and 5G core.

The biggest difference in this scenario compared to above listed are:

(A) At data collection additional positioning sensors like UWB (Ultra-Wideband), Bluetooth or WLAN as position beacons and lasers to track exact UAV heading are used.

(B) In this scenario a position software which is run on MEC is created and used.

(C) All possible data are collected and stored for future positioning algorithm development projects. The practical limitations are bandwidth and storage space.

In this use-case scenario like above listed scenarios the following is needed i) two cross-domain network slices for UAV traffic control and drones' data: a uRLLC slice able to reduce delay and having a high priority for UAV traffic control, and an eMBB slice (no priority) for the data sent by drones; ii) a drone control application and parts for positioning software hosted at the edge. Furthermore, for faster application process at the edge, different MEC slices will be dedicated for

various application processing before being transmitted back to the operation center. Even though not all measurement or application will be processed at the MEC, services such as video processing, 3D positioning analysis, sensors measurement processing will be done at different MEC slices before further transmission to the operating center. However, live telemetry updates from the drone such as position trackers will be transmitted directed to the control center operator without processing through the MEC server.

3.4.3.3.2. High Level Architecture

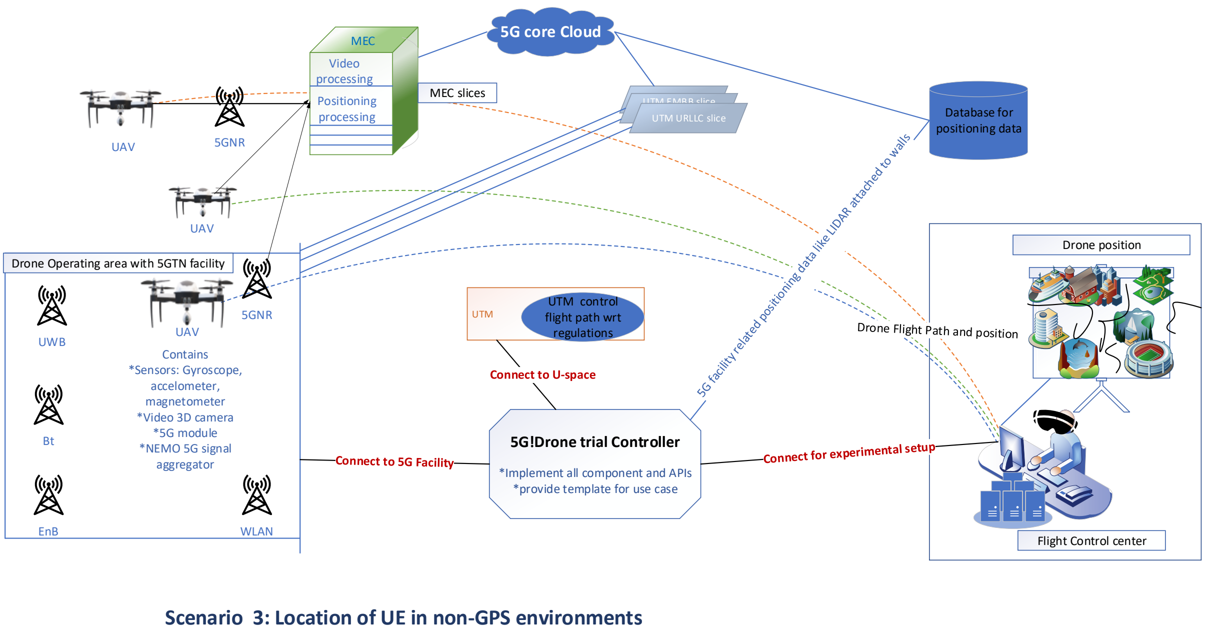

Figure 29: UC3:SC3 – High level architecture

3.4.3.3.3. UTM System

Please refer to Section 3.3.3. However, this is not a critical element as flights will be done indoor inside safety nets.

3.4.3.3.4. UAS System

UAVs in this use case scenario are expected to be deployed working semi-autonomous, but without connection to UTM as flights will be performed indoor.

3.4.3.3.5. Drones

The same cable drone made by University of Oulu which is defined in Section 3.4.1.2.5. Drones, will be used to record different position sensors and 5G RF signal characteristics in 3D space. The advantage of this type of drone replacements for this scenario is that it can make test series automatically, periodically, and with high precision. The drone to be used for the experiment has the following properties:

Table 50: UC3:SC3 – Drone Information

Manufacturer	DJI	Nokia
Model	Matrice M210RTK	NDN Electric Drone
Number of UAVs	1	1
Tether	No	No
Max Take Off Weight	6.14 kg	10 kg
Max Payload	2 kg	1.5 kg
Flight time	24 min (max payload) 32 min (no payload)	35 min (max payload) 55 min (no payload)
Limitations	Max Angular Velocity Pitch: 300°/s, Yaw: 150°/s Max Ascent Speed: 5 m/s Max Descent Speed: 3 m/s Max speed: 64.8 km/h	Max. speed 80 km/h
Resistance to the interferences	Default UAV control is over DJI 2.4 GHz and 5.8 GHz radio link. Different bands compared to 5G but small risk of harmonic frequency interference.	As drone control is over 5G, the risk of interference is larger so separate slice for C2 should be used. Back control 868 MHz.

Note: As NDN Electric Drone is quite large, it's route in test facilities will be limited comparing to Mavic. However, as the NDN Electric Drone has capacity to carry large payload, it will be used to carry more sensors than Mavic.

3.4.3.3.6. 5G Radio Access Network

This scenario will be trialled at University of Oulu's 5GTN test facility. A description of the facility has been previously provided in Section 3.4.1.2.6 and further information can be found in D1.2.

3.4.3.3.7. 5G Core Network

A description of the facility has been previously provided in Section **Error! Reference source not found.** and further information can be found in D1.2.

3.4.3.3.8. Mobile Edge Network

A description of the facility has been previously provided in Section 3.4.1.2.8 and further information can be found in D1.2.

3.4.3.3.9. Application Servers & Devices

An application within the edge server this include:

(A) Positioning analysis application at the MEC server.

(B) Data collection and mapping application for collect and store incoming data from drones, 5G equipment and core plus sensors, which are integrated to the OU test facility.

3.4.3.3.10. Security and regulation

Standard safety issues based on SORA. Since the experiment will be carried out at in indoor facility, safety nets will be installed to prevent drone destruction. For this scenario it is planned to use drones with take-off weights up to 10 kg (Nokia) and up to 1.1 kg (DJI Mavic).

In case the remote controller or CUP software would fail, the flight controller is configured to return to home safely and land (RTH). Mavic and Nokia drones will have a safety pilot on standby with a remote control who will be able to take over the autonomous mission at any time. During the trial a human operator will stay on-site who has the technical capabilities to intervene and take over control over the drone in case of emergencies.

3.4.3.3.11. Scenario Interactions High Level Workflow

(A) Preparation stage:

i. The experimental use case is expected to operate at a predefined indoor location within the 5GTN
   a. Preliminary testing facility is indoor 5GTN showroom, a size of 14 m x 18 m x 10 m (W x L x H) lobby with safety nets and required infrastructure
   b. Several additional indoor and outdoor based drone testing facilities are optionally available with a possibility to install 5G network or have a mobile 5G network during test runs..

ii. As seen in Figure 29, all UAS systems are provided in the Test facility, this include the UAV, small cells 5GNR and virtualized MEC facility except Nokia NDN Electric Drone.

iii. Drones are set up for activity at the Control center, with required settings of sensors, required 4K video cameras (NDN Electric Drone HD camera/thermal camera), and 5G parameters measurement tools.

iv. For ease connection establishment to the 5G Core Network, a 5G Dongle or Modem is on-board the drone. The 5G Dongle connects automatically to the 5G network at the experimental location.

(B) Preliminary flight stage:

i. At the experimental location before the drone start flying around it is tested that measurement and transmission of the required data works.

(C) Data collection flight stage

i. The Trial Controller provides the flight path from the control center location to the location of operation (in this case within the 5GTN indoor location). If there is a need for an outside test flight, then the flightpath is based on the provided UTM parameters.

ii. Other operations during the experiment are further handled by the Trial Controller, operations such as parameter update, flight path update etc.

iii. At the experimental location, the UAV is connected to the 5G facility and allocated specific slices based managed by the slice manager in the 5G Trial Controller.

iv. The UAV takes 4K/HD/Thermal live video within the location (processed at the MEC), uses the available sensors to measure position and take the readings or measurement of 5G parameters (data) in terms of bandwidth, throughput and latency at different points within the experimenting location.

v. Live videos taken at the location showing the flight terrain and other views plus other sensory information are processed at the Virtualized MEC server, and with the aid of the eMBB and uRLLC slice, transmit the processed data back to the control center to form an updated UAV position.

vi. Measured data from on-site sensors are also transmitted back to the control center.

vii. And finally, the 5G measurement data via the uRLLC slice, are updated and processed to form a visualized 3D UAV position.

viii. After extensive measurement, the drone follows the same flight back to the control center.
ix. The UAVs end their missions.
x. The Locked operation of the UAV within the Trial Controller is released and other operation from other UAV use cases can be performed.

(D) Analysis & reporting:
i. Flight telemetry data and sensor data is shared with and stored on the KPI monitoring module of the Trial Controller.
ii. Data is aggregated and analyzed.
iii. Results and conclusions are created to evaluate need for further reruns of © Data collection flight stage or proceed to the next step.
iv. Update of the experimental position points collected data during the flight phase are analyzed and the database is established.
v. Sensor data are collected and stored in for data aggregation and for further processing.
vi. All live feed 4K/HD/Thermal video established during the flight phase are store for further processing.

(E) Integrated system flight stage
i. Repeat all same steps than in © Data collection flight stage, but use updated positioning application like re-trained ML models for positioning calculation.

(F) Final analysis & reporting:
i. Repeat all same steps than in (D) Analysis & reporting, but results and conclusions are consolidated in a trial report.

3.4.3.3.12. Use Case Network & Drones Critical Parameters

Network performance requirement are summarized in table below:

Table 51: UC3:SC3 – Network critical parameters

Network Critical Parameters	Value
Data Type	1. C2 of the drone from the control center to the operation site is max 100 ms latency. 2. Application Data: including Video Streaming, images, sensor data to support event management applications. 3. 5G measurement parameters such as bandwidth, throughput, latency etc. are collected at different location to form the 3D mapping.
Heights	Preliminary testing facility is Indoor 5GTN showroom, a size of 14 m x 18 m x 10 m (W x L x H) lobby with safety nets and required infrastructure.
Speeds	Target horizontal speeds up to 30 km/h in max. as flights are performed indoor. If outdoor, then target horizontal speeds up to 80 km/h.
Latency	1. C2: UAS requirement is 10 ms (one way from eNB to UAV)

	2. Application Data: Latency value similar to LTE ground-based users.
Data Rates	1. C2: [60-100] kbps for uplink and downlink. 2. Application Data: min. 50 Mbps for UL.

Table 52: UC3:SC3 – Drone critical parameters

Drones Critical Parameters	Value
Flight Geo borders	Indoor space: 14 x 18 x 10 m.
Drone Operator location	Next to fly area, separated with safety nets
Time	It is expected to know provisioning period as the Drone Operator should know how many hours ahead should apply for the service.
No. of Drones	1 tethered, 2 flying
Minimum separation	5 m In this particular case, drone speed is not important, therefore ensuring separation using 5G networks is also not critical. The minimum separation on the level of 5 m can be ensured by defined flight areas (geofencing via UTM).
Drones battery Volume	DJI Matrice M210 RTK endurance 24 min (2kg payload) – 32min (no payload) NDN Electric Drone endurance 35 min (max payload), 55 min (no payload)
Drone velocity	DJI Matrice M210 RTK max vertical speed 82.8 km/h, max horizontal speed 64 km/h NDN Electric Drone max vertical speed 82.8 km/h

3.4.3.3.13. Target KPIs

The trial will be conducted in Oulu 5GTN facility and has similar KPIs. Please refer to 3.4.1.2.13.

3.4.3.3.14. Use Case Requirements

3.4.3.3.14.1. Functional Requirements

UC3.SC3-FUNC1	The mobile network must support 5 concurrent service slices		
Priority	Essential	Justification	Use case Driven
Description	Four different services shall be supported by the Use case: 1. Drone control slice for Control center communications – a uRLLC service 2. Drone data slice for video streaming – an eMBB service 3. Map update slice from drone to control center – a uRLLC service 4. Telemetry slice for UTM – a uRLLC service 5. User data slice for user equipment – an eMBB service		
Related Component(s)	The 5G core and Access network and MEC server Access network (5GNR, EWB, LORA)		

UC3.SC3-FUNC2	Mobile edge capabilities must be deployed near the UAV trial location		
Priority	Essential	Justification	Use case Driven
Description	The provision of the uRLLC service for the drones' command and control mandates the existence of a MEC center near the trial location MEC server will support video and other sensory data processing, UAV positioning processing at the edge before transmission to the control center.		
Related Component(s)	The EPC/5G core and Access network, MEC server		

UC2.SC2-FUNC3	Enforcement of separation between UAVs operating in close proximity		
Priority	Optional	Justification	3GPP r.16 22.825 UC5
Description	The requirements defined in [13] use case 5 for collision avoidance in cases that drones are flying in close proximity are relevant and should be considered when the technology is made available Drones C2 systems should use GPS RTK solution to improve precision of drone positions. The number of drones for a single operation can range from 1-5.		
Related Component(s)	The 5G core and Access network		

3.4.3.3.14.2. Non Functional Requirements

UC3.SC3-NFUNC1	Safe distance from spectators		
Priority	Essential	Justification	Regulation
Description	The drone deployment should be in safe distance from spectators.		
Related Component(s)	All		

UC3.SC3-NFUNC2	Approved Flight Plans		
Priority	Optional	Justification	Regulation
Description	If the drones fly below 120 m there is no obligation for approval.		
Related Component(s)	All		

UC3.SC3-NFUNC3	Certified Drone operators		
Priority	Essential	Justification	Regulation
Description	The drones must be operated by operators certified by the local authorities.		
Related Component(s)	All		

UC3.SC3-NFUNC4	Connectivity shall be provided in a secure manner		
Priority	Optional	**Justification**	Security
Description	The network deployed must be protected against denial of service attacks and other malicious attempts to compromise it.		
Related Component(s)	5G network		

3.4.4. Use Case 4: Connectivity during crowded events

3.4.4.1. Scenario 1: Connectivity extension and offloading

3.4.4.1.1. Detailed Description of Scenario

The purpose of this scenario is to demonstrate how UAVs through 5G network capabilities can improve connectivity services in a highly crowded environment e.g. during large events. The concept relies on providing end-to-end dedicated and reliable communication targeting specific user groups such as the event organisers to supervise and manage large events in an unhindered manner. At the same time, and with the proper dimensioning of the deployed solution in terms of capacity, the connectivity services can also be offered to the spectators.

The demonstration assumes that the Egaleo municipality, that is frequently in charge of cultural events, either of athletic nature in its stadium, or music concerts and other performances in its parks and open air theatres, as well as parades in the city center, shall own and operate a portable UAS system comprising of UAVs, small 5G cells other communication equipment and application servers necessary to support the broadcast and connectivity requirements required to guarantee the smooth event operation, independently of the location. At the same time, as the event will have a significant number of attendants, a “hotspot” traffic profile needs to be supported, to deal with the high user density at restricted areas. The perceived UAS mobile unit can also help enhance the connectivity service offered to the spectators through the 5G small cell that it will on-board. The trial for this demonstration shall be executed on the Egaleo stadium during a football match of the Egaleo city team.

The portable system to be deployed will consist of UAVs with 5G small cells on-board that will be deployed on top of the current infrastructure. One drone, dedicated for patrolling shall measure the radio network quality (QoS) and the other drone will provide video feed to the event organisers.

Drone operators start their mission after performing a risk assessment, taking into account the eventually very high population density, which might affect connectivity available for the UAS. As part of the flight planning, expected 2D/3D connectivity is analysed on 3D map to optimize the planned flight volume to achieve optimal connectivity.

Flight plans are provided to the 5G!Drones Test Facility UTM system with drone data, flight time, flight area in 3D and operator contacts. The UTM system will approve the flight taking into account different parameters, including the available and agreed connectivity (in operations connectivity should meet the requested level).

In operations, patrolling drone uses Android 5G device and application for measuring radio network quality. 5G device sends radio network quality data with GPS coordinates to CAFA 3D Map (cloud based service solution) and real time network quality in 3D environment will be shown to command center (Connectivity Service Provider) to change 5G base station directions or send one drone to provide relay based 5G connectivity. CAFA provides 3D portal access to command center.

The up-to-date network connectivity data will be used both in UTM and the command center.

The UTM might advise flight plan changes (adoption), put constraints on capacity in the area, reroute all traffic close or take other action to adapt the available network connectivity.

Furthermore, some stand-by drones shall be ready to take action based on the incident identified (e.g. large concentration of a fans group in a specific stand of the stadium, fireworks, lack of connectivity). If necessary, the newly deployed small cells will provide additional and enhanced connectivity to current and new users, spread across the football stands. The small cells mounted in the drones, will be distributed across the area, in order to share connectivity evenly and reduce interference noise.

Moreover, secure communication and authentication are vital to communicate with large variety of devices. To enable secure communication with a group of resource constraint drones, this use case will integrate lightweight orchestration mechanisms that will offer both scalable and high-speed communications.

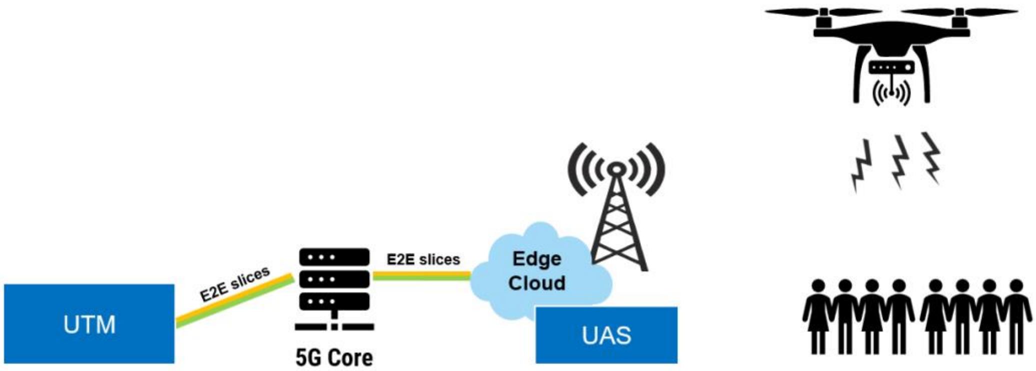

Figure 30: Overview of UC4:SC1

Three deployment variants are envisaged in respect to connectivity extension provisioning:

1. In the first variant, the drone will be carrying a 5G base station (gNB), and will have an RF backhaul link to the ground 5G Core. To implement this approach a tethered drone is required (also from C2 link radio interferences perspective), which offers unlimited power supply and secured data transfer for safer operations. This will expand the connectivity to a stadium, where a crowded event takes place or other stadium patrolling services are requiring a dedicated private connectivity.

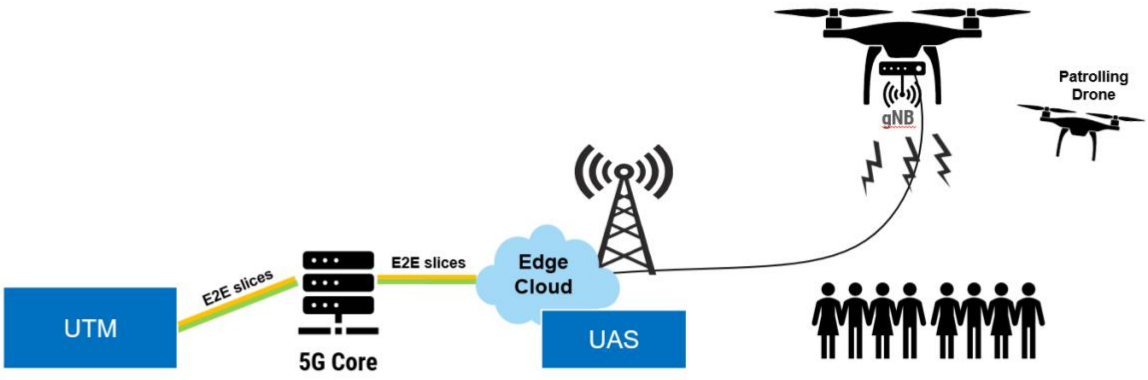

Figure 31: UC4:SC1 - Deployment 1 - Drone carries a gNB

2. In the second scenario, the drone will provide connectivity to the users via a relay link. This setup modifies the requirements of the drone to be used and therefore a simple (and not tethered) drone is considered. This modification, changes the flight characteristics of the drone itself, with most critical the limited flight time due to the on-board batteries. Moreover, connectivity expansion is performed only in under-served areas, since the capacity of the network is not modified, but only the signal quality reception is improved.

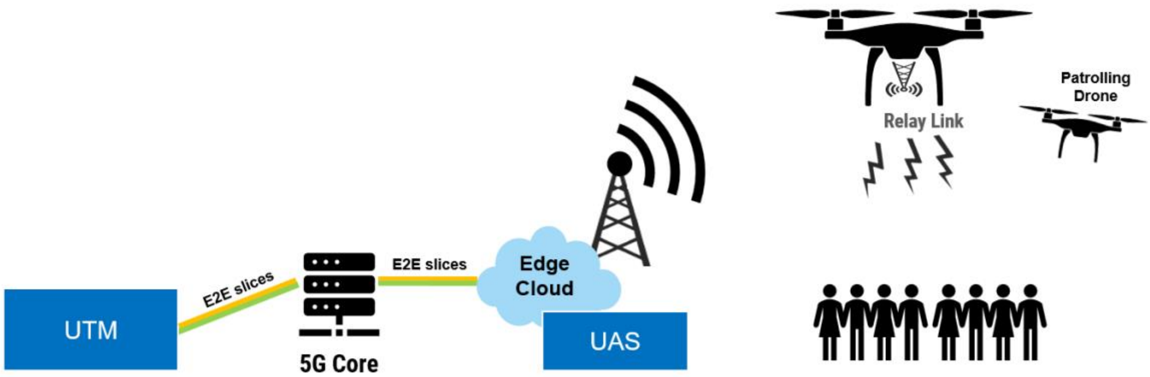

Figure 32: UC4:SC1 – Deployment 2 - Drone carries a Relay Link

3. In the third scenario, the drone will be carrying a lightweight 5G UE, which will provide connectivity to the users by creating a Wi-Fi hotspot, utilizing the 5G technologies as a backhaul between the WiFi hotspot and the gNB. In the variant, the connectivity expansion is performed in terms of the number of users, since a specific group of people will be connected at the WiFi spot and then via the 5G Backhaul to the gNB. By lifting more than one drone, the connectivity can be expanded not only in under-served areas, but also in terms of the number of users that can be connected to a specific gNB. An on-board policy controller and caching technology can reduce the bandwidth requirements, especially when the user requests refer to local services.

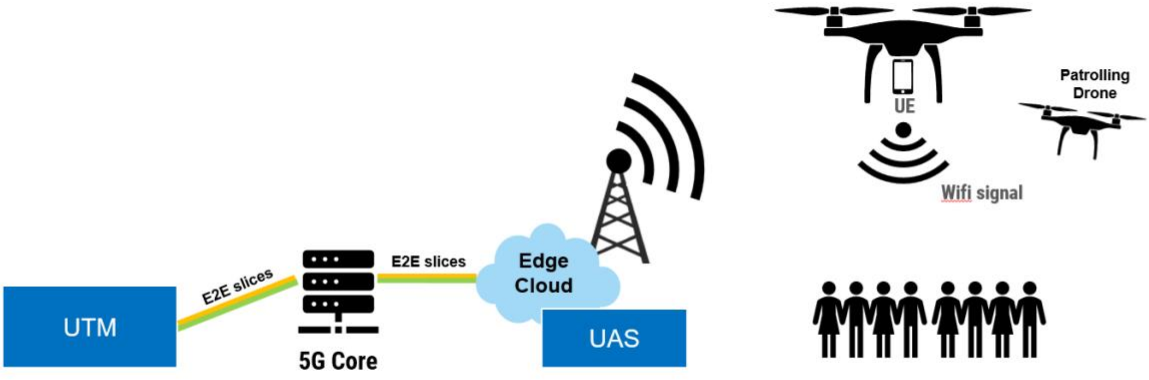

Figure 33: UC4:SC1 - Deployment 3 - Drone carries a 5G UE

3.4.4.1.2. High Level Architecture

The use case shall leverage the 5G experimentation capabilities of the 5GENESIS Athens platform. The Mobile Core network and other main data center facilities shall be hosted at the NCSRD premises, while the edge site, Egaleo, shall be prepared to provide the mobile edge facilities to ensure the necessary requirements for latency and bandwidth. The core components of the use case considered for this use case are depicted in the picture below:

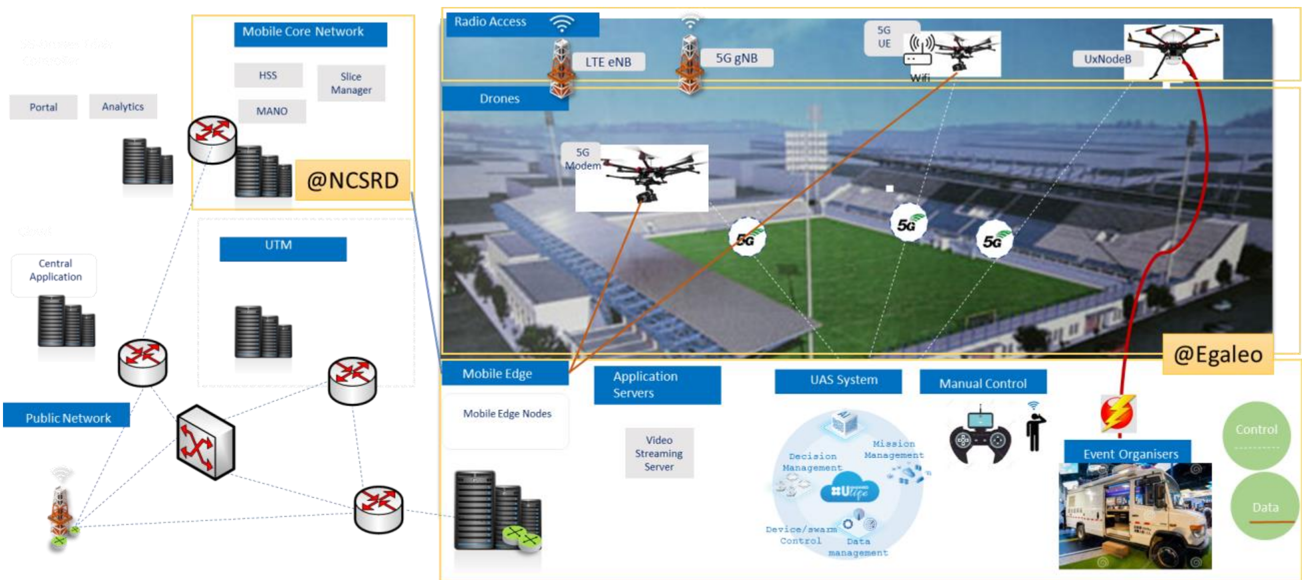

Figure 34: UC4:SC1 - High level architecture

The main components envisaged to have an active role in the use case execution and interact to ensure the proper operation are discussed below.

3.4.4.1.3. UTM System

Please refer to Section 3.3.3.

3.4.4.1.4. UAS System

UAVs in UC4 will be operated using the fully-autonomous edge deployment model described in Section 2.3.2.

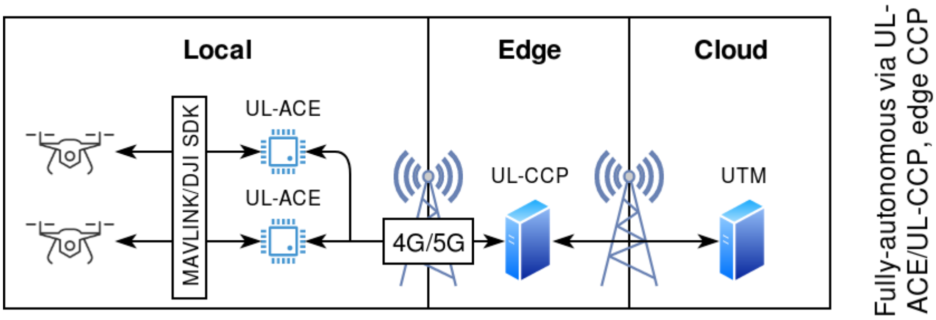

Figure 35: UC4:SC1 – UAS deployment model

UAVs flown in this mode must be augmented with the Unmanned Life autonomous control endpoint (UL-ACE) or Remote controller with Smartphone (for CUP) and communicate with the Unmanned Life central command platform (UL-CCP) or CAFA UGCS Platform for coordination in multi-UAS environments and run-time offloading of computation.

3.4.4.1.5. Drones

Table 53: UC4:SC1 – Drone Information

Manufacturer	DJI	DJI	Hepta
Model	Matrice M600	Mavic-2	HTR-10
Number of UAVs	2	1	1
Tether	No	No	Yes, up to 100m
Max Take Off Weight	15.1 kg	1 kg	35 kg
Max Payload	6 kg	190 g	10 kg
Hovering time	16 min (6 kg payload) – 35 min (no payload)	15 min	Tethered 120 min
Limitations	Max. Wind Resistance 8 m/s	8 m/s	Max. Wind Resistance 12 m/s
Resistance to the interferences	Default UAV control is over DJI 2.4 GHz and 5.8 GHz radio link. Different bands compared to 5G but small risk of harmonic frequency interference. Since drone control is over 5G, the risk of interference is larger so separate slice for C2 should be used.	UAV control only over DJI 2.4 GHz and 5.8 GHz radio link. Different bands compared to 5G but small risk of harmonic frequency interference.	UAV control will probably be over fiber optic cable. Risk of radio-interference is minimum.

3.4.4.1.6. 5G Radio Access network

5G New Radio (NR), is one of the novel and most promising components of 5G. 5GNR encompasses a new OFDM-based air interface, designed to support the wide variation of 5G device-types, services, deployments and spectrum.

OpenAirInterface (OAI) gNB: OpenAirInterface RAN (OAI-RAN) solution provided by Eurecom, both for the gNB and the UE will be deployed in the Athens platform.

The Athens platform will integrate the OAI 5GNR gNBs and UE components to perform end-to-end experimentation and KPI measurement collection. The initial deployment will be based on Non-Standalone Mode (NSA) Option 3. This assumes that a working chain of OAI software encompassing 4G radio should be available. In this context, in Athens the OAI version of 4G is already implemented and incrementally will be upgraded with 5G features as is foreseen by the 5G migration path.

The hardware platform, provided by Eurecom, is going to use the ETTUS N300 boards together with a powerful Laptop with an 8 core i9 processor. We will use a special adaptor to be able to connect the Thunderbolt 3 interface of the laptop with the 2x10 Gbit Ethernet interface of the USRP. An additional RF frontend and antenna will provide enough output power and amplification to operate in an outdoor environment.

3.4.4.1.7. 5G Core Network

With regards to the mobile core and access radio technologies, based on the proposed migration path from 4G to 5G, it is expected that for Non-Stand Alone (NSA) deployment mode a proper, working 4G infrastructure has to be leveraged. Moreover, 4G will also set the baseline for the performance and KPI validations. At the current stage of development, OAI 5G-NR is being implemented based on the Non-Standalone Architecture Option 3, where the gNB connects to eNB and Core network via the EPC.

Athonet's mobile core is based on a highly efficient and effective software-only implementation. The expensive, proprietary, hardware centric capex of traditional mobile core solutions has been replaced with a wholly software-only product that can run on either centralised or highly distributed on public cloud (e.g. AWS, Azure, Google, IBM, Oracle) or private cloud (e.g. telco cloud), enterprise data centers or on standard COTS servers running on Intel or ARM.

The existing platform is a full 4G mobile core that implements 3GPP defined network functions including MME, PGW, SGW, PCRF and HSS. Being a commercial solution, it can be connected to commercial OSS/BSS systems which enforce regulatory obligations and billing by means of standard interfaces, i.e., X1, X2 and X3 for lawful intercept and Bx and Gy for charging.

Athonet has implemented a web-based Element Management System (EMS) that caters for performance, configuration and fault management. The EMS includes the following main features:

- System configuration for networking and 3GPP elements;
- User subscriber management and QoS profile assignment/management;
- Automated installation and insertion of license key;
- System configuration backup;
- Detailed user activity;
- Individual users monitoring and global system usage; historical data and statistics are also provided, based on different time granularity (daily/weekly/monthly/yearly);
- Secure access to the GUI via dual-authentication method based on TLS 1.2;
- Access and activity logging.

3.4.4.1.8. Mobile Edge Network

The exploitation of computing and virtualization of capabilities at the edge closer to the end users is of great importance for the development and deployment of 5G. Introducing processing capabilities at the edge will make available processing of data close to the end user and will benefit applications that require low latency as data traffic no longer is needed to travel to the core in order to reach the applications servers. In order to leverage this capability, the Athens platform will deploy computing infrastructure either at designated locations at the edge or collocate computing capabilities along with small cells. In order to be able to manage and orchestrate these resources Athens platform deployments will align with the specification that are provided by ETSI Multi-Access Edge Computing (MEC) working group.

3.4.4.1.9. Application Servers & Devices

3.4.4.1.9.1. Unmanned Life Central Command Platform

The UL-CCP will be hosted on an edge server as described in Section 2.3.2. It is responsible for:

- Coordinating UAVs in a multi-robot environment.
- Task allocation to UAVs for mission management.
- Processing of sensor data for operational decision-making.
- Responding to UTM mission change requests.
- Forwarding of telemetry data to pre-operational UTM systems.

3.4.4.1.9.2. CAFA Tech UGCS based platform, CAFA Field Video Streaming Software, and CAFA 3D Map and Analyser for 3D and QoS Data

The CAFA Tech UGCS based platform will be hosted on an edge or local server as described in section 2.3.2. This platform is responsible for:

- Planning and Coordinating UAVs missions.
- Task allocation to UAVs for mission management.
- Processing of sensor data for operational decision-making.
- Responding to UTM mission change requests.
- Forwarding of telemetry data to pre-operational UTM systems.
- Providing access to CAFA 3D application for the network coverage visualizing and analysing in 3D.
- Providing access to GPS RTK (Real Time Kinematic) corrections.

3.4.4.1.10. Security and regulation

Since drone flights take place in the proximity of a crowded event, it is important to assume that Matrice 600 drone should not fly over people because its mass is approximately 15 kg.

Because the 3 drones work in a rather small area and one drone measures radio network quality, therefore there is clear need for accurate positioning and access for GPS RTK corrections.

DJI Matrice M600 Hovering Accuracy (P-Mode, with GPS): Vertical: ±0.5 m, Horizontal: ±1.5 m.

Greece UAV regulation requires that there be approval for commercial UAV flight. SORA is essential part to apply for CAA approval.

3.4.4.1.11. Scenario Interactions High Level Workflow

(A) Preparation stage: In addition to the common preparation stage steps mentioned in Section 3.3.11, this scenario will have the following additional steps:

i. Provide a portable setup comprised of UAVs, small 5G cells, other communication equipment and application servers necessary to support the broadcast and connectivity requirements..
ii. Deploy UAV operator software pilots to application servers provided in the test facility's portable setup.

(B) Preliminary flight stage: Please refer Section 3.3.11.

(C) Flight stage
i. Use the Trial Controller to initiate the drone trial.
ii. Autonomous take-off of the 5G-enabled patrolling UAV (drone with camera).
iii. Autonomous take-off of the 5G network-measuring UAV (drone with UE).
iv. Drones follow the agreed flight plan to scan the area and stream the data for analysis and logging to the edge.
   a. Drones report their position periodically.
   b. Drones can receive information with regards to re-routing.
   c. The 5G enabled patrolling UAV scans the area using its camera and provides the video feed back to the event organizers.
   d. The 5G network-measuring UAV measures 5G connectivity and the signal/network quality.
v. Identify stadium areas with overloaded network capacity and initiate UAV assisted 5G connectivity.
vi. Once finished the missions the drones return to the home base and land autonomously.

(D) Analysis & reporting: Please refer Section 3.3.11.

3.4.4.1.12. Use Case Network & Drones Critical Parameters

The following network critical parameters have been considered:

Table 54: UC4:SC1 – Network critical parameters

Network Critical Parameters	Value
Data Type	1. C2 of the drone is max 100 ms latency 2. Application data: including video streaming, images, sensor data to support event management applications 3. Basic connectivity, to support organisers as well as spectators connectivity needs in a saturated environment
Heights	Max 120 m AGL. This is an upper limit of VLL airspace according to Eurocontrol definition.
Speeds	Target horizontal speeds up to 70 km/h for all scenarios
Latency	1. C2: UAS requirement is 10 ms (one way from eNB to UAV) 2. Application data: Latency value similar to LTE ground based users 3. Basic connectivity

Data Rates	1. C2: [60-100] kbps for uplink and downlink 2. Application data: up to 50 Mbps for UL 3. Basic connectivity: 0.5 Mbps
C2 Reliability	As low as 10^{-3} Packet Error Rate
Position Accuracy	1 m

With respect to the drone specific parameters, the following hold:

Table 55: UC4:SC1 – Drone critical parameters

Drones Critical Parameters	Value
Flight Geo borders	Polygon max: 500 x 500 m.
Drone Operator location	Within area. On ground or remote.
Time	It is expected to know provisioning period as the Drone Operator should know how many hours ahead should apply for the service.
No. of Drones	1 tethered, 2 flying
Minimum Separation	50 m In this particular case, drone speed is not important, therefore ensuring separation using 5G networks is also not critical. The minimum separation on the level of 50 m can be ensured by defined flight areas (geofencing via UTM).
Drones Battery Volume	DJI Matrice M600 6 x TB47S (6 x 4500 mAh). DJI Matrice M600 endurance 16 min (6 kg payload) – 35 min (no payload). DJI Mavic 2 endurance is 15 min (with 190 g payload) – 25 min (no payload) Hepta HTR-10 tethered, endurance more than 120 min, backup battery 10 Ah for safe landing in case of tether disconnect.
Drone Velocity	DJI Matrice M600 max vertical speed 5 m/s, max horizontal speed 18 m/s. DJI Mavic2 max vertical speed 5m/s, max horizontal 20 m/s Hepta HTR-10 tethered max vertical speed 2 m/s, max. horizontal speed 0 m/s (tethered drone to be considered stationary) Max 10m/s. Horizontal 0 for tethered flights.
Resistance to Radio Interference.	To be physically checked especially in the flying base station scenario.

3.4.4.1.13. Target KPIs

In the light of the above context, the target KPIs that are considered for validation during the use case execution are listed in below table:

Table 56: UC4:SC1 – Target KPIs

KPI	Description	Target Values
Capacity	3GPP consolidated KPIs for UAV considers an uplink data rate between 4 Mbps and 9 Mbps for video streaming for the provision of HD video streaming. Considering the case of 4K video, the target value is increased further, reaching 30 Mbps (since 3GPPP recommends 120 Mbps for a 4*4K surveillance system)	>50 Mbps
Latency	3GPP considers different target values for control latency based on the planned service. The proposed target value is 10 ms, which covers a great variety of services, considering that provides an accurate control environment for the UAV.	<= 10 ms
Service Creation Time	The target KPI value proposed by 5G-PPP is the reduction of the average service creation time from 90 days to 90 min. This allows the agile creation and deployment of services, making possible the fast response of the mobile network to the needs of the vertical industries.	The proposed use case can serve and adapted to a great variety of services. Therefore it is very important the service creation time to be low in order to be possible its fast match to different vertical industries. Considering the proposal made by 5G-PPP, in our use case we aim at decreasing the service creation time by at least one order of magnitude, compared to 4G. Clear improvement of the level of automation of service related processes (i.e. activating group communications in MCS, patrolling etc.)

3.4.4.1.14. Use Case Requirements

3.4.4.1.14.1. Functional Requirements

UC4.SC1-FUNC1	The mobile network must support 3 concurrent service slices		
Priority	Essential	**Justification**	Use case Driven
Description	Three different services shall be supported by the Use case: C2 of the drone, a uRLLC service. Multimedia Streaming from the Patrolling Drone, an eMBB Service. Sending radio network quality measurement data. Basic connectivity for the spectators, also an eMBB service.		
Related Component(s)	The 5G core and Access network		

UC4.SC1-FUNC2	Mobile edge capabilities must be deployed in the stadium		
Priority	Essential	**Justification**	Use case Driven
Description	The provision of the uRLLC service for the drones' command and control mandates the existence of a MEC center in Egaleo stadium.		
Related Component(s)	The 5G core and Access network		

UC4.SC1-FUNC3	Enforcement of separation between UAVs operating in close proximity		
Priority	Optional	**Justification**	3GPP r.16 22.825 UC5
Description	The requirements defined in [13] use case 5 for collision avoidance in cases that drones are flying in close proximity are relevant and should be considered when the technology is made available. Drones C2 systems should use GPS RTK solution to improve precision of drone positions.		
Related Component(s)	The 5G core and Access network		

UC4.SC1-FUNC4	Radio Access Node on-board UAV		
Priority	Essential	**Justification**	3GPP r.17 22.829 UC2
Description	The requirements defined in [18] Use case 2 and summarized in Table **58** as Requirements for UxNB must be considered, and most importantly: The 5G system shall be able to support wireless backhaul with required quality to enable a UxNB. The 3GPP system shall minimize interference among UxNBs in close proximity. Optionally, if the technology is made available, the 3GPP system shall be able to monitor UxNB (e.g. power consumption of the UAV etc.) and provide means to minimize power consumption of the UxNB (e.g. optimizing operation parameter, optimized traffic delivery) without degradation of service provided. Until this is possible, a tethered drone can be used to resolve power consumption concerns.		
Related Component(s)	The 5G core and Access network		

UC4.SC1-FUNC5	The drone serving as UxNB should be capable to lift gNodeB equipment		
Priority	Essential	**Justification**	Use Case Specific
Description	The drone that shall lift radio access components should make sure that can lift the gNodeB provided as part of the experiment.		
Related Component(s)	Drone		

UC4.SC1-FUNC6	Initial authorization to operate a UAV		
Priority	Essential	**Justification**	3GPP r.16 TS 22.825 UC1
Description	The requirements defined in [13] Use case 2 and summarized in Table **58** are relevant and must be considered when the technology implementing them is made available.		
Related Component(s)	The 5G Core and Access network		

UC4.SC1-FUNC7	Data acquisition from the UTM by law enforcement		
Priority	Essential	**Justification**	3GPP r.16 TS 22.825 UC3
Description	The requirements defined in [13] Use case 3 and summarized in Table **58** are relevant and must be considered when the technology implementing them is made available.		
Related Component(s)	The 5G Core and Access network		

UC4.SC1-FUNC8	Simultaneously support data transmission for UAVs and eMBB users		
Priority	Essential	**Justification**	3GPP r.17 22.829 UC4
Description	The 5G system shall need to optimize the resource use of the control plane and/or user plane for transfer of continuous uplink data that requires both high data rate and very low end-to-end latency. The requirements defined in [18] Use case 4 are relevant and must be considered when the technology implementing them is made available.		
Related Component(s)	The 5G Core and Access network		

UC4.SC1-FUNC9	Autonomous UAVs controlled by AI		
Priority	Essential	**Justification**	3GPP r.17 TS 22.829 UC5
Description	The UAVs shall be controlled through a UAS system and as such all requirements set in [18] Use Case 5 must be considered. Specifically, the 5G network must: Consider UAV requirements for both high uplink rate transmission and low delay downlink transmission To provide high precision positioning information to the AI system to assist the calculation and decision-making for UAV flight.		
Related Component(s)	The 5G Core and Access network		

3.4.4.1.14.2. Non Functional Requirements

UC4.SC1-NFUNC1	Safe distance from spectators		
Priority	Essential	**Justification**	Regulation
Description	The drone deployment should be in safe distance from spectators.		
Related Component(s)	UAS		

UC4.SC1-NFUNC2	Approved Flight Plans		
Priority	Optional	**Justification**	Regulation
Description	If the drones fly below 120m there is no obligation for approval.		
Related Component(s)	UAS		

UC4.SC1-NFUNC3	Certified Drone operators		
Priority	Essential	**Justification**	Regulation
Description	The drones must be operated by certified (by the local authorities or EU member state authorities) operators.		
Related Component(s)	UAS		

UC4.SC1-NFUNC4	Connectivity shall be provided in a secure manner		
Priority	Optional	**Justification**	Security
Description	The network deployed must be protected against denial of service attacks and other malicious attempts to compromise it.		
Related Component(s)	5G network		

UC4.SC1-NFUNC5	Approved Flight Plans of tethered Drones		
Priority	Essential	**Justification**	Regulation
Description	HCAA (Hellenic Civil Aviation Authority) authorization needed for flight plans because tethered drone mass is over 25 kg.		
Related Component(s)	UAS		

4. CONCLUSION

This deliverable provided a detailed description of the various use cases and scenarios attached that are planned to be trialled as a part of the 5G!Drones project. Within each use case scenario, the necessary components were identified and described in detail. The deliverable also provided a high-level workflow describing the manner in which the trials would take place. Finally, the KPIs that need to be measured were identified.

Since the work done within this deliverable covers a wide range of topics, it should be used as a foundation for multiple subsequent tasks across work packages who can use the information gathered within this deliverable to drive their specific activities. The work done in this task will form the basis of the development the trials and its outcome will have a direct impact on the following activities in the ongoing and upcoming tasks:

1. T1.4, to ensure that the 5G!Drones architecture design support the target use cases,
2. T2.4, to select the appropriate data analysis and visualisation tools to cover the important aspects of each use case,
3. T3.1, so that the network slice management enablers can support the performance, isolation, and other requirements (e.g. security) of each use case,
4. T3.4, for the development of the necessary UAV service components that each use case entails,
5. T4.2, for the preparation and execution of trials,
6. T4.3, to appropriately interpret the results of the trials.

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ANNEX 1: 3GPP Rel.16 22.825 Generic Use Cases Requirements

Table 57: 3GPP Rel.16 22.825 Generic Use Cases and Requirements

3GPP Rel. 16 22.825 Use Cases & Requirements
3GPPr16UC.1. Initial authorization to operate a UAV
3GPPr16Req.1. The 3GPP system shall enable a UAS to send the following UAV data to a UTM: unique identity (this may be unique 3GPP identity), UE capability of the UAV, make & model, serial number, take-off weight, position, owner identity, owner address, owner contact details, owner certification, take-off location and time, mission type, route data, operating status. **3GPPr16Req.2.** The 3GPP system shall enable a UAS to send the following UAV controller data to a UTM: unique identity, UE capability of the UAV controller, position, owner identity, owner address, owner contact details, owner certification, the identity of the UAV operator who operate the UAV controller, UAV operator license and certification. **3GPPr16Req.3.** The 3GPP system shall enable a UAS to send different UAS data to UTM based on the different authentication and authorizations level which are applied to the UAS. **3GPPr16Req.4.** The 3GPP system shall support capability to extend UAS data being sent to UTM with the evolution of UTM and its support applications in future. **3GPPr16Req.5.** The 3GPP system shall protect against spoofing attacks of the UAS identities. **3GPPr16Req.6.** The 3GPP system shall protect the integrity of the message(s) sent from UAS to a UTM containing the UAS identities. **3GPPr16Req.7.** The 3GPP system shall enable a UE in a UAS to send the following identifiers to a UTM: IMSI, IMEI, MSISDN. **3GPPr16Req.8.** The 3GPP system shall protect the confidentiality of the message(s) sent between UAS to a UTM containing the UAS identities. **3GPPr16Req.9.** The 3GPP system may enable an MNO to augment the data sent to a UTM with the following: network-based positioning information, preconfigured pairing data. **3GPPr16Req.10.** A UAS may optimise subsequent messages sent to an UTM by omitting unchanged static or semi-static data (e.g. owner identity, owner address, owner contact details, owner certification). **3GPPr16Req.11.** The UTM shall be able to associate the UAV and UAV controller, identify them as a UAS, and authorise a UAS to operate. **3GPPr16Req.12.** The UTM shall be able to coordinate the route data provided in the authorisation to operate and change it if needed. **3GPPr16Req.13.** The UTM shall be able to refuse authorisation for a UAS to operate. **3GPPr16Req.14.** The UTM shall be able to inform an MNO of the outcome of an authorisation to operate. **3GPPr16Req.15.** An MNO shall be able to enforce the authorisation for a UAS to operate (e.g. by enabling or disabling communication between the UAV and UAV controller). **3GPPr16Req.16.** The 3GPP system shall enable an MNO to allow a UAS authorisation request only if appropriate subscription information is present.
3GPPr16UC.2. Live data acquisition by UTM
3GPPr16Req.17. The 3GPP system shall enable a UTM to be aware of the identity/identities of a UAS. **3GPPr16Req.18.** The 3GPP system shall enable a UAS to update a UTM with the live location of a UAV.

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3GPPr16Req.19. The 3GPP system shall enable a UAS to send the location of the UAV and UAV controller towards UTM with at least a periodicity of 1 update per second. **3GPPr16Req.20.** The 3GPP system may enable an MNO to supplement location information sent to a UTM. **3GPPr16Req.21.** The 3GPP system shall enable a UTM to send route modification information to a UAS with a latency of less than 1 second.
3GPPr16UC.3. Data acquisition from the UTM by law enforcement.
3GPPr16Req.22. The 3GPP system shall enable an authorised official to query a UTM for information and identities of an active UAS when an authorised official provides a subset of UAS data (e.g. an IMSI, general location, or IMEI). **3GPPr16Req.23.** The 3GPP system shall enable an authorised official to query a UTM for the current location(s) of an active UAS when an authorised official provides a subset of UAS data (e.g. an IMSI, general location, or IMEI). **3GPPr16Req.24.** The 3GPP system shall enable a UTM to authenticate the identity and authority of the official making a request for UAS identity and information.
3GPPr16UC.4. Enforcement of no-fly zones
3GPPr16Req.25. The 3GPP system shall enable a UAS to update a UTM with the live location of a UAV. **3GPPr16Req.26.** The 3GPP system may enable an MNO to supplement location information sent to a UTM. **3GPPr16Req.27.** The 3GPP system shall enable a UTM to send route modification information to a UAS with a latency of less than [500 ms]. **3GPPr16Req.28.** The 3GPP system shall enable a UTM to send a notification to a UAV controller with a latency of less than [500 ms].
3GPPr16UC.5. Enforcement of separation between UAVs operating in close proximity
3GPPr16Req.29. The 3GPP system shall enable a UAV to broadcast the following identity data in a short-range area for collision The 3GPP system shall enable UAV to broadcast the identity information which preserves the privacy of the owner of the UAV and the UAV operator. **3GPPr16Req.30.** The 3GPP system shall enable a UAV to receive local broadcast communication transport service from other UAV in short range. **3GPPr16Req.31.** A UAV shall be able to use a direct UAV to UAV local broadcast communication transport service when served or not served by a 3GPP network. **3GPPr16Req.32.** A UAV shall be able to use a direct UAV to UAV local broadcast communication transport service when served or not served by the same 3GPP network. **3GPPr16Req.33.** The 3GPP system shall support a direct UAV to UAV local broadcast communication transport service at relative speeds of up to 320 kmph. **3GPPr16Req.34.** The 3GPP system shall support a direct UAV to UAV local broadcast communication transport service at absolute speeds of up to 160 kmph. **3GPPr16Req.35.** The 3GPP system shall support a direct UAV to UAV local broadcast communication transport service with variable message payloads of 50-1500 bytes, not including security-related message component(s).

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3GPPr16Req.36. The 3GPP system shall support a direct UAV to UAV local broadcast communication transport service which can maintain a separation distance between two UAVs of greater than 50 m. **3GPPr16Req.37.** The 3GPP system shall support a direct UAV to UAV local broadcast communication transport service which supports a range of up to 600 m **3GPPr16Req.38.** The 3GPP system shall support a direct UAV to UAV local broadcast communication transport service which supports a range sufficient to give the UAVs ample time to perform manoeuvres to maintain a separation distance of 50 m (e.g. 6.5 s). **3GPPr16Req.39.** The 3GPP system shall support a direct UAV to UAV local broadcast communication transport service which can transmit messages at a frequency of at least 10 messages per second. **3GPPr16Req.40.** The 3GPP system shall support a direct UAV to UAV local broadcast communication transport service which can transmit messages with an end-to-end latency of at most 100 ms. avoidance: [UAV type, current location and time, route data, operating status].
3GPPr16UC.6. Local broadcast of UAS identity
3GPPr16Req.41. The UAS shall be able to locally broadcast its identity and location with a rate of at least once per 1 s up to a range of 500 m.
3GPPr16UC.7. Differentiation between UAVs with integral cellular capabilities and conventional mobile phones attached to UAVs
3GPPr16Req.42. 3GPP system shall support the UAS identification data which can differentiate the UAS with UAS-capable UE and the UAS with non-UAS-capable UE. **3GPPr16Req.43.** The 3GPP system shall support identification and reporting unauthorized UAVs to a UTM.
3GPPr16UC.8. Cloud-based Non-Line of Sight (NLOS) UAV operation.
3GPPr16Req.44. The 3GPP system shall be able to support a UAV to transmit a message to identity the UAV via direct device connection in addition to network connection.
3GPPr16UC.9. UAV fly range restriction
3GPPr16Req.45. 3GPP system shall enable a UAS to update a UTM with the live location information of a UAV and its UAV controller. **3GPPr16Req.46.** The 3GPP system shall support a UTM to consume Location Service provided by the network. **3GPPr16Req.47.** The 3GPP system shall be able to enforce the authorisation for an in-flight UAS to operate basing on UAS subscription information or under the instructions from U The 3GPP system shall be able to supplement location information of UAV and its UAV controller.
3GPPr16UC.10. UAV based remote inspection of infrastructure.
3GPPr16Req.48. MNO shall be able to enforce the authorisation for assisting a UAS to operate. **3GPPr16Req.49.** 3GPP network shall establish a reliable route to deliver the commands/control messages between the UAV and UAV controller. **3GPPr16Req.50.** 3GPP network shall be able to support roaming when providing network assisted UAS operation.

ANNEX 2: 3GPP Rel.17 22.829 Generic Use Cases Requirements

Table 58: 3GPP Rel.17 22.829 Generic Use Cases and Requirements

3GPP Rel. 17 22.829 Use Cases	Consolidated Requirements
3GPPr17UC.1 UAV supporting high resolution video live broadcast application **3GPPr17UC.2 Radio Access Node on-board UAV** **3GPPr17UC.3 UAS Command and Control (C2) Communication** **3GPPr17UC.4 Simultaneously support data transmission for UAVs and eMBB users** **3GPPr17UC.5 Autonomous UAVs controlled by AI** **3GPPr17UC.6 Isolated deployment of Radio Access Through UAV** **3GPPr17UC.7 Radio Access through UAV** **3GPPr17UC.8 Separation of UAV service area** **3GPPr17UC.9 Service experience assurance**	**<u>KPIs for UAV Services</u>** **3GPPr17Req.1** The 5G system shall be able to provide unmanned aerial vehicle with the service performance requirements reported in Table 4. **<u>KPIs for UAV periodic control</u>** **3GPPr17Req.2** UAV has a variety of flight control modes, including periodic control instructions. The KPIs imported for each mode are work in progress. **<u>Other KPIs for UAV</u>** **3GPPr17Req.3** The 5G system shall support a mechanism to switch between C2 communication modes for UAS operation, e.g. from indirect C2 communication to direct C2 communication, and ensure the interruption time is below [10] ms. **3GPPr17Req.4** The 3GPP system shall enable concurrent communications between the UAV-controller and UAV and between the UTM and the UAV that may require different QoS. **3GPPr17Req.5** The 3GPP system shall be capable of changing QoS, as requested by the UAV-controller or the UTM, within [500ms]. **<u>Requirements for Network Exposure</u>** **3GPPr17Req.6** The 3GPP system shall provide means to allow a 3rd party to request and obtain real-time monitoring the status information (e.g., location of UAV, communication link status) of a UAV. **3GPPr17Req.7** Based on operator 's policy, the 3GPP system shall provide means to provide a 3rd party with the information regarding the service availability status for UAVs in a certain geographical area at a certain time. **<u>Requirements for UxNB</u>** **3GPPr17Req.8** The 5G system shall be able to support wireless backhaul with required quality to enable a UxNB. **3GPPr17Req.9** The 3GPP system shall be able to monitor UxNB (e.g. power consumption of the UAV etc.) and provide means to minimize power consumption of the UxNB (e.g. optimizing operation parameter, optimized traffic delivery) without degradation of service provided. **3GPPr17Req.10** The 3GPP system shall minimize interference among UxNBs in close proximity. **<u>Requirements for service restriction for UEs onboard UAV</u>** **3GPPr17Req.11** The 3GPP system shall be able to prevent a UE, located in a position where the UE onboard of UAV is not authorized for a connectivity service (e.g., operating above certain altitude within a cell), from accessing any network except for emergency service. **3GPPr17Req.12** The 3GPP network shall be able to support network-based 3D space positioning (e.g., with altitude 30~300m) of a UE onboard UAV. **3GPPr17Req.13** The 3GPP system shall be able to collect charging information for a UE onboard of UAV with a subscription to aerial service with information on the position (e.g., altitude) for the delivered traffic. **3GPPr17Req.14** The 3GPP system shall be able to notify the authorized third party of potential stopping of connectivity service before the UE onboard of UAV enters an area (e.g., due to altitude) where the connectivity service is not authorized for the UE. **<u>Requirements for C2 Communication</u>**

3GPP Rel. 17 22.829 Use Cases	Consolidated Requirements
3GPPr17UC.10 Service availability to UAVs needs **3GPPr17UC.11 Swarm of UAVs in logistics** **3GPPr17UC.12 Changing UAV Controller** **3GPPr17UC.13 Steering KPIs of UAV**	**3GPPr17Req.15** The 3GPP system shall support requested QoS for the various C2 communication modes (e.g. using direct ProSe Communication between UAV and the UAV controller, UTM-navigated C2 communication based on flight plan between UTM and the UAV). **3GPPr17Req.16** The 3GPP system shall support C2 communication with requested QoS when switching between the C2 communications modes. **3GPPr17Req.17** The 3GPP system shall support a mechanism for the UTM to request monitoring QoS of the C2 communication (e.g. using direct ProSe Communication between UAV and the UAV controller, UTM-navigated C2 communication between UTM and the UAV).