"5G for Drone-based Vertical Applications"

D4.3 – Trial plan

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Executive summary

This deliverable provides a detailed plan of the trials that will be carried out, including a trial schedule, use case scenarios and KPIs to be tested, 5G facilities and resources to be used and trial participants. The previous deliverables D1.1 [1] and D1.5 [2] describe the initial scenarios, which have been updated during the preparation of this document, considering the results of the feasibility tests and developments in WP2 and WP3 enablers, as well as changes in EU regulations.

The objective of this document is to describe the experience gained from the feasibility tests and pretrials carried out in 2020 and 2021 and to provide general principles and detailed plans to conduct trials in 2021-2022. The Trials plan provides project partners with a harmonized approach to conducting trials to achieve project objectives. The results collected during the Trials will be analysed by Task 4.3 and the results will be presented in the deliverable D4.4, to be submitted in M42.

In 2020-2021, feasibility tests were performed physically using Aalto University, University of Oulu and NCSRD 5G networks. Remote feasibility tests were performed in EURECOM in December 2020 due to COVID-19 restrictions. ORA team conducted tests in November and December 2020 to identify interferences generated by cellular UAV on terrestrial UE in neighbour cells in Lannion (France). Based on results of over 96 measurements, ORA team can conclude that UAV communicating on cellular bands have no major impact on the normal mobile communication traffic on ground.

5G!Drones partners remotely conducted pretrials in June 2021 using the EURECOM infrastructure. The mission was to test Integration Release 1 components, including Web Portal 1 and Web Portal 2 existing enablers, WP2 and WP3 enablers and UC1:SC1, UC2:SC1, and UC2:SC2 scenarios as much as possible for collecting feedback for next physical tests. The tests were successful and the connection between Web Portal 1 and Web Portal 2 worked smoothly.

According to the project schedule, the developments of WP2 and WP3 enablers are planned to be completed by M36 at the latest. There are in total 4 integration releases (from May 2021 to June 2022) planned, which will assure that Trial Controller system is ready to fulfil 5G!Drones requirements.

Trials are planned to be conducted in two rounds in 2021 and 2022 based on Integration Releases:

- 1st Round from July to October 2021 to test Integration Release 1 and 2 components.
- 2nd Round from June to September 2022 to test Integration Release 3 and 4 components, i.e. complete solutions of the 5G! Drones project.
- In May 2022, the project partners will conduct 5G!Drones showcasing event and trials in Tallinn,

Since the 31-Dec-2020, the European Commission Implementing Regulation (EU) 2019/947 [3] is replacing each EU state's existing laws with respect to drone's operations. In April 2021 the European Commission published Implementing Regulation (EU) 2021/664 on a regulatory framework for the U-space [4]. Its entry into force is planned for January 2023. Testing of U-space services is planned in the project trials, which will provide valuable experience to share with stakeholders who adapt their systems to comply with the U-space regulations by January 2023.

At the EU level, there are no restrictions for using cellular communication (mobile networks) for drones however, such restrictions exist in Finland. The CEPT Electronic Communications Committee (ECC) Report 309 "Analysis of the usage of aerial UE for communication in current MFCN harmonised bands" [5] deals with the use of mobile frequencies in unmanned aircraft systems. On the basis of the report, an ECC decision will be drawn up and will be sent to member states and stakeholders to get feedback (expected on second half of 2022).

In summary, the trials of the 5G!Drones project are very relevant to work within the framework of the new EU UAV flights and U-space regulation and to use cellular devices on board drones and also considering the roll-out of 5G in Europe.

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List of abbreviations

3GPP	3rd Generation Partnership Project
4G	4th Generation Cellular Technology
5G	5th Generation Cellular Technology
5GS	5G system
AAS	Active Antenna Systems
AGL	Above Ground Level
A2Vs	Advanced Aerodynamics Vessels
ATC	Air Traffic Control
ATM	Air Traffic Management
BER	Bit Error Rate
BLER	BLock Error Rate
BS	Base Station
BVLOS	Beyond Visual Line Of Sight
C2	Command and Control
CAA	Civil Aviation Authority
CEPT	Conférence Européenne des administrations des Postes et des Télécommunications (European Conference of Postal and Telecommunication Administrations)
CET	Central European Time
COVID-19	CoronaVIrus Disease 2019
CPC	Companion Personal Computer
DBSs	Drone base stations
DGAC	Direction Générale de l'Aviation Civile (French Civil Aviation Authority)
dFPL	drone Flight Plan
DL	DownLink
DTT	Digital Terrestrial Television
Dx.y	Deliverable number y of the Work Package x
EASA	European Aviation Safety Agency
EC	European Commission
ECC	Electronic Communication Committee (in CEPT)
EEST	Eastern European Summer Time
eMBB	Enhanced Mobile BroadBand
eNodeB	E-UTRAN Node B, also known as Evolved Node B
ETSI	European Telecommunications Standards Institute
EVLOS	Extended Visual Line Of Sight
eVTOL	electric Vertical Take-Off and Landing
FAA	Federal Aviation Agency (in the USA)
FSS	Fixed Satellite Service (Earth to space)
GCS	Ground Control Station
GDPR	General Data Protection Regulation
GPRS	General Packet Radio Service
GPS	Global Positioning System

GPT-C	GPRS Tunnelling Protocol communication protocol
HCAA	Hellenic Civil Aviation Authority
HD	High Definition (video)
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
IMEI	International Mobile Equipment Identity
IMSI	International Mobile Subscriber Identity
IMT	International Mobile Telecommunications
IoT	Internet of Things
ISS	International Space Station
ITU	International Telecommunication Union
ITU-R	ITU Radiocommunication Sector
KPI	Key Performance Indicator
LAANC	Low Altitude Authorization and Notification Capability (in the USA)
LBO	Local Break-Out
LIDAR	LIght Detection And Ranging
LMF	Location Management Function
LTE	Long-Term Evolution
MAP	French “Manuel d’Activités Particulières” – Specific Activities Manual
MFCN	Mobile Fixed Communications Network
mMTC	massive Machine-Type Communication
NG RAN	Next Generation Radio Access Network
NS	Network Slicing
NSA	Non-Stand Alone
OAI	OpenAirInterface
OPEX	OPerating EXpense
OSS	Operation Support System
PER	Packet Error Rate
QoS	Quality of Service
RPi4	Raspberry Pi 4
RSRP	Reference Signal Received Power
RSSI	Received Signal Strength Indicator
RSRQ	Reference Signal Received Quality
RC	Radio Communication
RPAS	Remotely Piloted Aircraft Systems
RTT	Round Trip Time
SA	Stand Alone
SAR	Search And Rescue
SESAR JU	Single European Sky ATM Research Joint Undertaking
SINR	Signal to Interference and Noise Ratio
SLA	Service Level Agreement
SORA	Specific Operations Risk Assessment
SPoC	Single Point of Contact
sUAS	small Unmanned Aerial System

SUT	System Under Test
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UE	User Equipment
UL	UpLink
UL-VA	Unmanned Life Video Analytics
uRLLC	ultra-Reliable and Low Latency Communication
UTM	UAS Traffic Management
VBR	Variable Bit Rate
VIM	Virtualisation Infrastructure Manager
VLOS	Visual Line Of Sight
WP	Work Package

1 Introduction

1.1 Objective of the document

The objective of this document is to describe the experience gained from the feasibility tests and pretrials carried out in 2020 and 2021 and provide general principles and detailed plans as accurately as all factors can be predicted to conduct trials in 2021-2022.

The Trials plan provides project partners with a harmonized approach to conducting trials to achieve project objectives. The results collected during the Trials will be analysed by Task 4.3 and the results will be presented in the deliverable D4.4, which will be presented in M42.

1.2 Structure of the document

This Deliverable is structured in four chapters:

- Chapter 1 presents an introduction of the deliverable focusing on its objectives, structure and target audience.
- Chapter 2 presents and analyses the overview of 5G!Drones feasibility tests and pretrials conducted in 2020-2021.
- Chapter 3 presents general principles, enablers, scheduling and KPIs, which are similar to all scenarios.
- Chapter 4 presents detailed plans of conducting trials on different 5G facilities, incl. showcasing trial, in 2021-2022.

1.3 Target audience

This deliverable is mainly addressed to:

- **The Project Consortium** to validate the project objectives, since the deliverable D4.3 provides an appropriate overview of previous feasibility tests and pretrials in 2020-2021 and descriptions and requirements of Trials in 2021-2022.
- **The Research Community and funding EC Organisation** by presenting the 5G!Drones' project experiences from feasibility tests and pretrials and plans for conducting 5G cellular drones' trials in 2021-2022.
- **The UAV industry and stakeholders** who will become aware of the 5G cellular drones use cases and how to use 5G communication to support drone businesses.
- **The general public** to obtain a better understanding of the 5G cellular drone usefulness for UAV business areas and for society.

2 Results of feasibility tests and pretrials conducted in 2020-2021

The purpose of this chapter is to offer an overview of 5G!Drones feasibility tests and pretrials conducted in 2020-2021. Mission of feasibility tests and pretrials was to conduct physically or remotely the tests in Finland, Greece and France in 2020-2021, to map deficiencies and to collect inputs for 5G!Drones next developments and actions.

An overview of the feasibility tests and pretrials conducted in 2020-2021 is presented in the Table 1 below.

Table 1. Overview of the feasibility tests and pretrials conducted in 2020-2021

Date	Type of test	Facility	Mode
30-Jun-2020	**Feasibility tests**	NCSRD, CAF	Remotely
24-Aug-2020	**Feasibility tests**	AU	Physically
27-Aug-2020 – 28-Aug-2020	**Feasibility tests**	UO	Physically
19-Oct-2020 – 21-Oct-2020	**Feasibility tests**	NCSRD, COS, MOE	Physically
19-Nov-2020, 11-Dec-2020	**Interference tests**	ORA	Physically
17-Dec-2020 – 18-Dec-2020	**Feasibility tests**	EUR, CAF	Remotely
22-Jan-2021	**Simulation tests**	NCSRD, COS, UMS	Remotely
23-Apr-2021	**Simulation tests**	NCSRD, COS, UMS	Remotely
04-Jun-2021	**Service continuity tests**	ORA	Physically
17-Jun-2021	**Pretrials**	EUR, CAF, UMS	Remotely

2.1 Aalto University feasibility tests in August 2020

On 24-Aug-2020, 5G!Drones partners AU, CAF, REX performed physical feasibility tests at the Aalto University campus in Espoo, Finland.

Description of the architecture is described in the Figure 1 below.

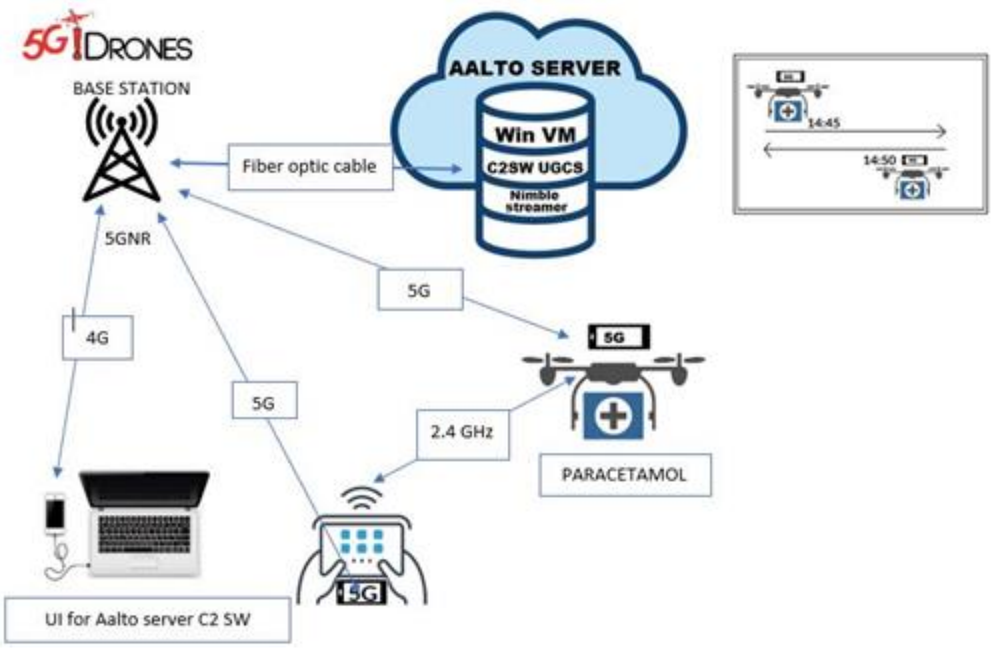


Figure 1. Description of technologies of the final tests in Location 2 of Aalto University

Locations and measurements results are described in the Table 2 below.

Table 2. Locations and measurements and flights of the Aalto University feasibility tests

Location nr and name	Time	Flights/ measurements and test description	DL (Mbps)	UL (Mbps)	Ping (ms)
1. Behind the Tietotekniikan building	24-Aug-2020 10:58	At 1.5 m AGL, measuring with 2 different 5G smartphones. Jitter was 9 ms. At 11:45 5G network connection lost and the connection could not be re-established.	14	6	14
	24-Aug-2020 11:15-12:15	At 1.5 m AGL, measuring with 2 different 5G smartphones. 5G network connection lost and the connection could not be re-established.	N/A	N/A	N/A
2. Open grass area	24-Aug-2020 14:30-14:45	CAFA Tech flight with onboard 5G UE with video streaming. At ground level for Ground Control Station (laptop) UL was 5 Mbps, DL was 45 Mbps.	25	9	25

Trials locations 1 and 2 and Base-station (marked as BS at the bottom of the figure) are shown in the Figure 2 below.

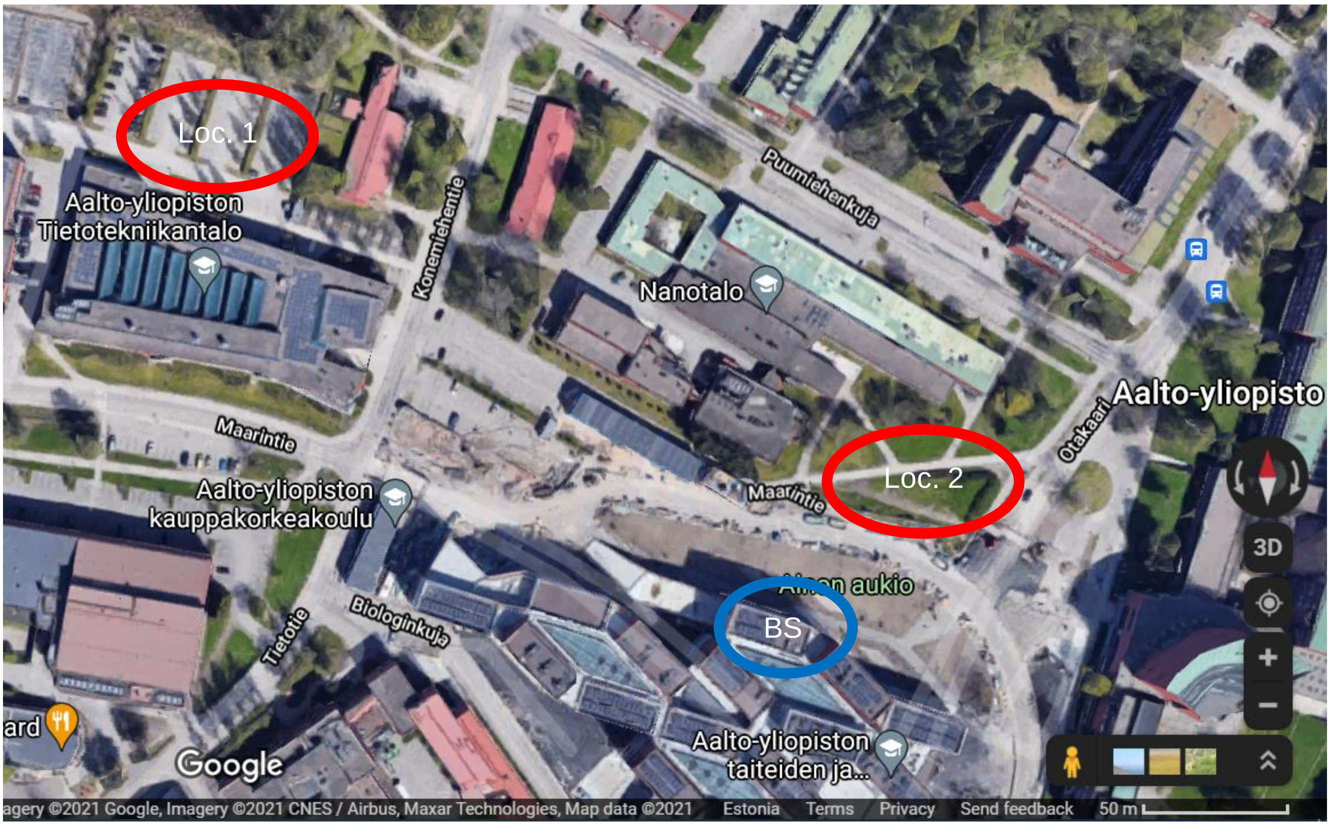


Figure 2. Aalto University feasibility tests locations in August 2020

Experiment setup and detailed description of Aalto University feasibility tests, 24-Aug-2020

Scenario

1. Paracetamol (headache medicine) tablets with packaging was attached to the drone.
2. Flight plan was created and uploaded to the drone.
3. Drone automatically took off, transported the packaging to the recipient's location and landed (with manual confirmation).
4. Recipient detached the packaging from the drone.
5. Another flight plan was created and uploaded to the drone.
6. Drone automatically took off, flew back to the original location and landed.

UgCS C2 cloud native application enhanced by CAFA Tech (CAFA CUP) server components and video server (Nimble streamer) were set up in Aalto's virtual machine (Windows 10). UgCS is an acronym of Universal ground Station Software. It has several client and server components. More details are available at the webpage https://www.ugcs.com/. The laptop (UgCS Desktop client) was using 4G tethering for its Internet connection (for connecting to Aalto edge server – UgCS server software).

- 1st Huawei Mate 20 5G smartphone was used for UgCS for DJI app;
- 2nd Huawei Mate 20 5G smartphone Larix broadcaster for on-board video streaming;
- 3rd Samsung Galaxy A90 smartphone (not connected to 5G network, but using 4G) provided datalink for laptop (user's screen, i.e. User Interface for Aalto edge server).

Video streaming parameters: 720p, 30 fps, 5 Mbps, VBR (Variable Bit Rate) active (logarithmic).

Overall smallest video delay over the entire communication chain (actual event->smartphone->video server->client's screen) was close to 1 s using the web page.

5G service interruptions were observed on Location 1, which caused web page player to increase it is buffering from 1 s to 5 s. Interruptions were also observable on UgCS Desktop app, which itself was connected (over 4G), but Android client's connection was intermittent.

Trial outcome

Location 1: Flight plan was designed in narrow spatial conditions. Drone started, but after rising to the proper height (5 m AGL), it turned off the route. After the serious deviation was obvious, drone pilot paused the execution of automated flight with remote controller's pause button leaving the drone hovering in its position. Air Safety Coordinator was notified immediately. After setting the drone to manual mode from UgCS Desktop software, the drone could be recovered with the aid of remote controller.

Possible cause of deviation: Unknown communication failure between UgCS for DJI app and UgCS Server (5G smartphone attached to RC lost the connection with 5G network). At the same time, 5G communication of the Aalto 5G network lost and did not re-establish.

Compared to Location 1, Location 2 was more open. 5G network connection stability was observed and found stable. There were no interruptions between UgCS for DJI app and UgCS Server anymore.

Flight plans were similar to the Location 1 flight plan, equipment was the same except the drone also carried an additional payload (paracetamol tablet with packaging) on top of it. In Location 2 there were also no issues with the video feed.

2.2 University of Oulu feasibility tests in August 2020

On 27-Aug-2020 and 28-Aug-2020, the 5G!Drones partners OU, CAF, REX, NOK, HEP performed feasibility tests at the University of Oulu campus.

Description of the architecture is described in the Figure 3 below.

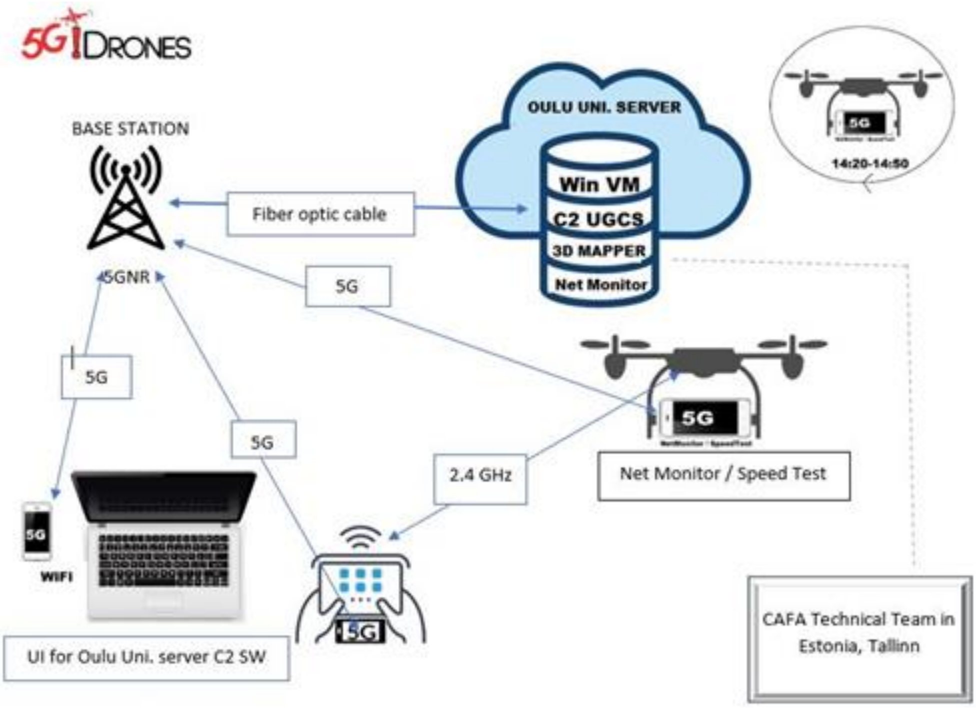


Figure 3. Description of technologies on the feasibility tests in Oulu University campus

For the feasibility tests partners used applications running on the 5G network in OU edge server. All flights took place automated way, i.e. the C2 application running on the Edge server sent the flight plan to a drone that performed 5G QoS measurement mission. The CAFA Tech safety pilot present on the site was for safety only.

The locations and measurements results are described in the Table 3 below.

Table 3. Locations and measurements and flights of the Oulu University feasibility tests

Location nr and name	Time	Flights/measurements and test description	DL (Mbps)	UL (Mbps)	Ping (ms)
1. Botanical Garden	27-Aug-2020 11:00-11:10	At 1.5 m AGL, measuring with 3 different 5G smartphones	12	0.5	25
	27-Aug-2020 15:50-16:00	Hepta test flight with onboard 5G smartphone for measuring. At ground level / DL 15 Mbps and UL 0.5 Mbps	32	5	25
2. Parking slot NW area	27-Aug-2020 11:50-13:00	CAFA Tech technical tests with onboard 5G UE. At 0 m AGL DL 55 Mbps, UL 2 Mbps	60	3	24
3. Forestry	27-Aug-2020 15:30-16:00	CAFA Tech 3D mapping flight and tests at the ground level At 0 m AGL, DL 35 Mbps and UL 1.5 Mbps, Ping 25 ms	35	1.5	25
	27-Aug-2020 16:00-16:30	Hepta flight with 5G smartphone	60	5	25
	28-Aug-2020 10:10-10:20	CAFA Tech 3D mapping flight At 0 m AGL DL 35 Mbps and UL 1.5 Mbps, Ping 25 ms	35	1.5	25
4. Main entrance	28-Aug-2020 12:45-13:00	At ground level measurements with 3 smartphones. Differences between smartphones on the same position	300	30	21
	28-Aug-2020 14:00-14:15	CAFA Tech 5G QoS measuring flight at 20 m AGL using NetMonitor application	RSSI: from -58 dBm to -83 dBm		
	28-Aug-2020 14:30-14:45	CAFA Tech 5G QoS measuring flight at 40 m AGL using NetMonitor application	RSSI: from -72 dBm to -84 dBm		
	28-Aug-2020 14:48-14:55	CAFA Tech 5G QoS measuring flight at 30 m AGL using Ookla Speedtest application. Total 6 measurements points	298	From 3 to 25	21

The trials locations 1, 2, 3 and 4 and the base station (marked with blue circle and capital letters BS on the centre of picture) are shown in the Figure 4 below.

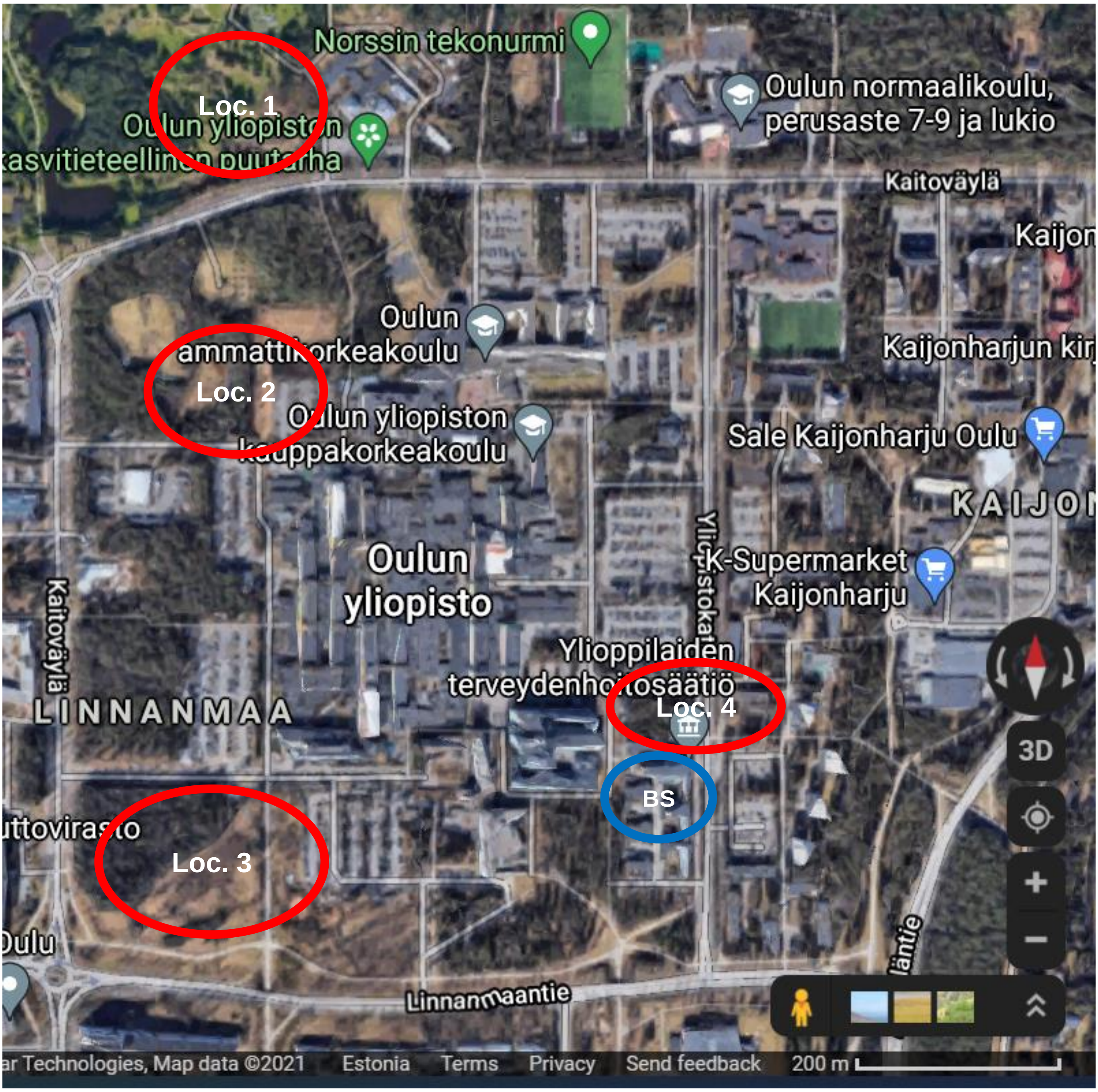


Figure 4. Locations of Oulu University feasibility tests in August 2020

5G QoS measurements

Measuring time: 28-Aug-2020 14:00-14:55 EEST.

Measuring devices and applications and levels: 5G smartphone OnePlus Pro, which used NetMonitor application for signal strength measuring and Ookla Speedtest for measuring DL/UL.

Measuring levels: 20 m AGL and 40 m AGL for signal strength measurements and 30 m AGL for speed tests.

Map for visualisation: Google Earth Pro.

5G QoS and Speedtests at Location 4 were measured at height level 20 m, 30 m and 40 m AGL on 28-Aug-2020 at 14:15-14:55 EEST. Combined results are shown in the Figure 5 below.

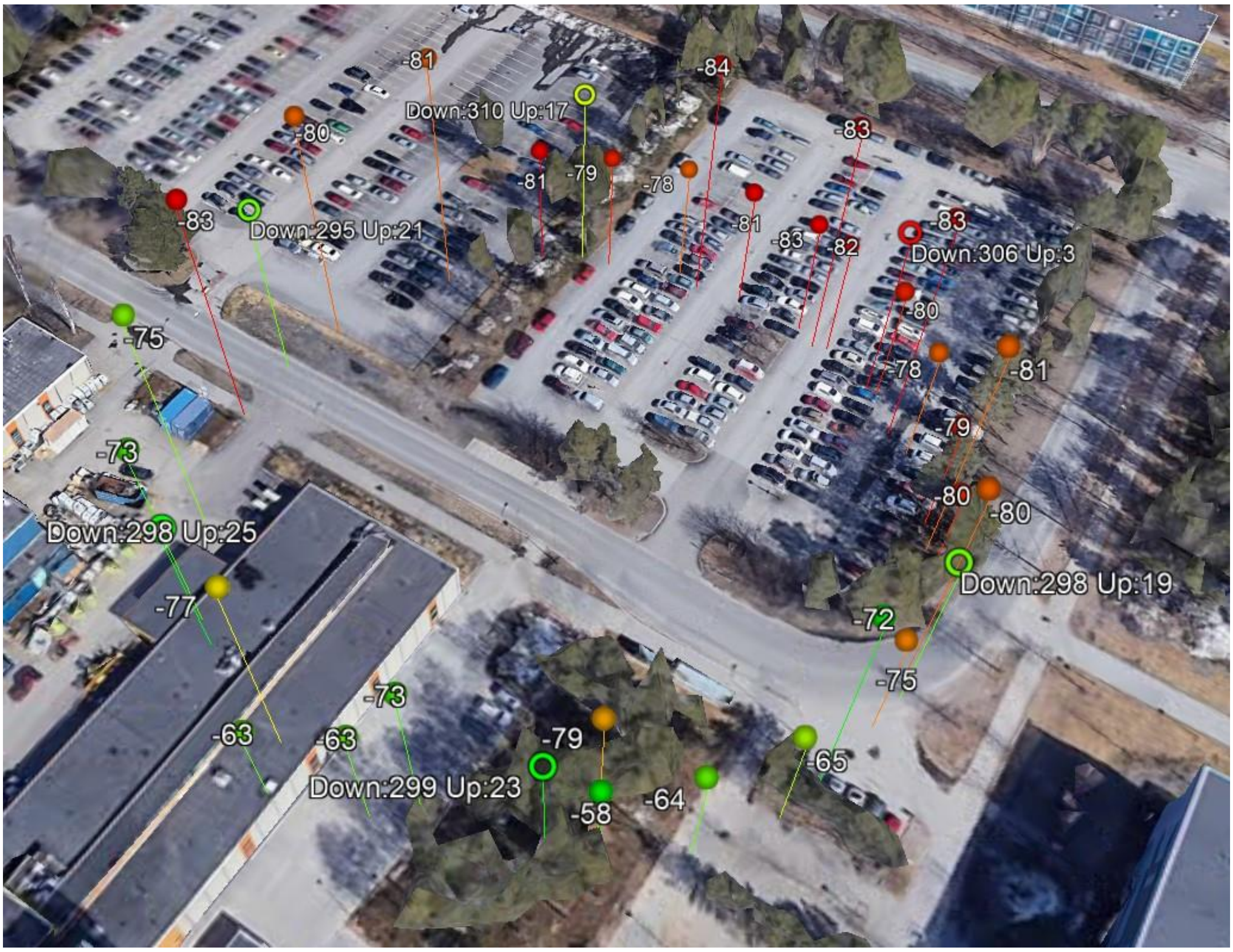


Figure 5. 5G QoS and Speedtests at Location 4 in University of Oulu campus

Hepta system setup

The UAV was planned to be 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. As collision avoidance and mapping sensors are identical. Actual trial setup comprised of one LiDAR to lower MTOW according M600 payload requirements. For the same reason we also divided 4K camera and LiDAR into separated flights. The description of the initial architecture of the Hepta flight is described in the Figure 6 below.

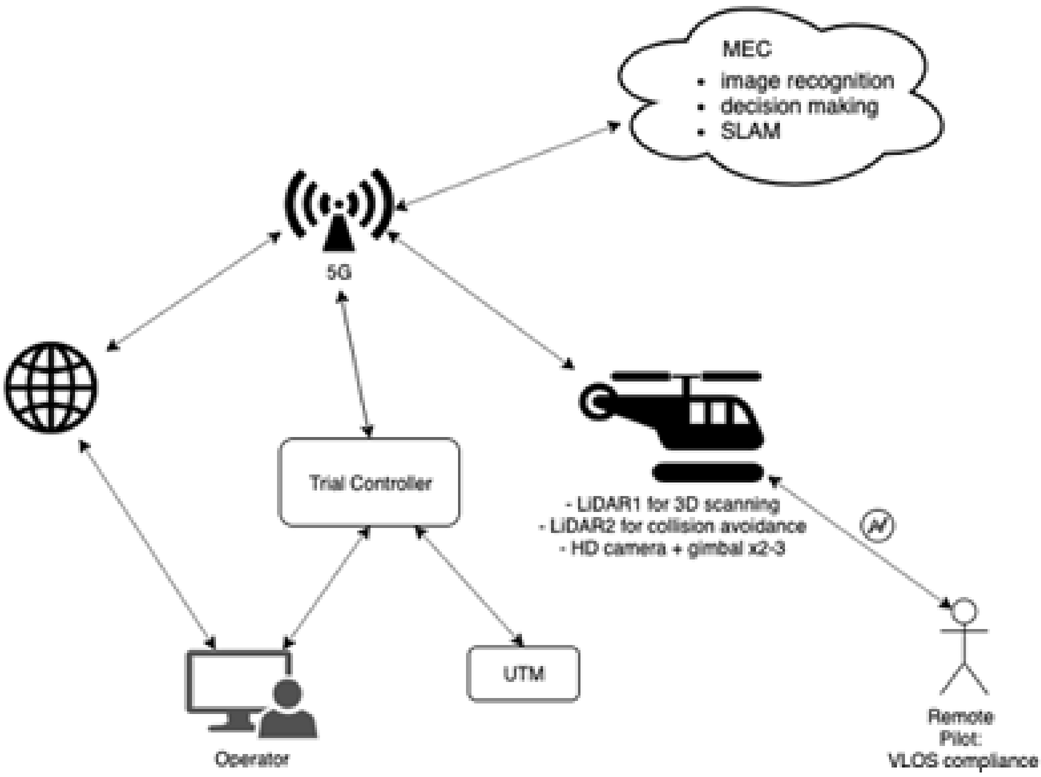


Figure 6. Initially planned architecture for long range power line inspection scenario

The description of the software setup of the Hepta flight is described in the Figure 7 below.

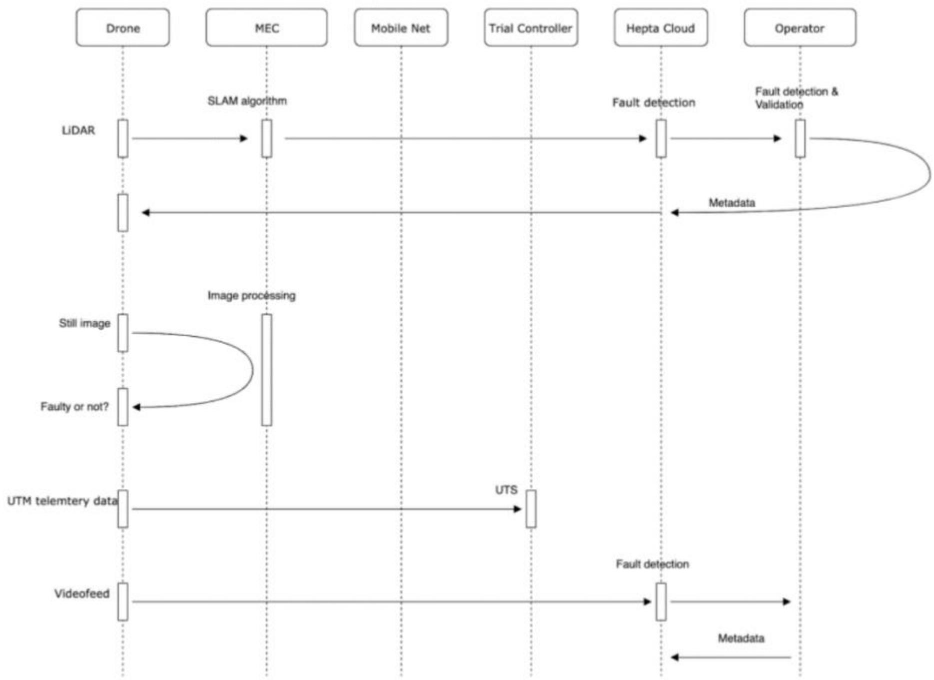


Figure 7. Initially planned software setup for long range power line inspection scenario

Results of Hepta tests

5G data speed tests carried out on first day indicated that available upload speed is insufficient for streaming 4K camera and LiDAR data with the tested equipment. 5G measurements made on different locations showed no significant improvements in signal quality. Test-system setup used DJI M600 Pro for carrying Hepta's main copter avionics. Onboard real-time data stream from separated computers was over 2.4 GHz Wi-Fi and was unstable probably because of interference from DJI's 2.4 GHz remote control.

The main take-aways from the tests were that transmitted data volumes need to be reduced and the streaming setup needs to be robust in varying link quality conditions. To lower the transmitted data volumes, it was decided to use another lidar for infrastructure inspection, limit the capture angle, take HD images instead of 4K video and use only one camera at a time.

2.3 Athens feasibility tests in June and in October 2020

To prepare for the October 2020 the physical feasibility tests, the remotely tests were conducted in June 2020 and in October 2020. The feasibility tests provided to all participants common understanding and practical feedback for next developments and preparations for trials in 2021-2022.

Remote tests on 30-Jun-2020

On 30-Jun-2020, the 5G!Drones partners NCSRD and CAF conducted remotely the feasibility tests related to UC4:SC1 in Athens to map deficiencies and testing procedures as much as possible. NCSRD and CAF team set VPN connection between NCSRD server where Drone C2 software UgCS worked. UgCS is an acronym of Universal ground Station Software. It has several client and server components, which have been tested with VPN and with 5G network.

NCSRD and CAF team set VPN connection between NCSRD server where Drone C2 software UgCS worked. It has been tested with VPN and with 5G network. The main idea of having UgCS server components on a dedicated server is to manage and share resources among many drone operators in a common environment. Also, the progress of jobs (taking video, taking pictures) can be visualized to many participants for business purposes. Important configurations, missions and flight plans can be saved on server so there is less hassle about configuring client software.

As there was no drone in the NCSRD testbed, the drone flight was made in Tallinn. To this end, a flight plan was created for the drone DJI Mavic using the UgCS application running on the NCSRD server.

Then a real flight was made – this flight plan was sent to the A3 smartphone connected to the drone remote control by the NCSRD server. The A3 smartphone transmitted it to the DJI Mavic drone via this drone remote. At 12:35, the DJI Mavic drone rose to a height of 4 m AGL in Tallinn based on a flight plan, which was sent from NCSRD server to C2 client application in Tallinn.

The flight plan seen on Android Samsung Galaxy A90 Device after upload from NCSRD server, i.e. from UgCS Desktop, is shown in the Figure 8. The connection was still active with UgCS server software operated in NCSRD server as shows the green marker after the word UCS in the Figure 8 below.

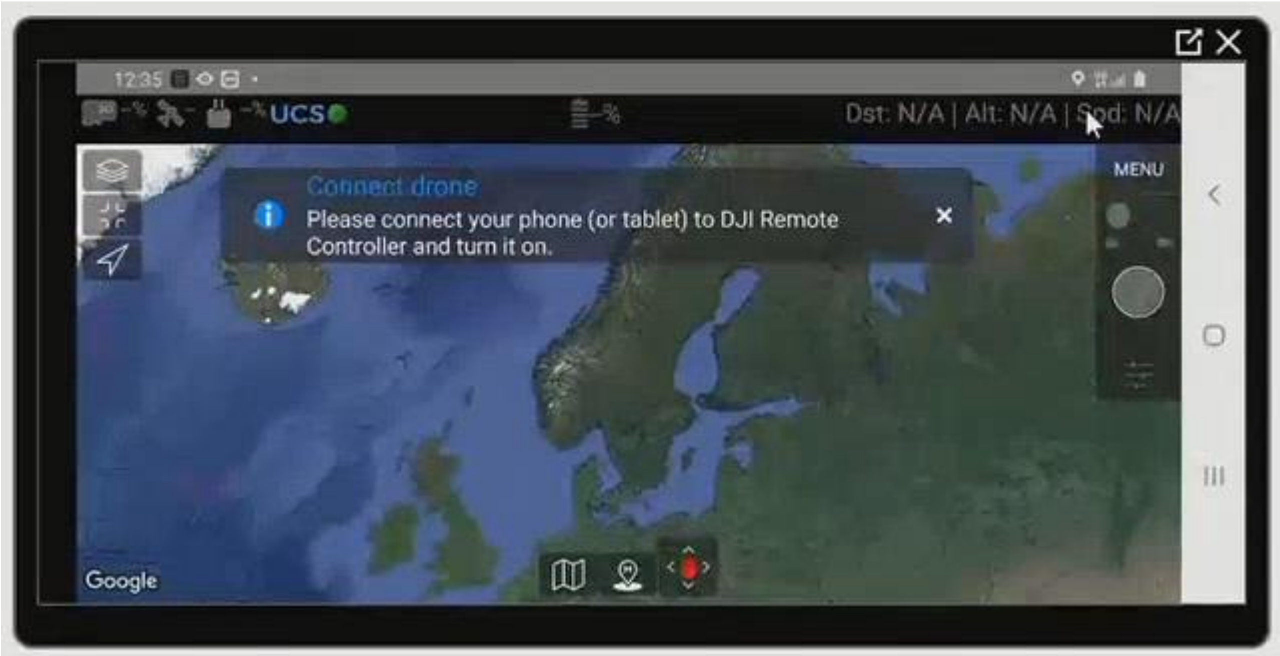


Figure 8. NCSRD Samsung Galaxy A90 screenshot with UgCS

Athens physical feasibility tests on 19-Oct-2020 – 21-Oct-2020

On 19-Oct-2020 and 20-Oct-2020, the participants NCSRD, COS, CAF, REX, HEP, MOE, INF conducted physical feasibility tests at the Egaleo stadium. The architecture for 19-Oct-2020 tests is described in the Figure 9 below.

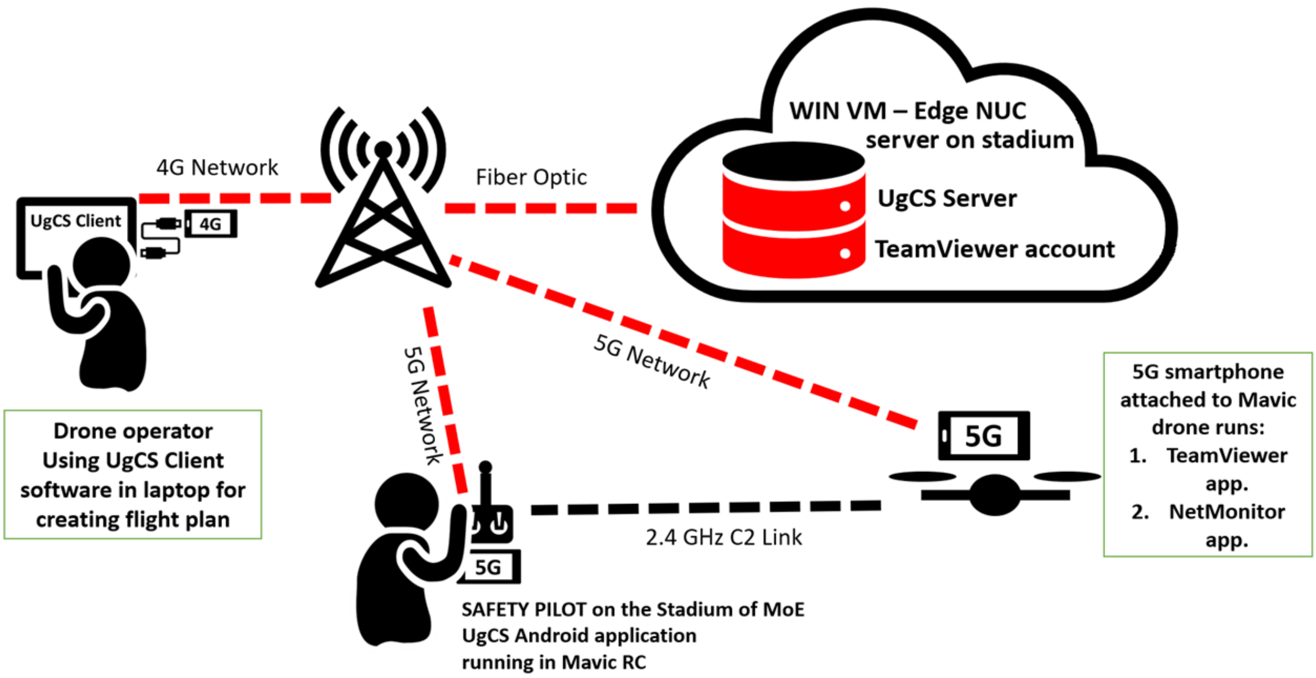


Figure 9. Description of architecture of CAFA Tech flight tests, Egaleo stadium on 19-Oct-2020 – 20-Oct-2020

Main actions and results:

1. Set up NCSRD 5G Base-station and Edge Server: solutions worked smoothly.
2. CAFA Tech C2 software worked in Edge Server and all C2 communication worked over 5G.
3. CAFA Tech conducted drone flights at 10 m AGL, during which we measured the strength of the 5G QoS signal and performed Speedtests at 10 m AGL.
4. Hepta conducted helicopter drone test flights. Hepta drone was able to lift the 10 kg payload nicely.
5. UTM integration with Frequentis and DroneRadar systems worked and the location of the CAFA Tech Mavic drone was visible in real time in the UTM system (described in the Figure 10 below).

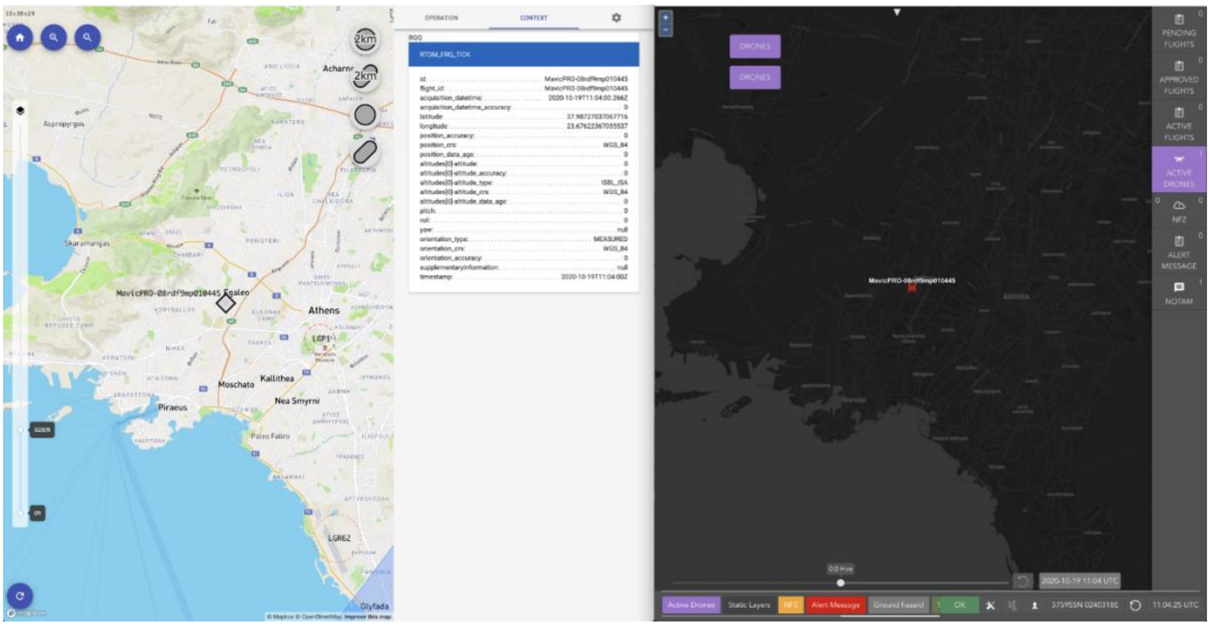


Figure 10. DroneRadar and Frequentis UTM systems screens shots on 19-Oct-2020

On 19-Oct-2020, 5G coverage measurements were done at the level of 10 m AGL (above the ground level) using a 5G telephone attached to a DJI Mavic drone. Base-station was located at 3 m AGL on the east tribune of Egaleo stadium and was directed to west, marked with red circle in the Figure 11 below. The data on the right side of the stadium are located there, because the drone was prepared for flights in the eastern part of the stadium square (on the right side)

Figure 11. 5G signal strength measured with NetMonitor application, Egaleo stadium on 19-Oct-2020

The Ookla Speedtest application was used for measurement. Uplink results ranged from 13 to 142 Mbps and Downlink results ranged from 11 to 37 Mbps. Measurements results are described in the Table 4 below.

Table 4. 5G QoS measurements results on 19/OCT/2020 at the Egaleo stadium

Measurement number and time	Position	Download (Mbps)	Upload (Mbps)	Ping (ms)	Jitter (ms)	Loss (%)
1. 14:15	1 m behind the 5G Base Station (behind the antenna)	95.3	11.2	17	13	0
2. 14:47	1#	103	27			
3. 14:48	2#	88	35			
4. 14:49	3#	123	37			
5. 14:50	4#	105	36			
6. 14:51	5#	127	32			
7. 14:52	6#	13	22			
8. 14:53	7#	108	29			
9. 14:54	8#	142	25			
10. 14:54	9#	13	26			
11. 14:55	10#	136	36			
12. 14:55	11#	67	35			
13. 14:56	12#	129	34			

On 20-Oct-2020, the participants met at the Egaleo stadium for the 2nd day trial. Participants: NCSRD, COS, CAF, REX, HEP, MOE, INF.

The architecture for 20-Oct-2020 tests is described in the Figure 9 above (CAFA Tech flights 19-Oct-2020 – 20-Oct-2020) and Figure 12 below (Hepta flight 20-Oct-2020).

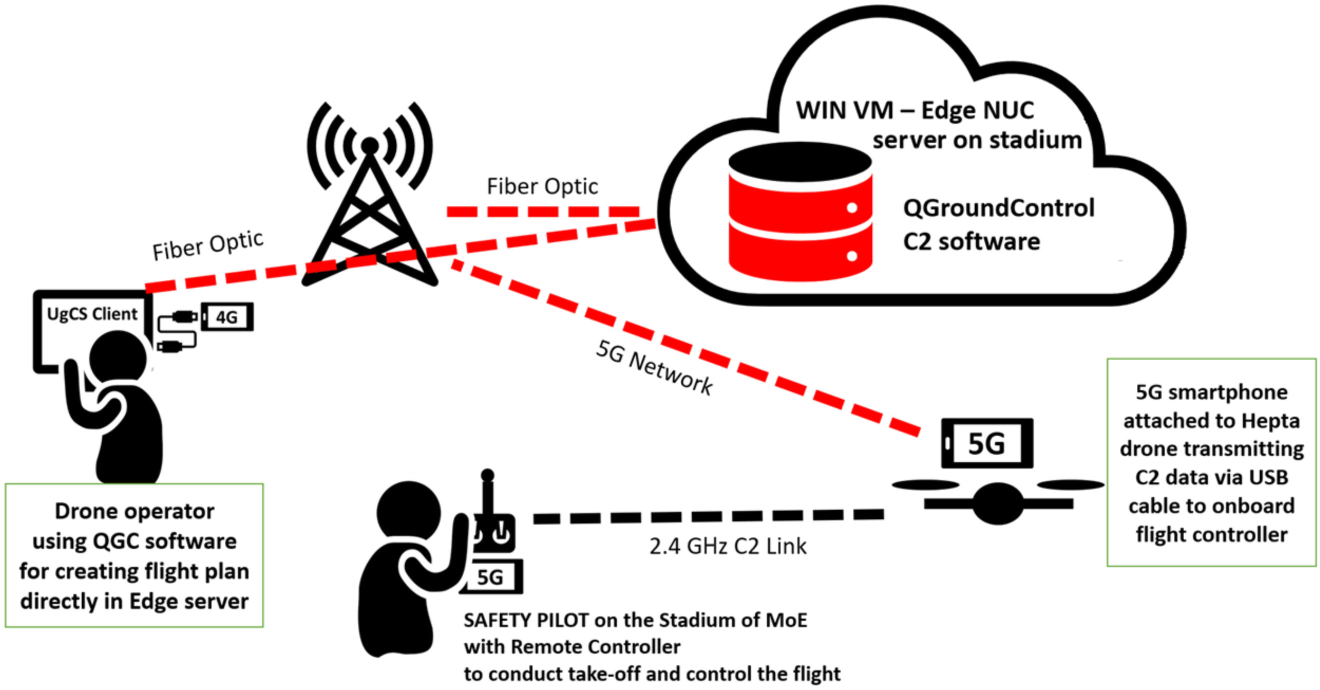


Figure 12. Description of architecture of Hepta flight tests, Egaleo stadium on 20-Oct-2020

Participants of 20-Oct-2020 trials: NCSRD, COS, CAF, REX, HEP, MOE, INF.

Main actions and results:

1. NCSRD 5G Base station and Edge Server solution set up in 90 minutes on the 2nd position and everything worked smoothly.
2. CAFA Tech C2 software worked in Edge Server and all C2 communication worked over 5G.
3. Hepta C2 software worked in Edge Server and all C2 communication worked over 5G.
4. Made several manual flights to identify where 5G coverage is disappearing. We gained significant experience in planning the next tests.
5. Conducted co-existence flight at the end of the testing day:

CAFA Tech drone Mavic and Hepta drone flew at the same time: Hepta drone had a 5G phone on board, which transmitted C2 information between the NUC server QGC application and the drone. A 5G smartphone was attached to the CAFA Tech Mavic drone Remote Controller, which transmitted C2 information between the UgCS C2 application in the NUC server and the drone.

Hepta's mission: climb to a height of 20 m and hover at this level for 5 minutes.

CAFA Tech drone mission: to make a circular flight around the Hepta drone at a height of 10 m and a radius of 20 m from the Hepta drone, the flight length was 5 minutes.

At 16:17 (Greece time) both drones took off and at 16:22 both drones landed. The 5G coverage was available throughout the flight. Mission completed successfully.

On 20-Oct-2020, measurements of the 5G coverage area were performed at a height of 10 m AGL, where the coverage area of the 5G test network was available (described in the Figure 13 below). The 5G base station was in the northern part of the stadium marked with the red circle in the Figure 13. The problem was that if the 5G smartphone on board the drone lost its 5G coverage, the flight had to be interrupted and on the ground the smartphone had to be switched on to the 5G network again. Therefore, only a few tests were performed at altitudes of 15 m to 25 m. At the same time, the central axis of the antenna of the 5G base station was turned upwards, which helped to achieve 5G coverage at a height of 25 m in the central part of the stadium. Measurements taken at altitudes of 14 m to 30 m showed that the 5G propagation was related to the direction and pitch of the 5G antenna. When the antenna was turned upwards, the 5G coverage was also available at a height of 25 m, where previously the coverage was only up to a height of 14 m. Speedtest results measured using Ookla at the Egaleo stadium are shown in the Figure 13 below.

Figure 13. Speedtest results measured using Ookla, Egaleo stadium at 10 m AGL, 20-Oct-2020

Signal strengths are shown in the Figure 14 below. The data on the right side of the stadium are located there, because the drone was prepared for flights in the eastern part of the stadium square (on the right side). The base station was in the northern part of the stadium marked with the red circle shown in the Figure 14 below.

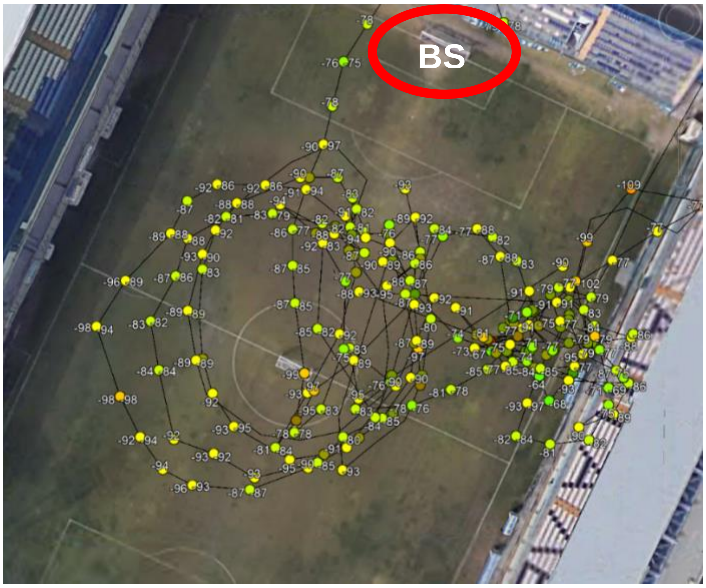


Figure 14. NetMonitor measurements, Egaleo stadium on 20-Oct-2020

Description and results of feasibility tests in OTE Academy, 21-Oct-2020

On 21-Oct-2020, the participants met at OTE Academy (a part of COSMOTE).

Link to Google Maps **https://goo.gl/maps/7yutPoe85rGuGkjp7** Coordinates: 38°02’58.8”N 23°47’17.0”E or format: 38.049674, 23.788043

Participants: NCSRD, COS, CAF, REX, INF.

The architecture for 21-Oct-2020 tests is described in the Figure 15 below.

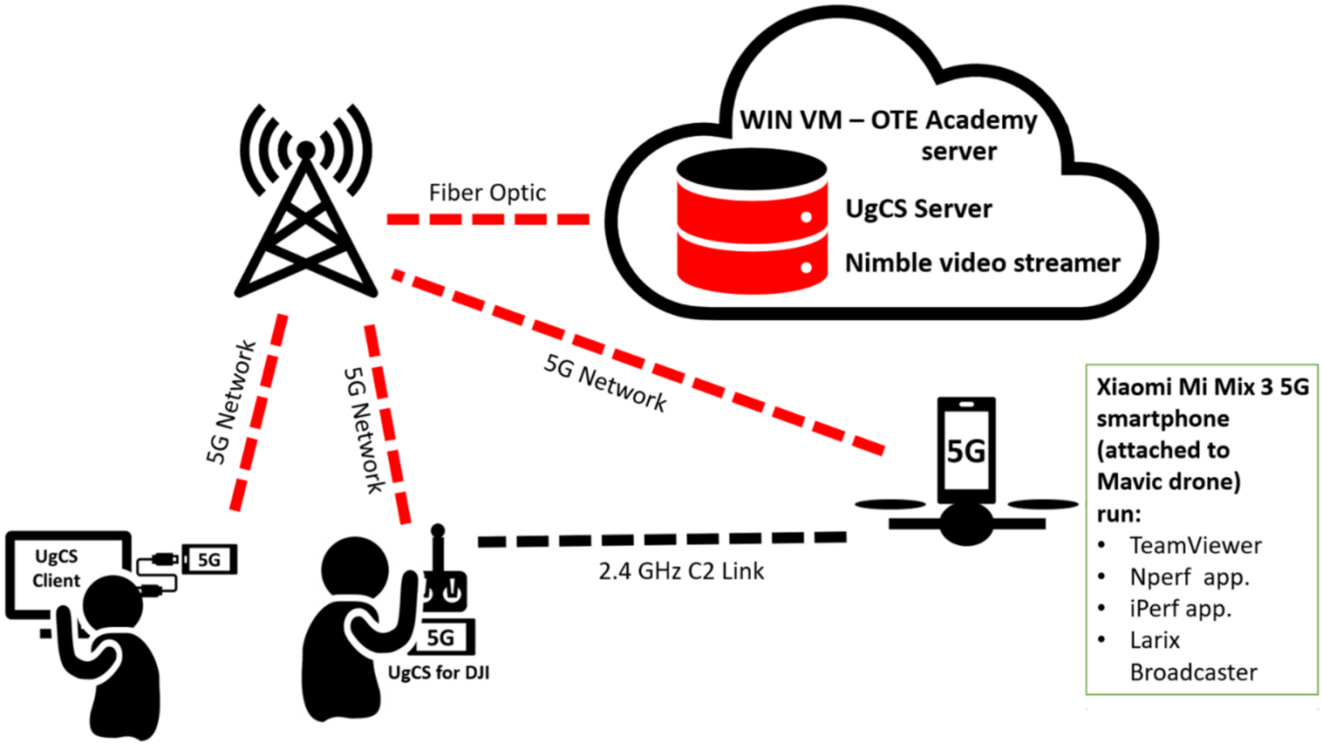


Figure 15. Description of architecture of tests, OTE Academy on 21-Oct-2020

The UC4 description states that the video stream is transmitted from the Egaleo stadium to the COSMOTE Private edge server.

At OTE Academy (premises of COSMOTE private cloud), 5G!Drones team set up a Control Room from which all activities were managed.

Main actions:

1. Set up video server and C2 software UgCS into COS Private cloud server (as described in UC4 description). Have set external IP for sharing video stream. Downloaded applications to 5G phones: TeamViewer, LarixBroadcaster, iPerf, nPerf and for remote controller UgCS client.
2. Manual (only vertical) flights for conducting 5G QoS measurements with iPerf and nPerf application. 5G Xiaomi smartphone was attached to CAFA Tech DJI Mavic Platinum drone. Measurements were taken remotely using the TeamViewer application to turn on the measurements. Measurements made by iPerf and nPerf applications during different flights. The 5G smartphone was attached to the drone. 5G QoS measurements performed at levels: AGL, 5 m, 10 m, 15 m, 20 m, 25 m, 30 m, and 35 m.
3. Manual flight (vertical flight from same position as 1st flight) for conducting video streaming over 5G using Larix Broadcaster application in 5G Xiaomi smartphone, which was attached to CAFA Tech DJI Mavic Platinum drone. Larix Broadcaster streamed video to video server in OTE private cloud and users in Control Room saw the video stream on the laptop screen using Videoplayer chanel 5G!Drones/direct. The laptop was connected to COSMOTE Wi-Fi. Latency was 1.7 s mainly due to LarixBroadcaster packet preparation protocol.
4. Automated 5G drone flight take-off. CAFA Tech DJI Mavic Platinum drone flight over 5G: the 5G Xiaomi smartphone was attached to Remote Controller and C2 software was run in COSMOTE Private cloud server, which sent the mission to the drone and got telemetry from the drone over 5G. The second 5G Xiaomi smartphone was attached onboard the drone and NetMonitor application logged and saved 5G QoS signal strengths. At same time LarixBroadcaster run and streamed video

to Command Centre. Flight route: take off and climbing to altitude 30 m and then circle flight with diameter 40 m.

5. Speedtests performed against LBO using iPerf.

On 21-Oct-2020, the measurements of the 5G coverage area were performed during different flights at a different height from ground level up to 35 m, where the coverage area of the 5G test network was available (described in the Figure 16). Measurements taken at different altitudes using iPerf and nPerf applications and recorded. The gNB was located at 2nd floor at 7 m AGL as shown in the Figure 16 with red circle and capital letters BS and was directed to south. nPerf measurements at levels 0 m – 5 m – 8 m – 12 m – 15 m – 20 m – 30 m are shown in the Figure 16 below.

Figure 16. OTE Academy Speedtest with nPerf on 21-Oct-2020

2.4 EURECOM remote feasibility tests in December 2020

5G!Drones partners conducted remote feasibility tests using EURECOM and CAFA Tech facilities on 17-Dec-2020 and 18-Dec-2020 to test how 5G!Drones containers (C2 + U-space and MCS containers) working in EUR servers and connections with these containers' client applications in smartphones to collect inputs for next developments.

The description of the architecture of the tests is described in the Figure 17 below.

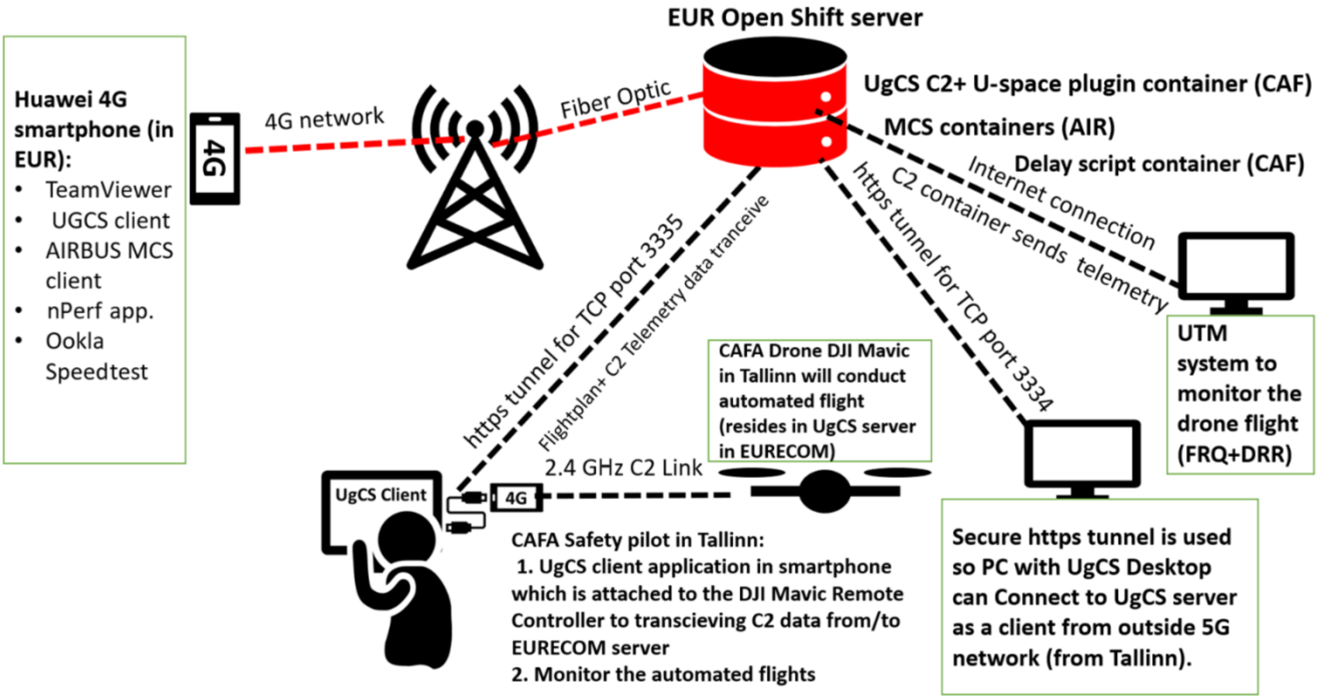


Figure 17. Overall architecture of the EURECOM remote tests on 17-Dec-2020 and 18-Dec-2020

Description and main results of the EURECOM remote feasibility tests, 17-Dec-2020

Participants: EUR, CAF, FRQ, AIR

Time schedule (in CET):

At 13:35-14:10, Airbus MCS test to test how the Airbus MCS client application works on a smartphone that uses the Airbus MCS container solution.

At 13:37, a remote connection was established with EURECOM's Huawei 4G smartphone using the TeamViewer (TV) application. A Speedtest was then performed on the EURECOM OpenAirInterface (OAI) base station. The result was Download: 28 Mbps and Upload: 6 Mbps.

The Airbus MCS client was then launched on a Huawei smartphone using a TV, which was live and video streamed. An attempt was also made to test the operation of the Airbus MCS with another smartphone, Google Pixel, using a TV, in which the GPS did not work, because the phone was in the EURECOM building. 2. The phone screen could not be controlled by the TV, because the network quality was poor and the upload speed was low.

18-Dec-2020

At 14:00, the WebEx meeting started for real-time remote test. Participants check: EUR, CAF, FRQ, AIR, DRR.

Drone flight with CAFA Tech UgCS C2 container-based application in EURECOM Open Shift server and client application in Tallinn with Frequentis and DroneRadar UTM system integration.

At 14:05-14:35 CET:

1. Secure https tunnel was used so CAFA Tech Drone Operator was able to connect UgCS Desktop to UgCS container server in EURECOM from outside 5G network (from Tallinn). The CAFA Tech

Drone Operator compiled the flight plan (30 m vertical flight plan) in the CAFA Tech UgCS C2 container as described in the architectural figure above. The CAFA Tech UgCS C2 container was accessed by CAFA Tech Drone Operator from Tallinn.

2. After that the C2 software sent the flight plan over the Internet to the CAFA Tech Android UgCS client application (in Tallinn), which passed it to the DJI Mavic drone. Android Samsung A3 phone was attached to DJI Mavic Remote controller as UgCS client, which was connected via routed ports to SSH tunnels to EURECOM CAFA Tech UgCS C2 container.
3. CAFA Tech Safety pilot in Tallinn confirmed the automated flight plan and started to monitor the drone flight in Tallinn in Estonia. Take off and hovering at the 30 m level was automated flight.
4. In CAFA Tech UgCS C2 container was working with Frequentis plugin, which sent CAFA Tech drone real-time telemetry (Lat-Lon-Alt) to Frequentis and DroneRadar UTM systems as shown in the Figure 18 below.
5. At 14:35 the mission completed successfully.

The Figure 18 shows CAFA Tech DJI Mavic Pro drone at 3 m AGL on the Frequentis UTM SmartSIS screen.

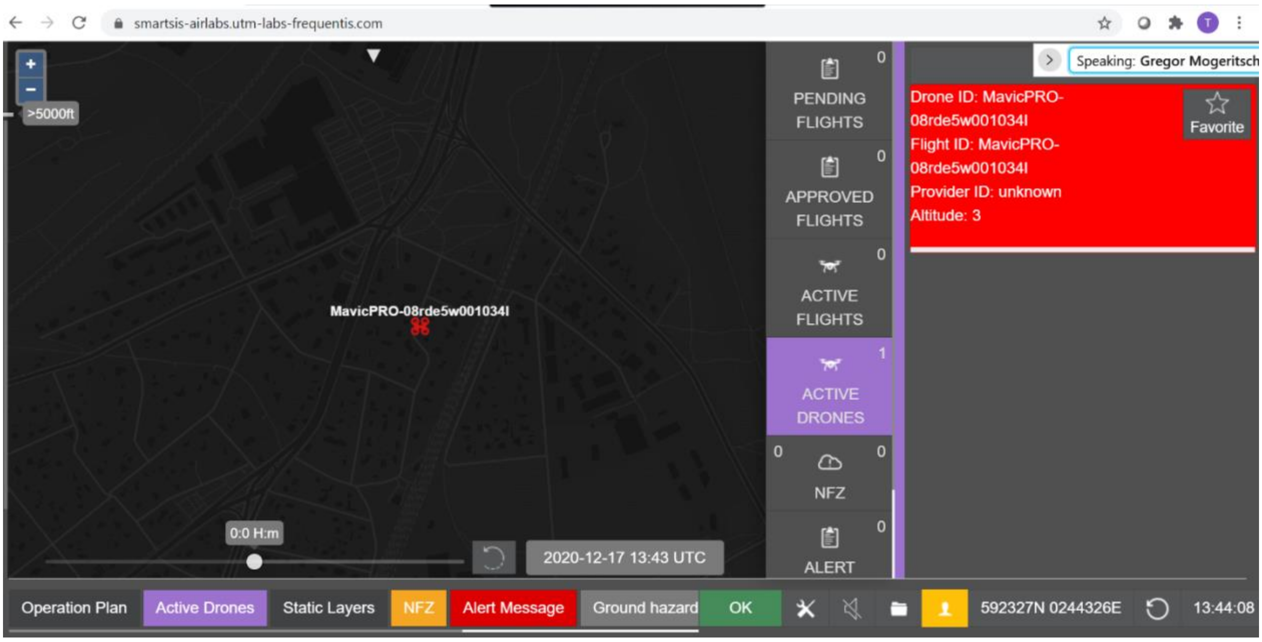


Figure 18. Screenshot from Frequentis UTM SmartSIS

2.5 Tests of interferences generated by cellular UAV on terrestrial UE in neighbour cells in Lannion in November and December 2020

Dates: 19-Nov-2020 and 11-Dec-2020

Participants: ORA team

Context and motivations: Commercial cellular networks would leverage promising use cases on long distance drone flights (natural resource discovery, power lines surveillance, parcel/medicine delivery in remote areas), but there are some issues with interference as mentioned in the CEPT Report 309 [5].

However, there are two major threats that should be more characterized for influencing regulators and mobile network operators to revisit their position. The first is about the impact of cellular UAV traffic on normal cellular traffic on ground due to interferences. The second is about coverage in altitude (e.g. between 30 m high and up to 120 m) due to antenna patterns (primary and side lobs).

The motivations of these tests were to achieve field measurements on interferences generated by cellular UAV on normal smartphones traffic in neighbour cells. Communications between base stations and UAV are line-of-sight. Therefore, cellular UAV are getting signal from base stations at longer distances than UE on ground, and therefore they are able to associate to more base stations than UE on ground. Reciprocally, a UAV carrying a cellular communication device that would transmit HD video flows in real time is expected to impact UE uplink communications in neighbour cells. Notice that interferences in the same cell are managed by the base station (whatever the case of UE); interferences between cells usually do not exist on ground or are negligible. New interferences appear with cellular UAV on the uplink.

Simulation results have been published in the CEPT Report 309 ("Use of MFCN for the command & control and payload links of UAS within the current MFCN harmonised regulatory framework") [5], especially those described in Annex 6 "in-band co-channel co-existence simulation scenarios".

The field measurements aim to confirm or infirm the results from simulations in order to provide recommendations, for instance if power transmission or the number of drones' cell should be limited.

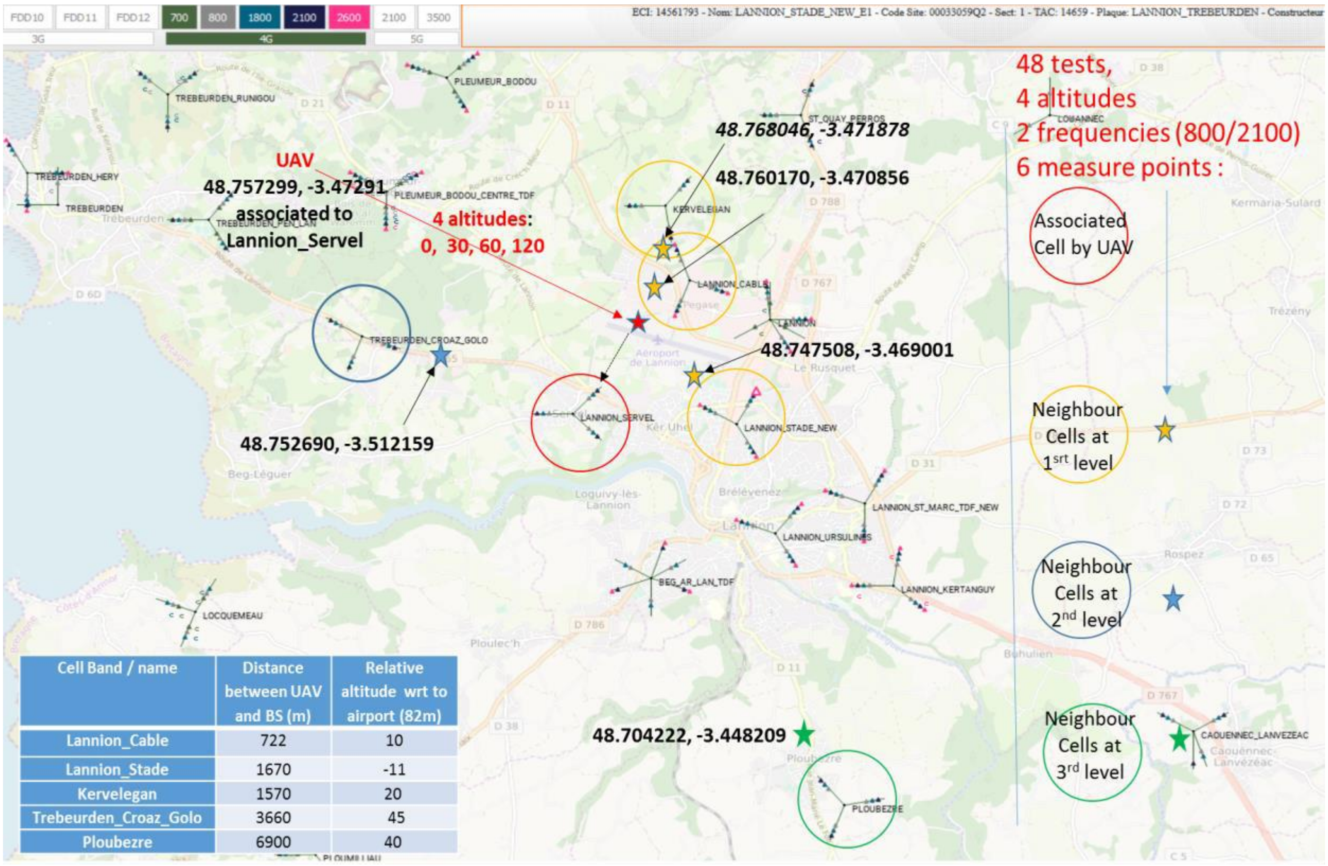
Tests on co-channel Interferences

Tests were located at Lannion airport, France (which is currently not used for commercial flights) within area given by CTDO (Centre Technologique Drone Ouest), which granted authorizations for safe flights. The area is representative of rural topologies as described in the Figure 19 below.

Tests have been achieved on the 4G commercial network provided by Orange around this location. During our tests, we adopted the same approach as the simulations in CEPT Report 309 [5], where an UAV uplink transmission on a serving cell is generating interferences in neighbour cells. These interferences can be seen by UE (smartphones) attached to these neighbour cells (only one is represented).

The UAV was located at cell edge in order to transmit with high power transmission, but the location was selected due to the stability of the association to Lannion_Servel Base Station (whatever UAV altitude and all over the time, except some rare cases that have been removed in results).

Overview of tests are shown in the Figure 19 below.



Cell Band / name	Distance between UAV and BS (m)	Relative altitude wrt to airport (82m)
Lannion_Cable	722	10
Lannion_Stade	1670	-11
Kervelegan	1570	20
Trebeurden_Croaz_Golo	3660	45
Ploubezre	6900	40

Figure 19. Tests on co-channel interferences

More precisely, the selection of various measurements points aimed to highlight the impact of:

1. Distance between UAV and impacted Base Station (BS), as well as altitude gap.

Testing team defined three levels: smaller than 2 km, higher than 5 km, and between both. The smallest distance available in our environment was 700 m (Lannion_cable).

2. Distance between impacted UE and impacted BS, taking into account that a UE having a bad budget link will suffer more than a UE with a good budget link.

Testing team selected measurement points with various budget links (RSRP value) for 66 dBm (cell centre) up to 132 dBm (cell edge).

3. Distances of cell edge values for band 20 (800 MHz) are higher than for band 1 (2100 MHz). Most of the time, we selected the same location for both bands in order to fast tests. There are locations where we did not get relevant results with band 1, because the smartphone was changing its association to another cell.

Measurements were achieved with UAV at 4 altitudes:

- Normal level similar to a person carrying the UE (named 0 m hereafter);
- 30 m;
- 60 m;
- 120 m.

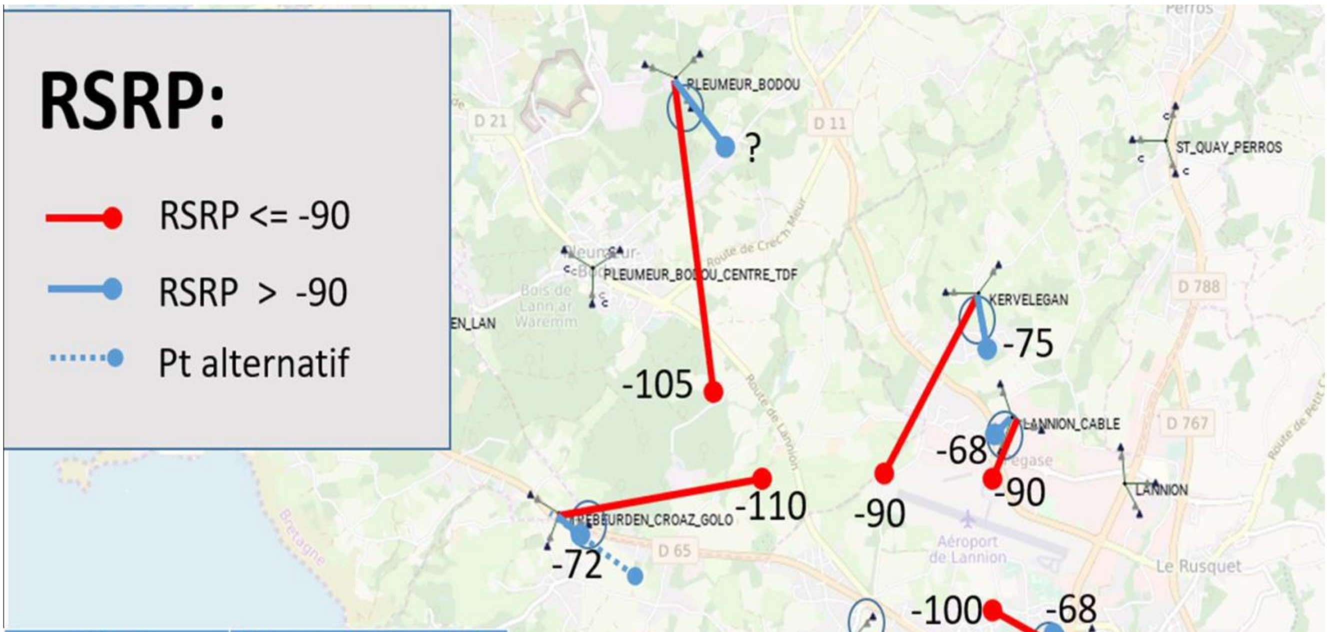
Two LTE bands have been tested:

- LTE Band 20 FDD (800 MHz): 852 MHz – 862 MHz;

- Band LTE 1 FDD (2100 MHz): 1950 MHz – 1955 MHz + 1965 MHz – 1980 MHz.

The tests have compared results of data rate observed at application level on a smartphone carried by a person located in different neighbour cells, whereas at the period of time a smartphone embedded in an UAV was transmitting full speed on uplink (iPerf) in order to generate interferences. Each elementary measure is based on a period of at least 3 minutes.

The testing team achieved some additional tests on the 11-Dec-2020 in order to add measurements points at cell edge (RSRP values given in the following Figure 20 are those in LTE Band 20):



Cell name	Measurement points coordinates
Lannion_Cable	48.761635,-3.469349 (center) 48.751107,-3.475549 (edge)
Lannion_Stade	48.7480300,-3.470866
Kervelegan	48.756212,-3.484981 (middle) 48.749515,-3.470466 (edge)
Trebeurden_Croaz_Golo	48,75783,-3,48373

Figure 20. Additional tests on 11-Dec-2020

Results

First of all, testing team measured the impact of UAV altitude on the budget link of the smartphone carried by the UAV. As we can see in the following figure the RSRP value in dBm issued from the smartphone carried by the UAV is varying when the UAV altitude changes, even if it is always Line-of-Sight. This is due to side lobs. Notice that this value is quite stable along the test period of time (every 2 s) at each altitude.

The impact of interferences at various UAV altitudes (0 m, 30 m, 60 m, 120 m) can be classified in 2 categories:

1. The budget link between the impacted smartphone and the impacted cell (i.e. the distance of the impacted smartphone in the impacted BS).
2. The distance between the UAV and the impacted cell.

Testing team sub-divided the results of first category in three (cell centre, cell middle, and cell edge). The range of these categories depends on the frequency band.

The following Figure 21 shows that the values for the same colour are very close, independent from the altitude (except at the border cell for 2100 MHz frequency in grey, where the measurements where very instable), that means that interferences impacts are very low. The values are percentages compared to measures without interferences:

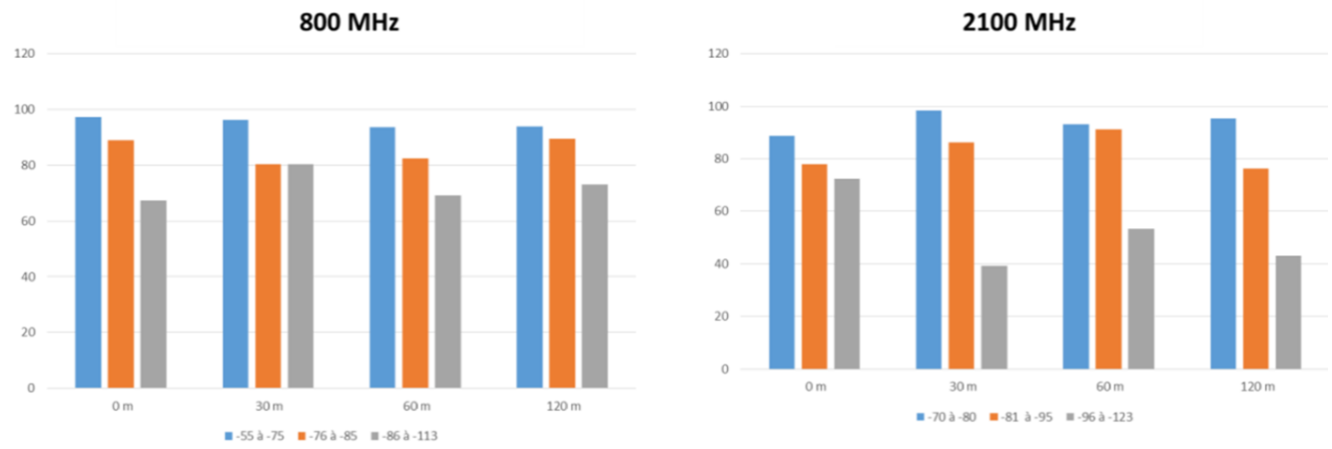


Figure 21. Measured values at various altitudes referred to respective values without interferences (percentage)

Next, here are unitary results that show the impact of the distance between the UAV and the impacted cell: Lannion_Stade at 1.6 km, Trebeurden_croas_golo at 3.6 km, and Ploubezre at 6.9 km. The following Figure 22 shows the percentage comparison with situation without interferences, for different UAV altitudes (0 m, 30 m, 60 m, 120 m):

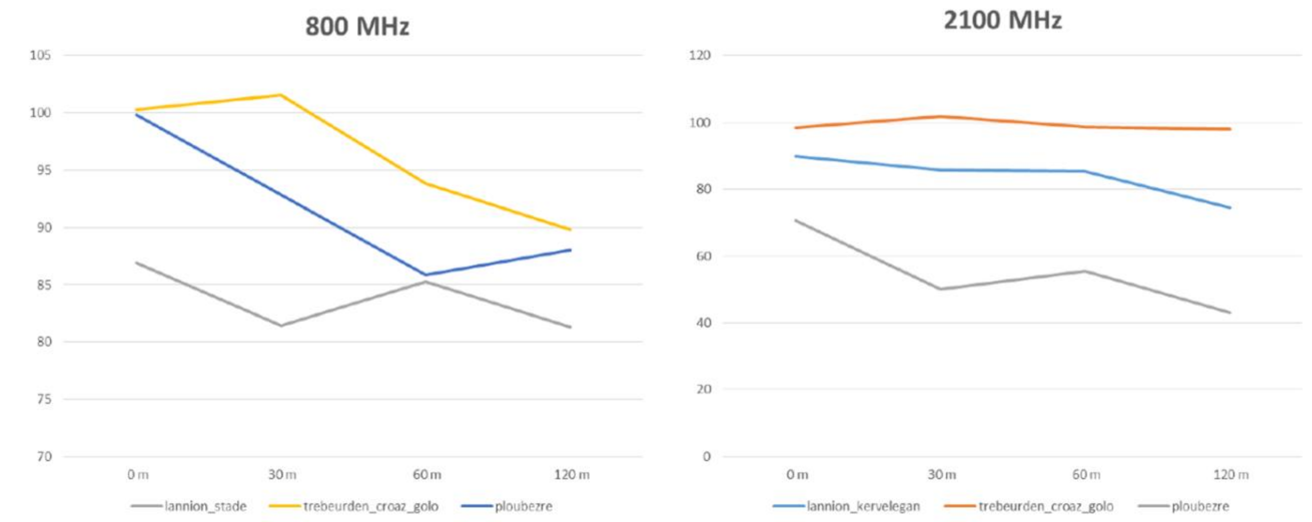


Figure 22. Impact of the distance between the UAV and the impacted cells

Conclusions

Based on the results of over 96 measurements (12 measurement points without various budget links, 2 frequencies, 5 impacted cells at various distances; and 4 UAV altitudes), we can conclude that UAV communicating on cellular bands have no major impact on the normal traffic on ground.

Results from real measurements on the field on a configuration closed to the worst case show less impacts than simulations in the same configuration described in CEPT Report 309 [5]. By joining results from simulation and real measurements we can conclude that interferences of UAV are negligible.

Measurements have been achieved on the commercial network, because this one enables large distances and large number of neighbour cells, whereas such environment is difficult to set up in an experimental network. But we have taken care that our measurements were resulting from our tests and were not impacted by other users using the network at the same time.

Commercial network load was very low during the measurements period (maybe due to the impact of the lock down within the industrial area choose for tests). We looked carefully at data from the network monitoring tools of each Base Station to ensure that it was really the case during the periods of tests. We are confident on whole results, but as the smallest granularity of probes information is fifteen minutes, we cannot guarantee that no measure was impacted. In fact, there were some unexpected results (e.g. the results better with interferences rather than those without interferences) that are buried in all the results.

Figure 23 shows detailed results giving absolute values for a subset of measurements. This shows that measurements in locations at cell edge were very low. Testing team are confident for having identified locations closed to the worst case.

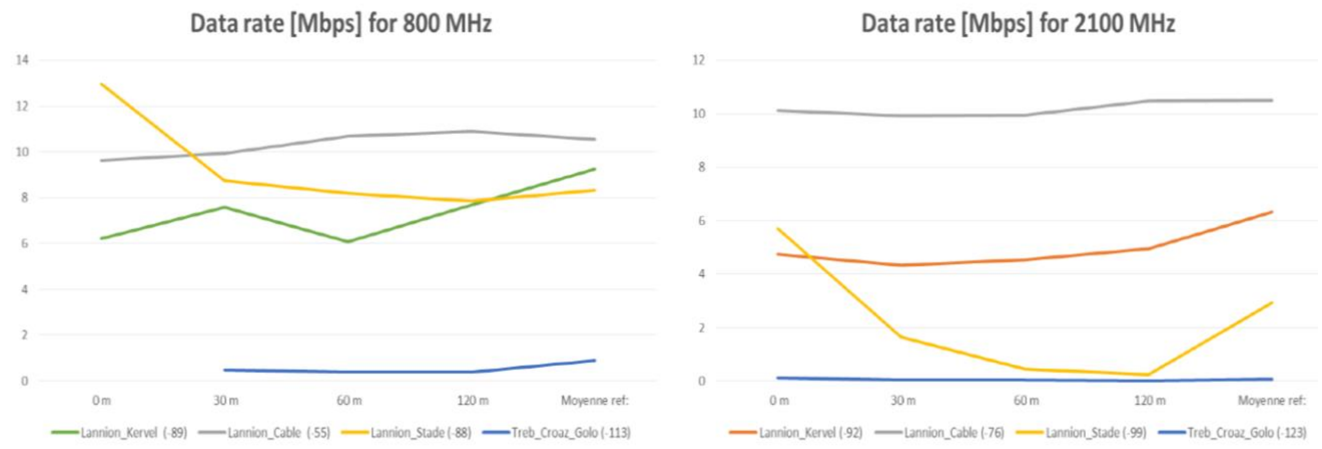


Figure 23. Absolute values for a subset of measurements

2.6 Service continuity tests in Lannion in June 2021

On 04-Jun-2021, the ORA team conducted technical tests. Measurements focused on service continuity and quality of service over a large area (600 m × 150 m perimeter). Tests are planned at the Lannion airport, France as shown in the Figure 24. The area was covered by 4 cells for UE on ground.

Results are expected to apply to other rural areas regarding the propagation model. The methodology will be assessed to apply it later to an urban area with 5G.

Figure 24. Service continuity tests plan

The measurements aim was to evaluate the impact of altitude and UAV speed on service continuity (e.g. number of packet loss, standard variation of Round Trip Time (RTT) for C2 communications, throughput for the payload) in regards with the increased number of hand-overs and the signal strength of line-of-sight communications over side lobs.

The expected results (KPI) of tests were:

- signal strength (RSRP, RSRQ, RSSI) from all reachable base stations all along the perimeter of the rectangular;
- the number of handovers between physical cells (PCI);
- the standard variation of RTT of telemetry messages;
- the evolution of throughput on the move (mainly UL traffic on TCP).

The measurements will apply to:

- a flight path over a perimeter of a rectangle of 600 m × 150 m, an open field environment with very few obstacles;
- various altitudes: 1.5 m (as a reference for a UE on ground), 30 m, 60 m, 90 m, 120 m;
- speeds: 3 m/s and 9 m/s.

Measures were collected at UE side and network side (a probe in the Gi interface of Core Network).

The tests will encompass network statistics from OSS (Operation Support Systems) in order to ensure the measures are valid, e.g. load of all the cells during tests.

The results of these tests are critical for MNOs and drone operators in order to evaluate the feasibility of using cellular networks for both C2 and communication payloads in regard with respectively drone safety and quality of service.

These measurements complement previous research for the following reasons:

- A bigger area;
- More results (various altitudes, 2 speeds);
- Reproducibility (several measurements in the same conditions);
- Monitoring at network side;
- Checking the network conditions during measurements.

2.7 Athens simulation trials in 2021

2.7.1 Simulation tests in NCSRD premises in January 2021

A preliminary simulation test for UC4:SC1 was be performed on 22-Jan-2021 by UMS from their office in Brussels, Belgium with support from NCSRD team in Athens, Greece. The companion PCs (CPCs) for the test were shipped to NCSRD facility in Athens by UMS. 5G phones necessary to perform the test were provided by NCSRD.

Participants: UMS, NCSRD

Objective

Based on the initial steps that UMS drafted as part of a successful simulation trial, a preliminary test was scheduled after the CPCs were received by NCSRD. Pre-trial Development and Remote Demo has already been completed.

The objective of this test was to validate the functionality of all system components along with network connectivity and communication by deploying UMS modules on the MEC server hosted by NCSRD. The architecture of the preliminary test that was conducted is provided in the Figure 25 below.

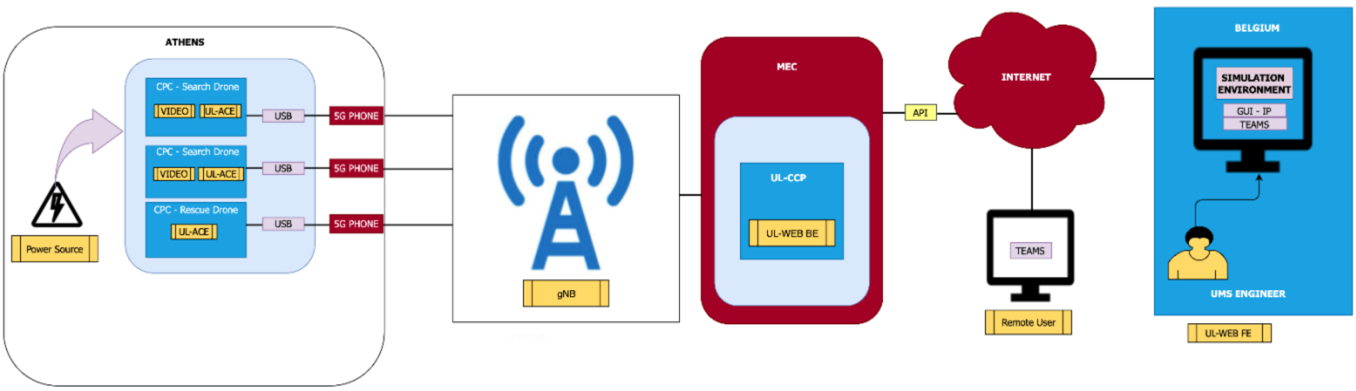


Figure 25. Architecture of the preliminary simulation test in January 2021

Test modules

As the goal was to create an environment as close to a real-world scenario as possible, a hybrid simulation platform was built for this project, i.e. it consisted of both hardware and software elements. The hardware component constituted CPCs that were installed with UL-ACE. For this project we have used Raspberry Pi 4 (RPi4) as the CPCs. The RPi4 is a tiny single-board computer, which means that all its components, from the memory to the USB ports, fit on one PCB without add-on cards or accessories. In addition to the 4 GB RAM, it has a Broadcom quad-core processor running at 1.5 GHz, four USB Type-A ports, two micro-HDMI video outputs, a gigabit Ethernet jack, radios for 802.11ac Wi-Fi, and Bluetooth 5.0. RPi4's 40-pin General Purpose Input/Output (GPIO) connectors can provide power for external sensors, as well as send data to and receive data from them.

Drones and flights, which were simulated, formed the software component of the setup. The simulation environment itself was developed in a framework known as Gazebo. Gazebo offered the ability to simulate robots accurately and efficiently in complex indoor and outdoor environments. We used Gazebo with Robot Operating System (ROS), a toolkit/offboard API for automating vehicle control. The setup also contained a Pixhawk flight controller with PX4 autopilot system.

UMS deployed its software modules UL-ACE and UL-CCP on the Edge infrastructure. These modules were dockerized containers with required features built into the system. UL-ACE contains *umd_copter*, which is a common interface designed to promote interoperability and reusability of core functionality between diverse aerial vehicles. UL-CCP contains *umd_mission*, which is a centralized hub for the implementation of the tasks performed by the "master" during multi-robot applications.

On the host PC in Belgium the following dockers are running:

- Gazebo simulation;

- *umd_mission*.

On the RPi4s in Greece, the following docker is running:

- *umd_copter*.

5G infrastructure

The 5G experimentation facility that was used for the needs of the simulation test is equipped with the Amarisoft Core Network. The tests were conducted in NSA mode, however the option for SA mode is also available and will be tested during the next phase of the simulation.

For 5G NSA mode, Amarisoft core implements the MME component with built-in SGW, PGW and HSS and supports several eNBs with standard S1 interface (S1AP and GTP-U protocols). Handling of UE procedures like attach, authentication, security configuration, detach, tracking area update, service access, radio bearer establishment, paging is also supported.

For 5G SA mode, Amarisoft Core supports 5G NR Release 15. Connectivity with gNBs is implemented through the standard NG interface using NGAP and GTP-U protocols. The 5GC includes built-in AMF, AUSF, SMF, UPF modules handling UE procedures and providing direct access to the IP network.

Amarisoft Radio Solution is an LTE/NR base station (eNodeB/gNodeB) implemented entirely in software and running on an x86 Linux-based host. The host generates a baseband signal, which is sent to a radio front end doing the digital to analogue conversion. The reverse is done for the reception. Amarisoft RAN interfaces with the LTE Core Network through the standard S1 interface and with a 5GS Core Network through the standard NG interface.

Test setup

The test setup consisted of 3 RPi4s connected to the 5G network via USB tethering as show in the Figure 26 given below.

Figure 26. Connection to the network

For the test, NCSRD used three 5G-enabled phones and connected them to the three corresponding RPi4s during the test as shown in the Figure 27 below.

Figure 27. Raspberry Pi 4 computers connected to the 5G network via USB tethering

Test procedure

In the first instance, the team connect to the network through a Virtual Private Network (VPN). Once a connection was established, the team use a Secure Shell (SSH) to access the RPi4s in Greece via the network remotely. SSH provided a secure channel over an unsecured network by using a client-server architecture, connecting an SSH client application with an SSH server.

A screenshot of how we SSH into the RPi4 is provided below in the Figure 28. The three RPi4s are identified as “robot 100”, “robot101”, and “robot102” respectively. The team were able to successfully connect and communicate with robot 101 and robot 102. A basic test that is conducted to verify a successful connection is by the “ping” command. The team sent packets to a specific known IP address on the network such as “Google” and record the response. The response that the team receive shows how long each packet took to make the round trip or tells us if it was not able to establish a connection to the network.

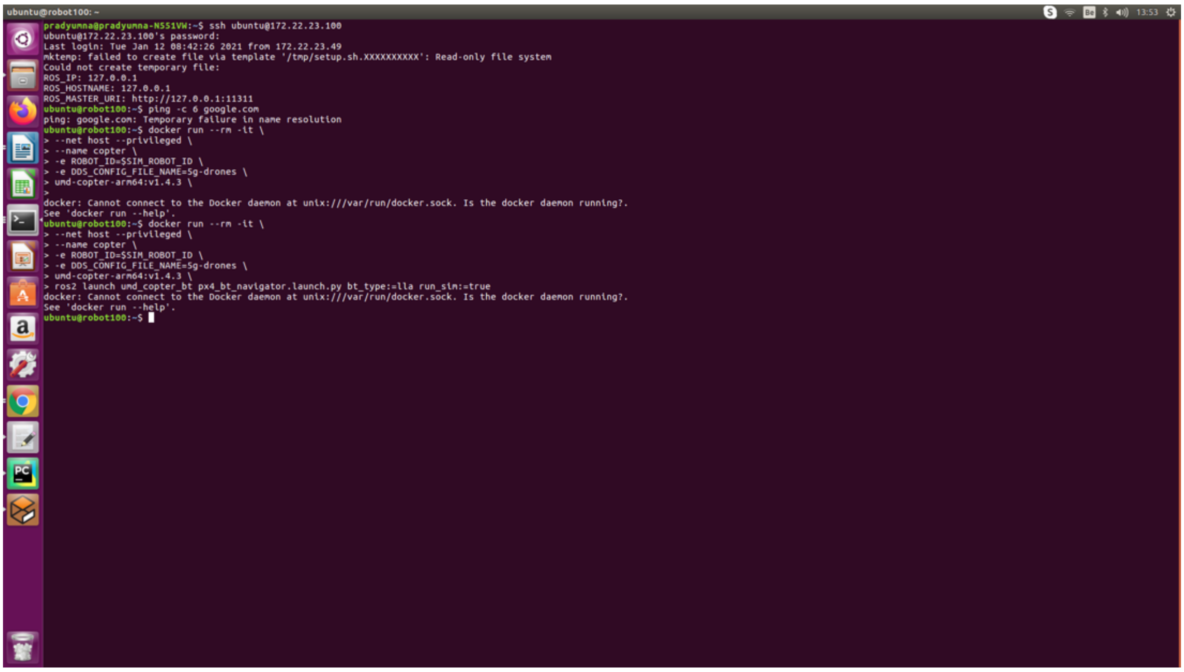


Figure 28. Screenshot of SSH establishment

In the next step, we launch the Gazebo simulation on the host PC as shown in the Figure 29 below.

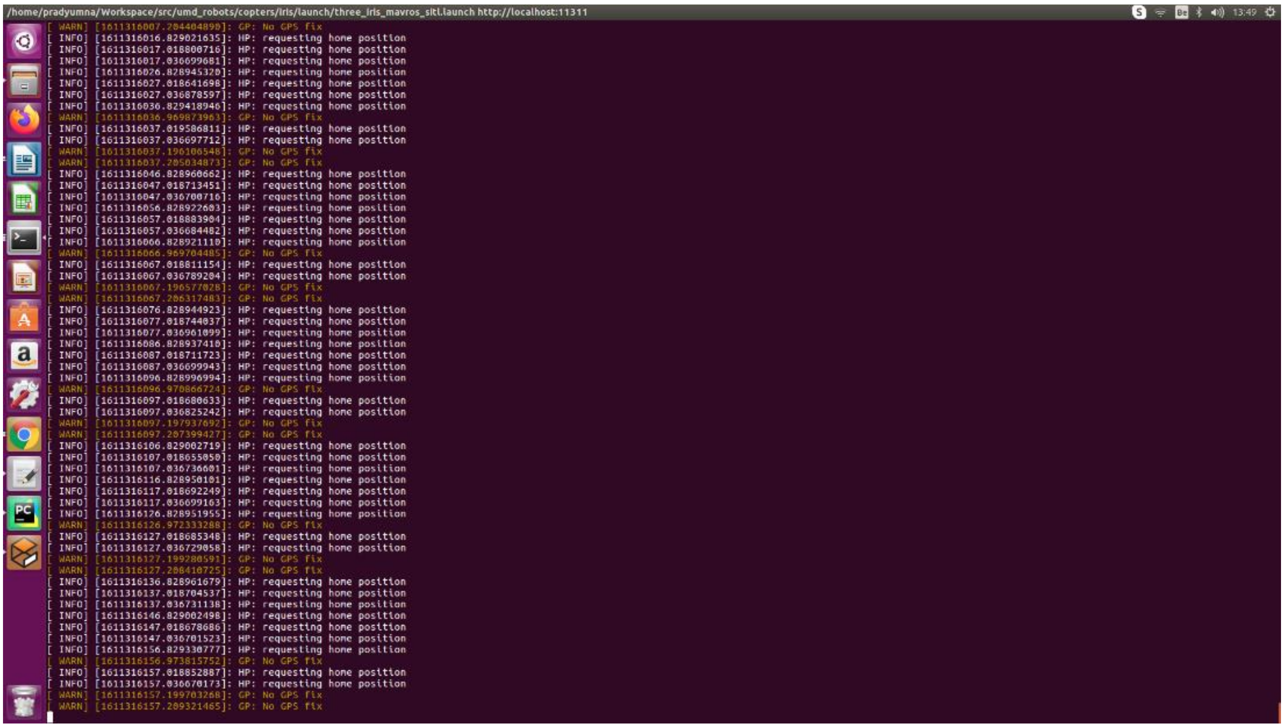


Figure 29. Screenshot of Gazebo simulation launch

The three simulated drones that are shown in the Figure 30 below on the simulation platform screenshot correspond to the three RPi4s. Ideally, these RPi4s will be placed and integrated into the physical drones in real-life demonstrations.

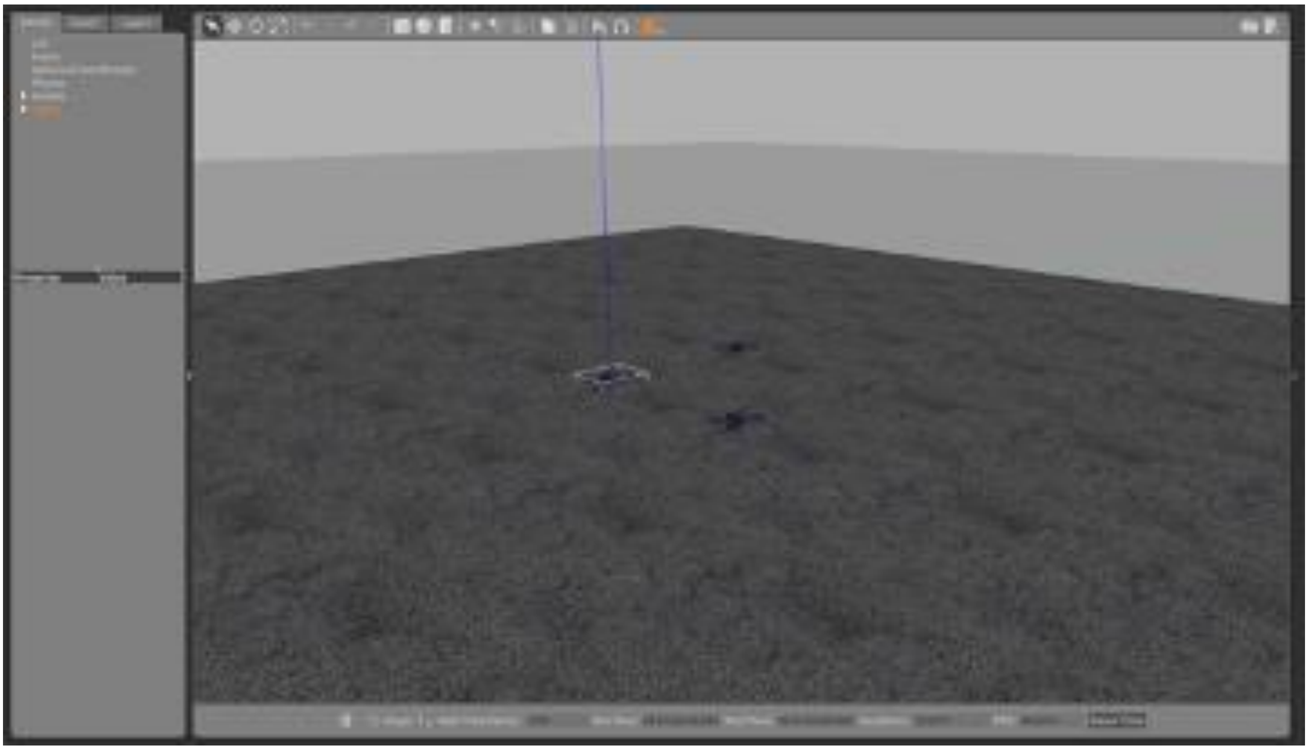


Figure 30. Screenshot of drones in a simulated environment

After the simulation was up and running, testing team launched the *umd_mission* docker on the host PC, which started the mission and began communicating with the simulated drones. A screenshot of the command window when the mission is launched is provided in the Figure 31 below.

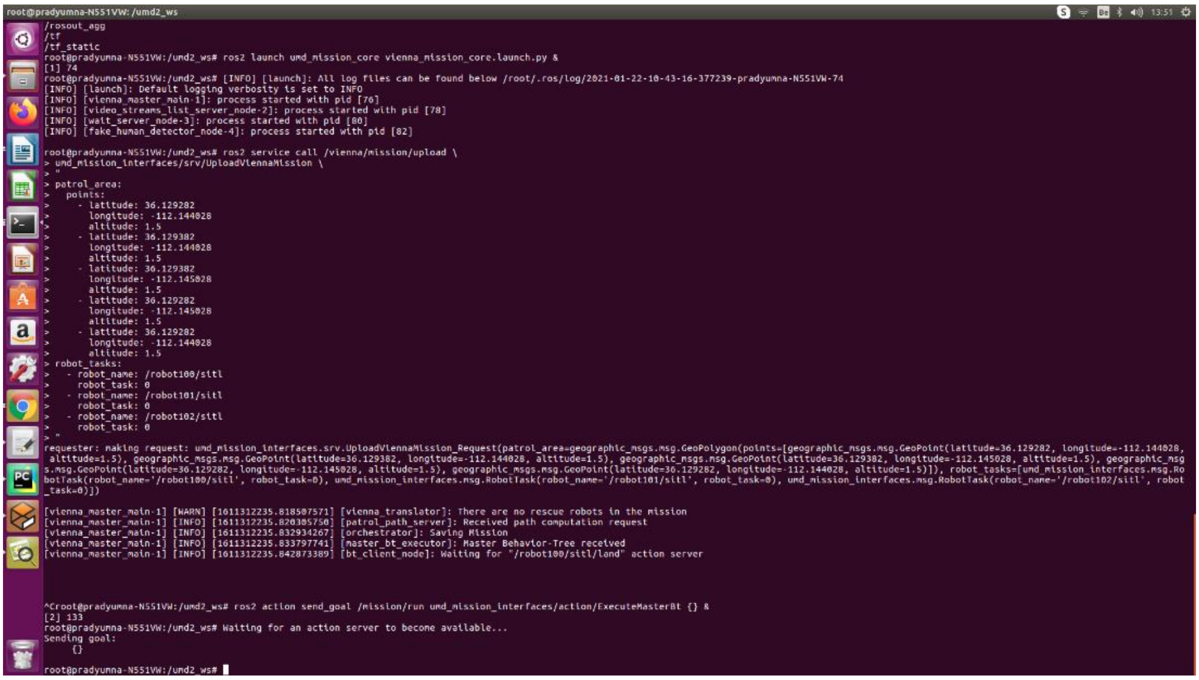


Figure 31. Screenshot of mission launch

Once the testing team launched the mission on the host PC, the next step was to launch *umd_copter* on the robot 101 and robot 102. This initiated communication between the mission running on the simulation platform and the UL-ACE modules deployed on the MEC infrastructure. A screenshots of both the robots (robot 101 and robot 102) depicting the data exchange between these two modules are provided in the Figure 32 and Figure 33 below.

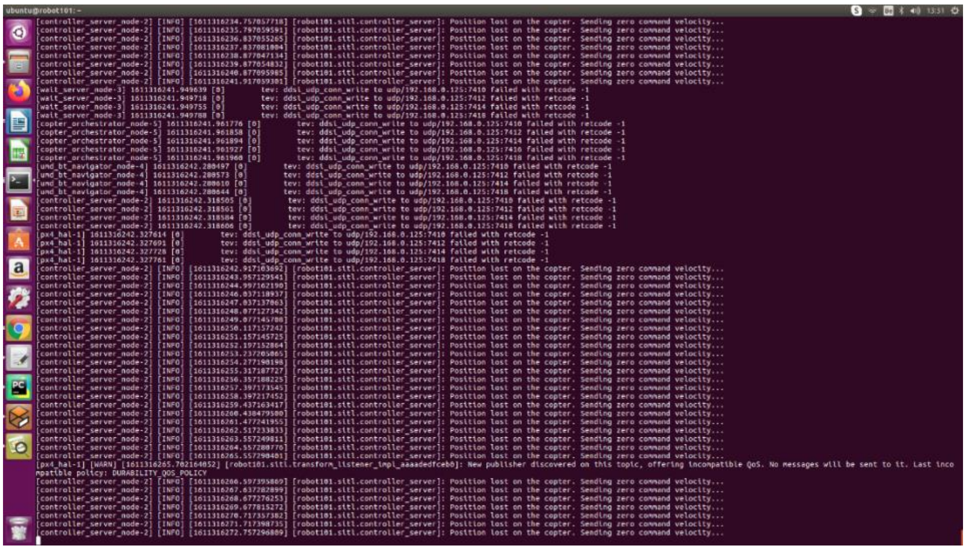


Figure 32. Screenshot of communication between software modules of UL-ACE and UL-CCP for "robot 101"

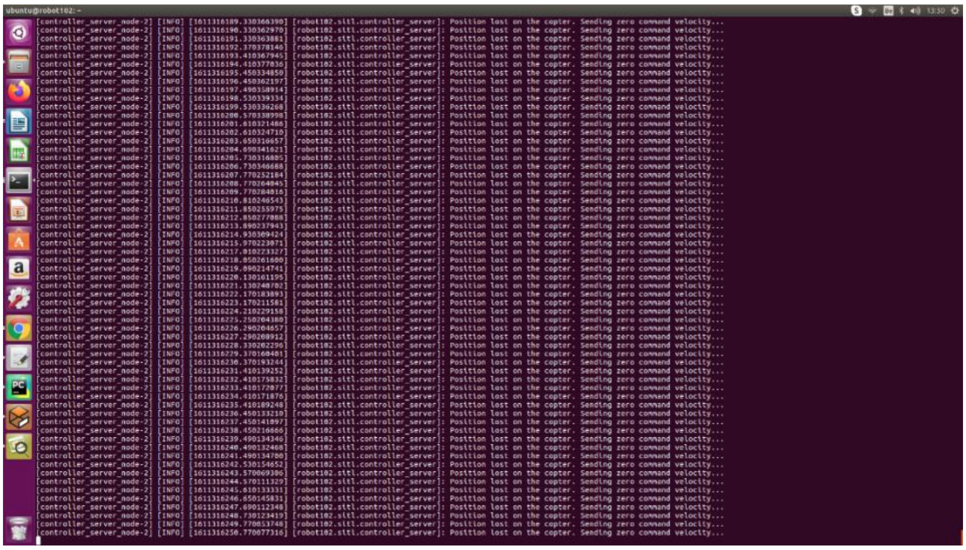


Figure 33. Screenshot of communication between software modules of UL-ACE and UL-CCP for "robot 102"

Test issues

The testing team was unable to connect with "robot 100" and deploy the UMS modules. However, NCSRD team was able to ping the device (RPi4) manually when connected to a display at their facility. The reason behind this could be related to the CPC flashing or communication. The problem was investigated further and appropriate measures to resolve it were taken before future tests.

2.7.2 Simulation tests in COS premises in April 2021

After validating connectivity and functionalities, UMS performed end-to-end simulation tests for UC4:SC1 on 23-Apr-2021 remotely (over the Internet) at the COS premises with support from NCSRD. The test also measured some basic KPIs and included UTM integration.

Participants: UMS, NCSRD, COS

Objective

The goal of this test was to shift towards a real-life demonstration setup. In this case, all the modules were hosted at the COS premises while the UMS team only providing support to run the tests remotely. Along with the modules used during the preliminary tests, UMS' video analytics enabler (UL-VA) was also part of the trial. An architecture of this test is provided below in the Figure 34.

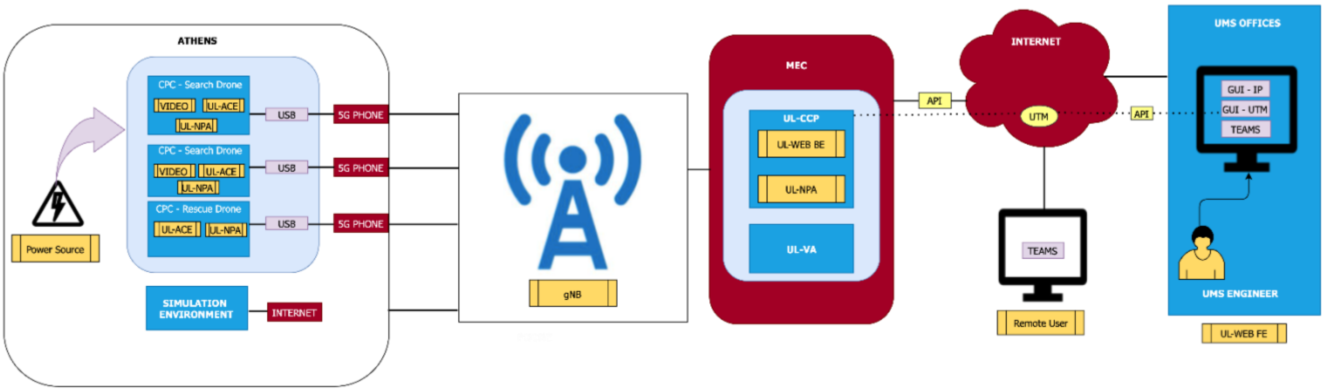


Figure 34. Architecture of the end-to-end simulation tests in April 2021

Test modules

During the test, UMS modules were hosted on the MEC infrastructure of COS. The UL-VA module collects and processes the sensor data streamed from the drone for computer vision tasks. The focus of this module is on the sensor type and analysis methods that can be applied for different system inspections, i.e. in the case of visual inspections, AI algorithms will be used to analyse the camera data to perform object detection. We are developing algorithms as part of this module for:

- Video analytics for inspection of search area;
- Detection of people in need of assistance;
- Video streaming for central processing.

We made use of existing video analytics tools for this project, which were adapted to obtain the required output for our behaviour tree. We also containerized the module to enable a seamless installation on different GPU and Edge infrastructures.

UML has designed and developed a custom web interface (UL-WEB) with the focus on Emergency Response. This interface was used on UMS premises as part of the trial. It allows the operator to:

- Control and configure a mission;
- Deploy and monitor a mission;
- Follow the video feed of the search drones.

5G MEC infrastructure

An integral part of the implementation of the 5GENESIS mobile network has been the interconnection of the previously independent mobile networks operated by NCSRD and COSMOTE. For the purpose of this, at the main data centre of COSMOTE an LBO (Local break Out) SGW node is installed that is based on a lightweight 4G EPC provided by ATHONET. The LBO-SGW has been connected to the NCSRD Athonet's vEPC over the GRNET connection, for serving 5GENESIS subscribers, with the capability either to break-out the traffic in the local COSMOTE edge cloud, or to route SGi traffic to the PGW at the NCSRD site, depending on the traffic characteristics. Typically, the rules of breaking out the traffic are very fine grained, spanning from the APN used, the target application server, as well as the UE IP pools. The LBO-SGW has been set up to support MOCN (Multi-Operator Core Network) so that to simultaneously support traffic from the COSMOTE (experimental) PLMN.Test Setup. In this case, the MEC LBO has been set to break out 5G-DRONES traffic (configured to use the APN atest2).

Test setup

For the purpose of the simulation trial, NCSRD 5GENESIS test SIMs have been attached and served by the Nokia 5G Airscale base station in COSMOTE and the user plane traffic generated was broken out from the NCSRD network to be served locally at the COS edge data centre. In COSMOTE site the edge cloud is implemented using OpenStack Ussuri installation over x86 workstation equipment and for the purpose of the trials, two virtual machines have been dedicated to host the video analytics application as well as the performance measurement server.

The test setup consisted of 3 RPi4s connected to 4G and 5G networks via USB tethering as shown in the Figure 35 given below.

Three 5G UEs were used:

- Xiaomi Mi 10 connected to RPi4 100;
- Xiaomi Mi Mix 3 connected to RPi4 101;
- Samsung Galaxy Note 20 to RPi4 102.

All UEs were connected to 5GENESIS PLMN (10101) using the atest2 APN that breaks-out traffic locally at the COSMOTE site and in the 5GENESIS cloud (VM: 172.16.13.101).

Figure 35. RPi4s connected to 5G UEs

A laptop to run the simulation software as shown in the Figure 36 below was provided by NCSRD.

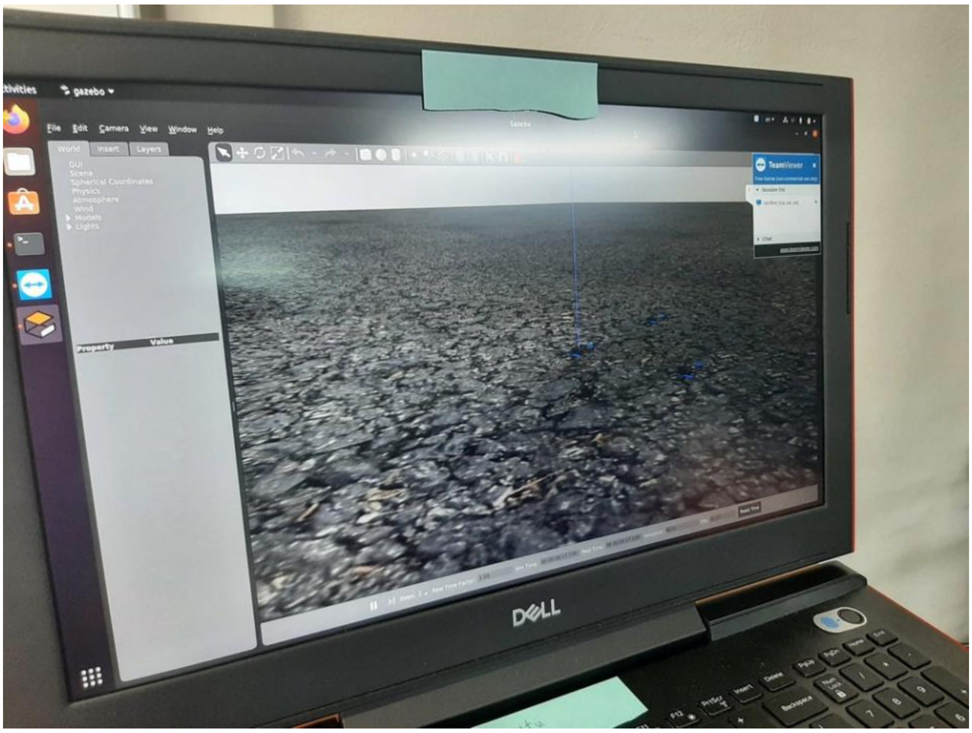


Figure 36. Simulation laptop

Test procedure

a. Mission preparation

Once the drones are in place on the simulation platform, the operator starts the simulation, which will automatically boot and connect to the network. After the drones are connected, they will appear as "Available" in the UL-WEB interface as shown in the Figure 37 below. The operator can now select the number of drones he wants to use for the mission by clicking on the drones upon which a selection menu will appear under the drone allowing the operator to select the function of the drone, i.e. search or rescue.

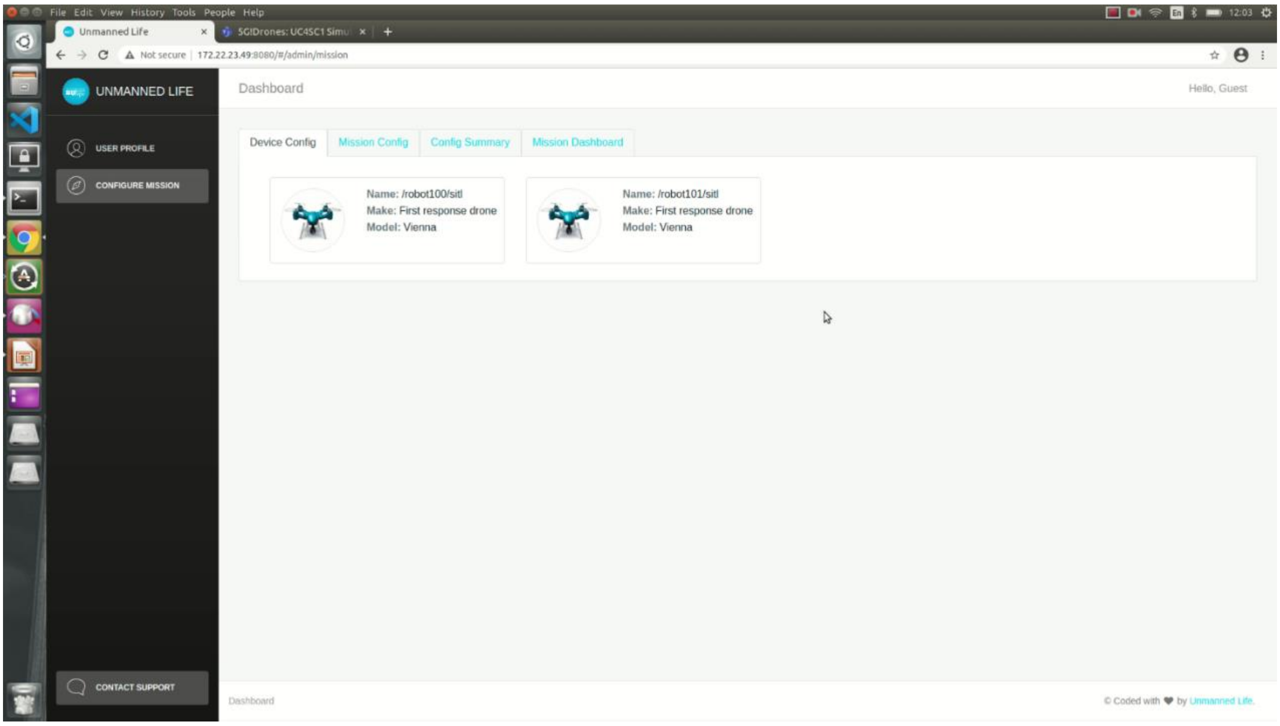


Figure 37. Connected and online devices

b. Drone selection

The operator can now select the number of drones he wants to use for the mission by clicking on the drones upon which a selection menu will appear under the drone as shown in the Figure 38 below allowing the operator to select the function of the drone, i.e. search or rescue.

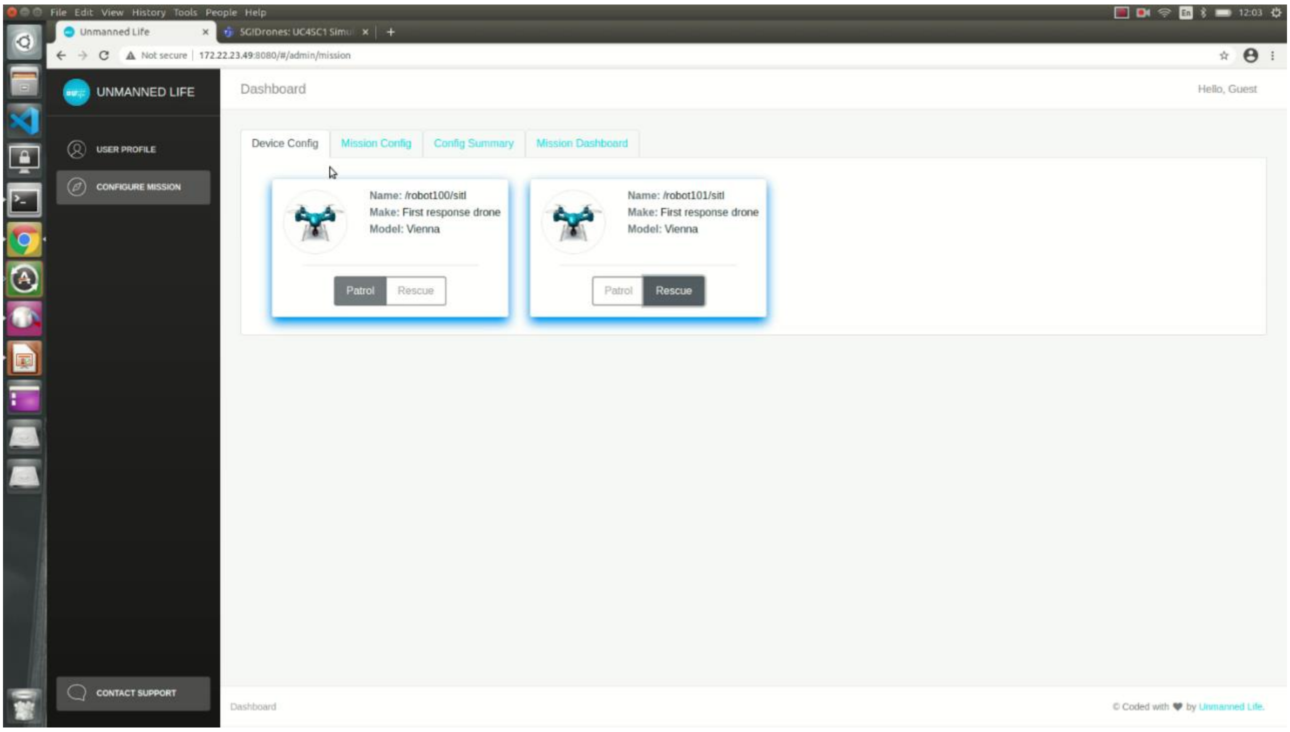


Figure 38. Drone selection page

c. Configure search area and mission settings

Once the devices are selected and configured, the operator will go to the “Mission Configuration” page where the desired search area can be set by indicating the area boundary points as required depending on the situation and location, as shown in the Figure 39 below.

The operator also has an option to store the settings for future deployments, which will be uploaded in the future instead of reconfiguring the settings manually.

There is no need to select the individual way points as done in other ground control stations as the UL-CCP will compute the optimal flight paths automatically saving a lot of time for the operator and avoiding human errors during the configuration when the operator is under pressure to save the lives that are at stake.

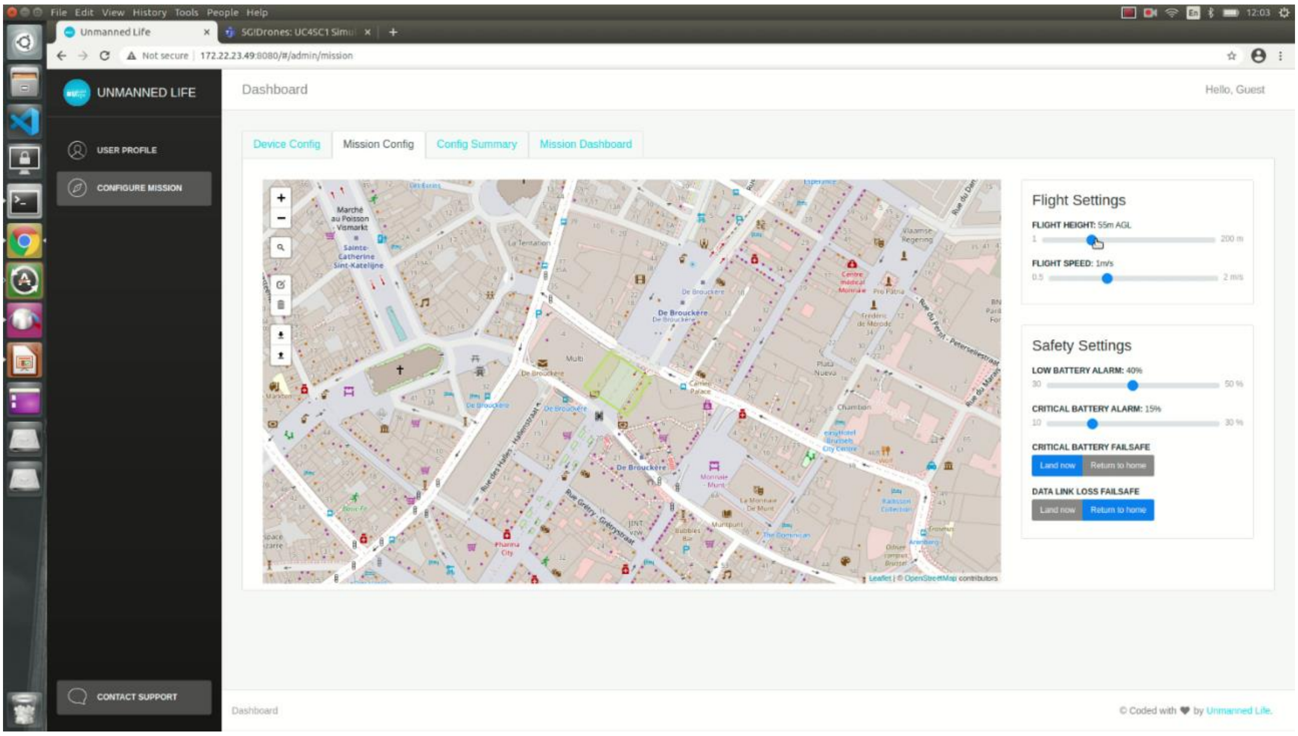


Figure 39. Mission configuration page

d. Mission summary and uploading

After configuring the mission, the operator will get a summary of the mission setting to review before uploading the mission to the UL-CCP. The mission uploaded to the UL-CCP still does not contain any flight paths, but only the area where the mission needs to take place.

After uploading the mission successfully to the UL-CCP, the operator will receive the feedback that the mission was uploaded with success. He will also see the area boundaries computed by the UL-CCP depending on the number of search drones and the flight paths for each drone within these boundaries. Following this, the “Mission” dashboard will also be available for the operator to launch and monitor the mission as shown in the Figure 40 below.

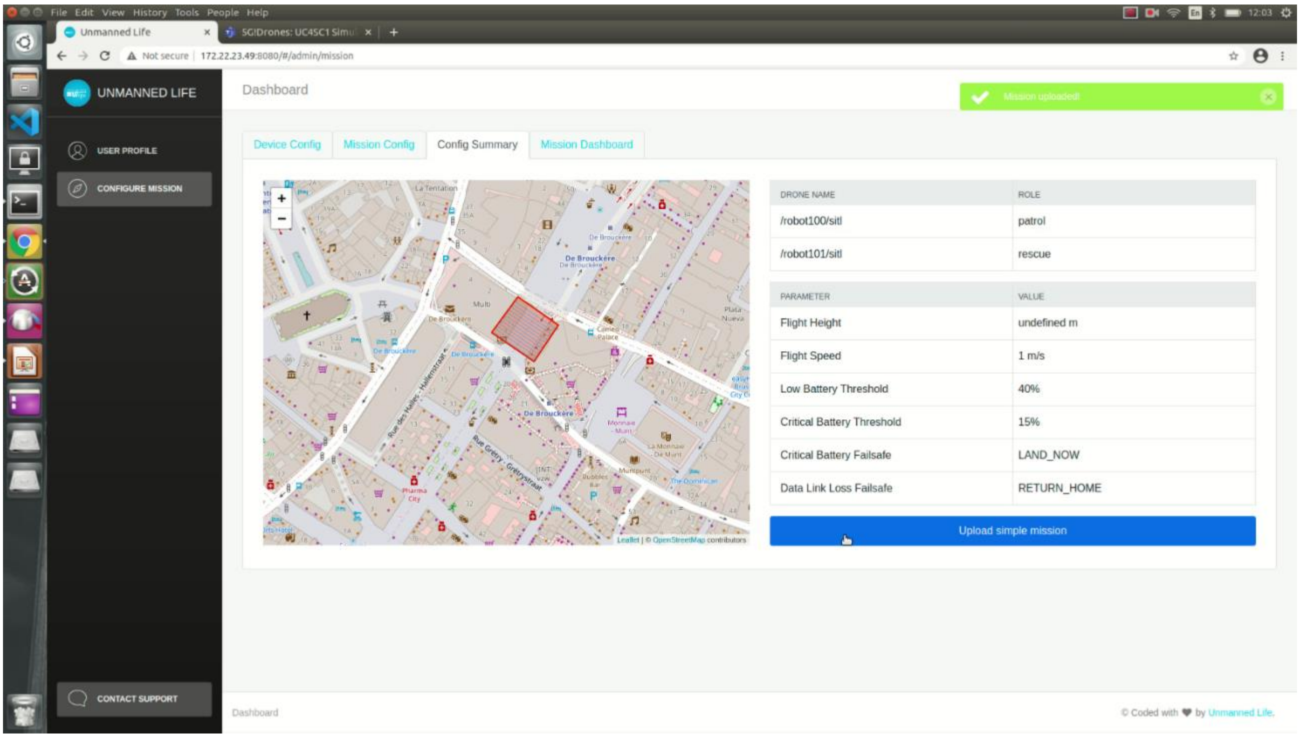


Figure 40. Mission uploaded successfully

e. Mission launch

When ready, the operator can push the “Launch” button on the interface as shown in the Figure 41 below. This will lead to a pop-up to confirm the action. Confirmation from the operator will initiate the autonomous take off and navigation of all active and selected search drones.

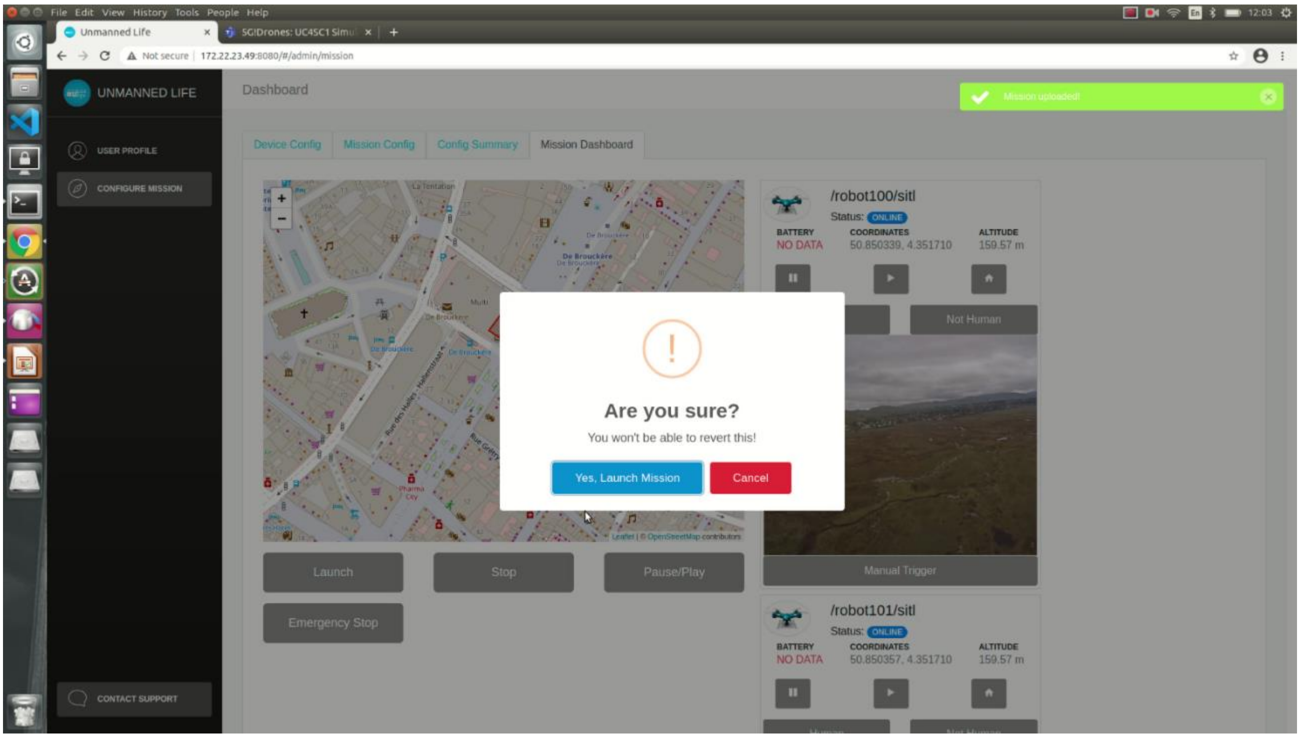


Figure 41. Mission launch

f. Autonomous searching

The search drones will now autonomously survey the area following the paths defined by the UL-CCP as shown in the Figure 42 below. During the navigation of the drones the operator can monitor vital parameters such as location, flight height, connection status and battery status as shown in the Figure 43 below.

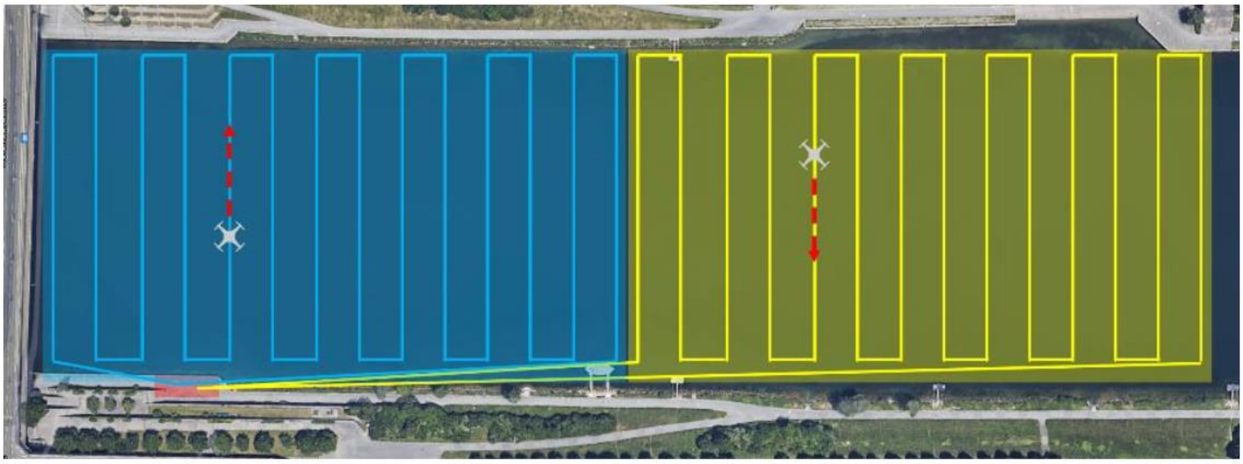


Figure 42. Principle of autonomous searching following calculated flight paths

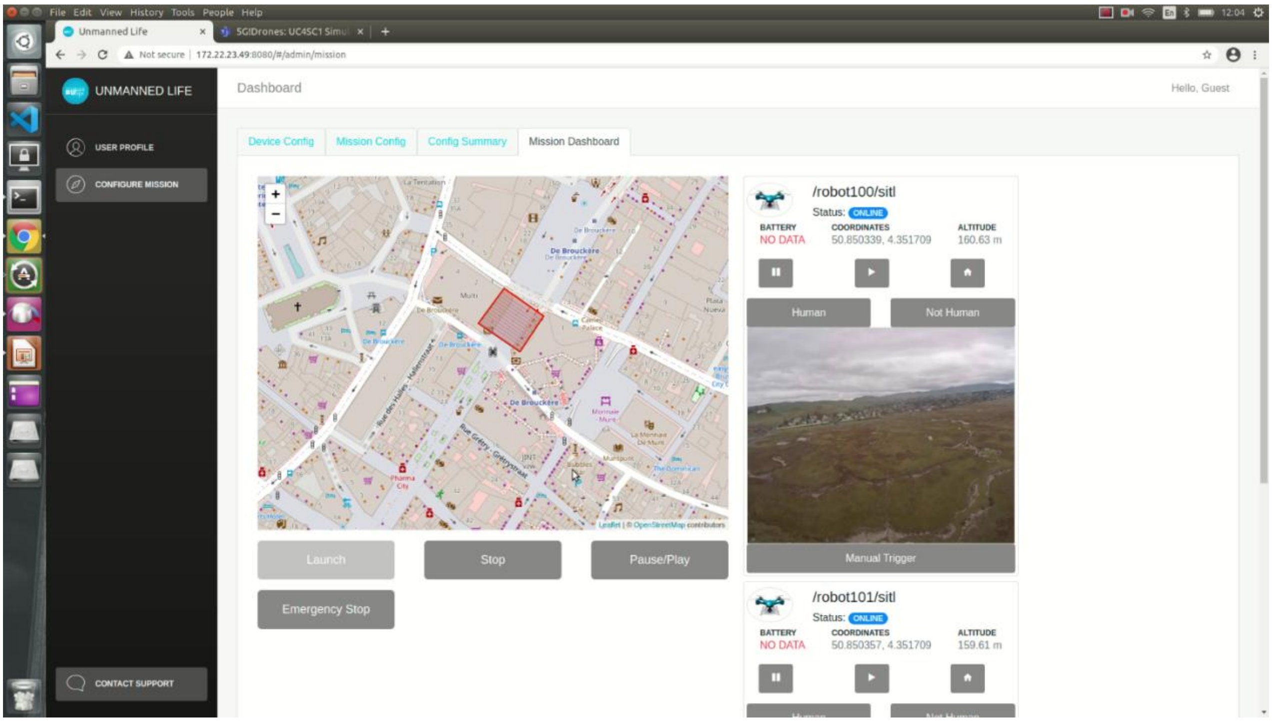


Figure 43. Mission monitoring

g. Person detection

During the flight, the operator can follow the pre-fed camera stream of each drone on the interface as shown in the Figure 44 below.

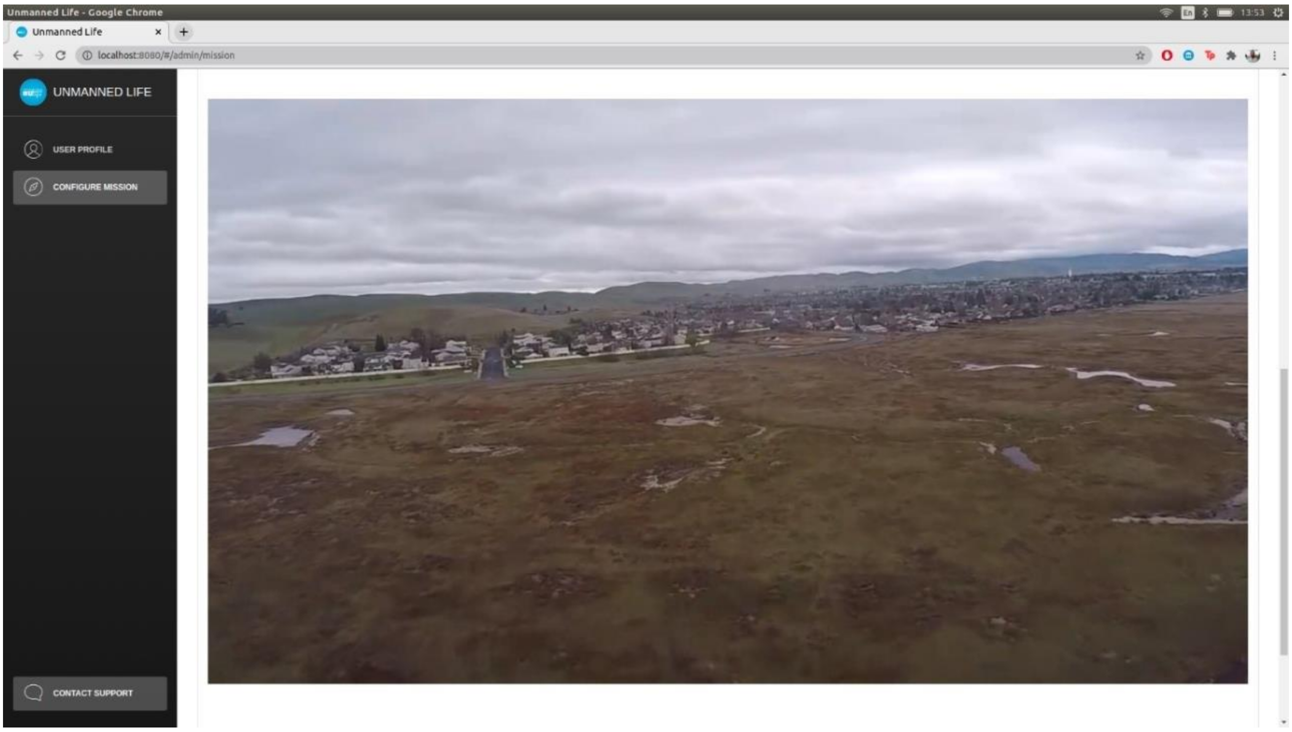


Figure 44. Prefed camera stream

However, AI object detection in the UL-VA module will support the operator in detecting people. Detection of a person by the UL-VA will pause the search drone above the target and will allow the operator to validate if the detection is a human via the stream on the screen as shown in the Figure 45 below.

Figure 45. Detection of a person in UL-VA

If the detection is correct, then the operator can confirm this via the interface by clicking on the 'Human' button. In all other cases he can inform the system to discard the detection and continue searching by clicking on the "Not a Human" button.

h. Launching a rescue drone

Upon confirmation of the operator that a human is found the search drone will upload the location of the detection to the UL-CCP. Here it will be merged with the location in the frame that the human was detected in to determine as accurate as possible the location for the rescue drone. After the location is computed, UL-CCP sets the flight plan for the rescue drone and the rescue drone will take off autonomously and navigate to the location where it needs to provide on-demand connectivity.

i. Providing on-demand connectivity

Once the rescue drone arrives at the location it will loiter and inform the UL-CCP it is ready to provide on-demand connectivity to the person in distress. The behaviour tree within the UL-CCP will instruct the drone to start the process and maintain connectivity as long as the drone is at the location.

j. Ending the mission

Once the connectivity is successfully provided the operator can instruct the drones to end the mission triggering all drones to return autonomously to the take-off location where they will land and disarm.

UTM integration

For the development of this functionality within the UML-ST, an API offered by Frequentis (FRQ) has been used, which allows users to share telemetry data with other consumers of the platform.

The telemetry data is represented with the Pose model, which includes the following fields: a) acquisition date-time, b) acquisition date-time accuracy, c) altitudes, d) flight ID, e) orientation, f) position, g) velocity.

First, *umd_utm*, the package in which the functionality has been developed, calls a ROS service to get the robots registered for the current mission. Once it knows, which robots are part of the mission, it subscribes to the corresponding ROS topics for each robot to get its real-time location. After configuring the packet to be sent to the FRQ API, it asks the API for an authentication token to be able to publish the data to the interface. Once *umd_utm* has the token, it can start sending telemetry data for each robot.

Every time a robot publishes a new position update, it is collected by *umd_utm* and sent to FRQ interface through the API.

UMS simulated drones being visualised in real time on the FRQ platform is shown in the Figure 46 below.

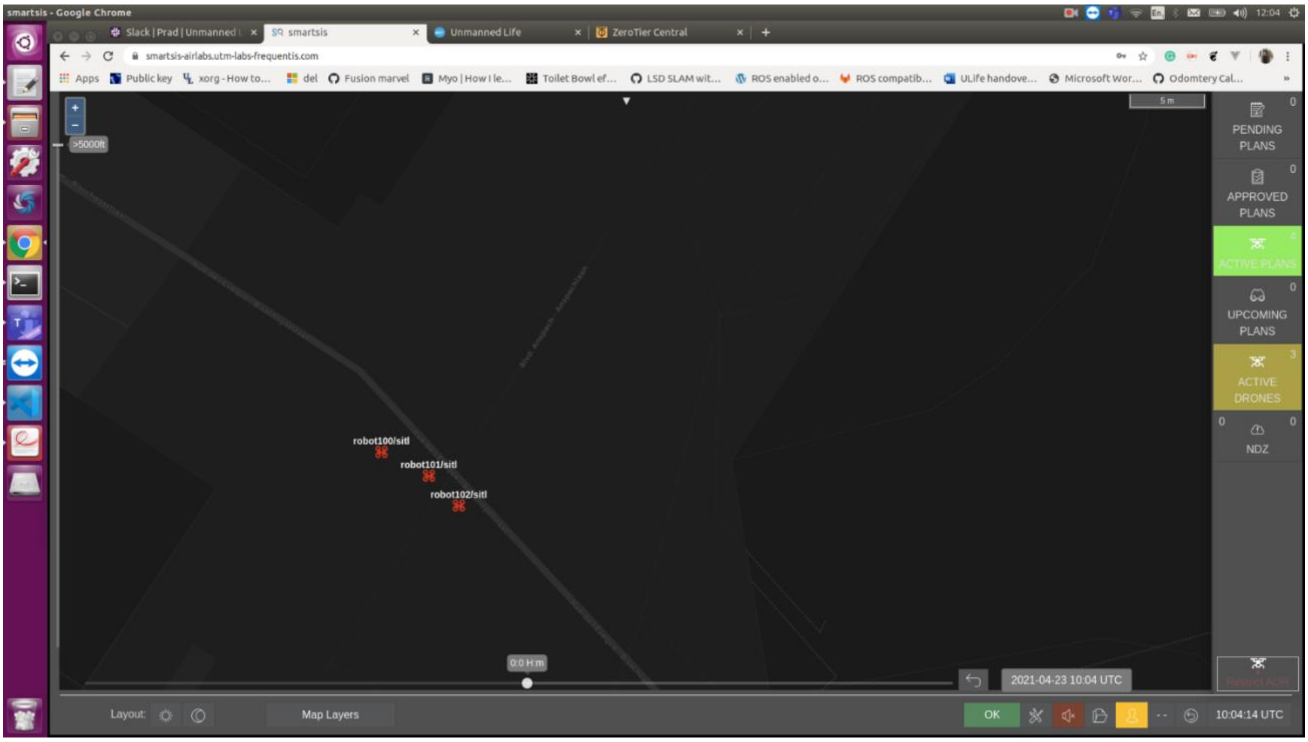


Figure 46. Visualization of UMS drones on FRQ UTM platform during mission operation

Test summary

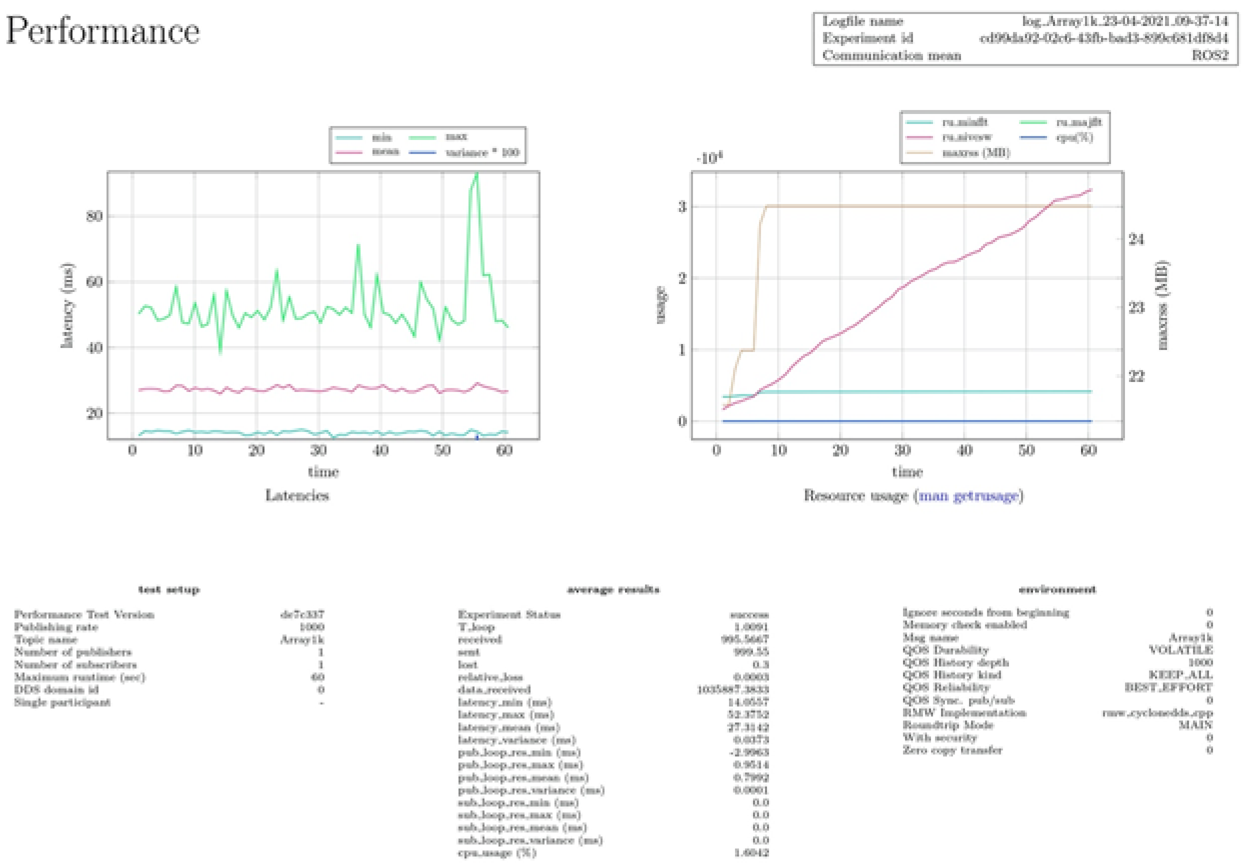
Multiple successful tests were conducted as part of these trials. We also integrated with UTM platform of Frequentis and could see our drones moving on their interface. Additionally, we were able to record latency measurements between RPi4s and our modules hosted on MEC, both with 4G and 5G networks.

UMS used its Network Performance Analyser (UL-NPA) tool to measure the latency between RPi4s and their modules deployed on the MEC infrastructure (UL-CCP, UL-VA). UL-NPA enables evaluation of performance and latency of various communication means like ROS 2, FastDDS, Connext DDS Micro, Eclipse Cyclone DDS and OpenDDS. Each metric value is recorded for every second of the experiment duration. It is used to simulate non-functional performance of our application. Some preliminary measurements of round-trip time over the network were measured before we move to more advanced trials involving additional KPI measurements.

The tool allowed us to quickly set up a pub/sub configuration, e.g. number of publisher/subscribers, message size, QOS settings, middleware. The following metrics were recorded while the tests were running:

- Latency: corresponds to the time a message takes to travel from a publisher to subscriber. The latency is measured by timestamping the sample when it is published and subtracting the timestamp (from the sample) from the measured time when the sample arrives at the subscriber;
- CPU usage: percentage of the total system wide CPU usage;
- Sample statistics: number of samples received, sent, and lost per experiment run.

Performance results for both 4G and 5G networks are provided in the Figure 47 and Figure 48 below.



test setup

Performance Test Version	de7c337
Publishing rate	1000
Topic name	Array1k
Number of publishers	1
Number of subscribers	1
Maximum runtime (sec)	60
DDS domain id	0
Single participant	-

average results

Experiment Status	success
T_loop	1.0091
received	995.5667
sent	999.55
lost	0.3
relative_loss	0.0003
data_received	1035887.3833
latency_min (ms)	14.0557
latency_max (ms)	52.3752
latency_mean (ms)	27.3142
latency_variance (ms)	0.0373
pub_loop_res_min (ms)	-2.9963
pub_loop_res_max (ms)	0.9514
pub_loop_res_mean (ms)	0.7992
pub_loop_res_variance (ms)	0.0001
sub_loop_res_min (ms)	0.0
sub_loop_res_max (ms)	0.0
sub_loop_res_mean (ms)	0.0
sub_loop_res_variance (ms)	0.0
cpu_usage (%)	1.6042

environment

Ignore seconds from beginning	0
Memory check enabled	0
Msg name	Array1k
QOS Durability	VOLATILE
QOS History depth	1000
QOS History kind	KEEP_ALL
QOS Reliability	BEST_EFFORT
QOS Sync. pub/sub	0
RMW Implementation	rmw_cyclonedds_cpp
Roundtrip Mode	MAIN
With security	0
Zero copy transfer	0

Figure 47. 4G performance measurements using UL-NPA

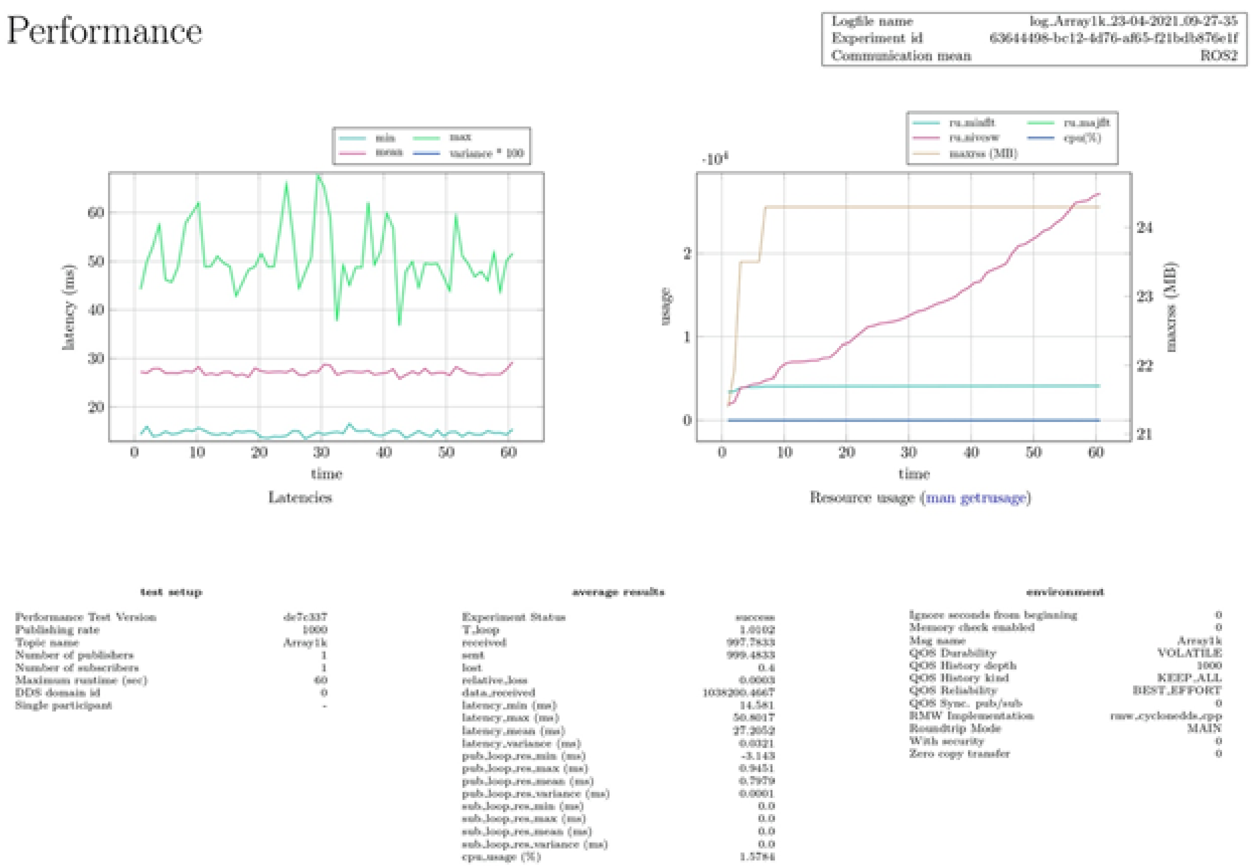


Figure 48. 5G performance measurements using UL-NPA

2.8 EURECOM pretrials in June 2021

5G!Drones partners AIR, CAF, DRR, EUR, INV and UMS remotely conducted pretrials on 17-Jun-2021 using EURECOM infrastructure in Sophia-Antipolis. The tests are called pre-trial, because the Web Portal 1 and 2 components were tested for the first time. However, the start of the trials is planned from July 2021. The tests were performed remotely using a WebEx environment to share a screenshot of the use of different applications. EUR team on-site in EURECOM premises in France, Sophia-Antipolis conducted physical tasks on servers and 5G smartphones.

The mission was to test Integration Release 1 components and UC1:SC1, UC2:SC1, and UC2:SC2 scenarios as much as possible for collecting feedback for next physical tests.

The Figure 49 below describes the architecture of EURECOM remote tests on 17-Jun-2021.

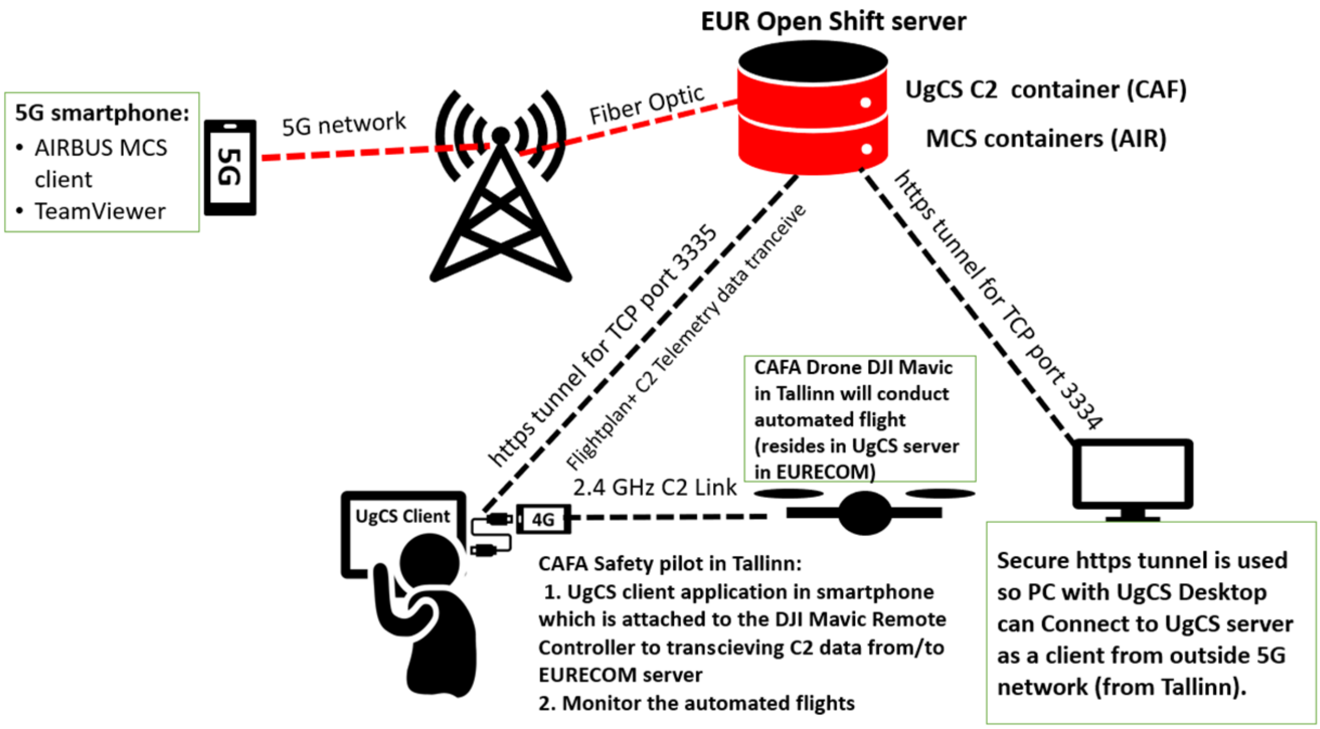


Figure 49. Architecture of EURECOM remote tests on 17-Jun-2021

Integration Release 1 testing and sequence scope is shown in the Figure 50 below.

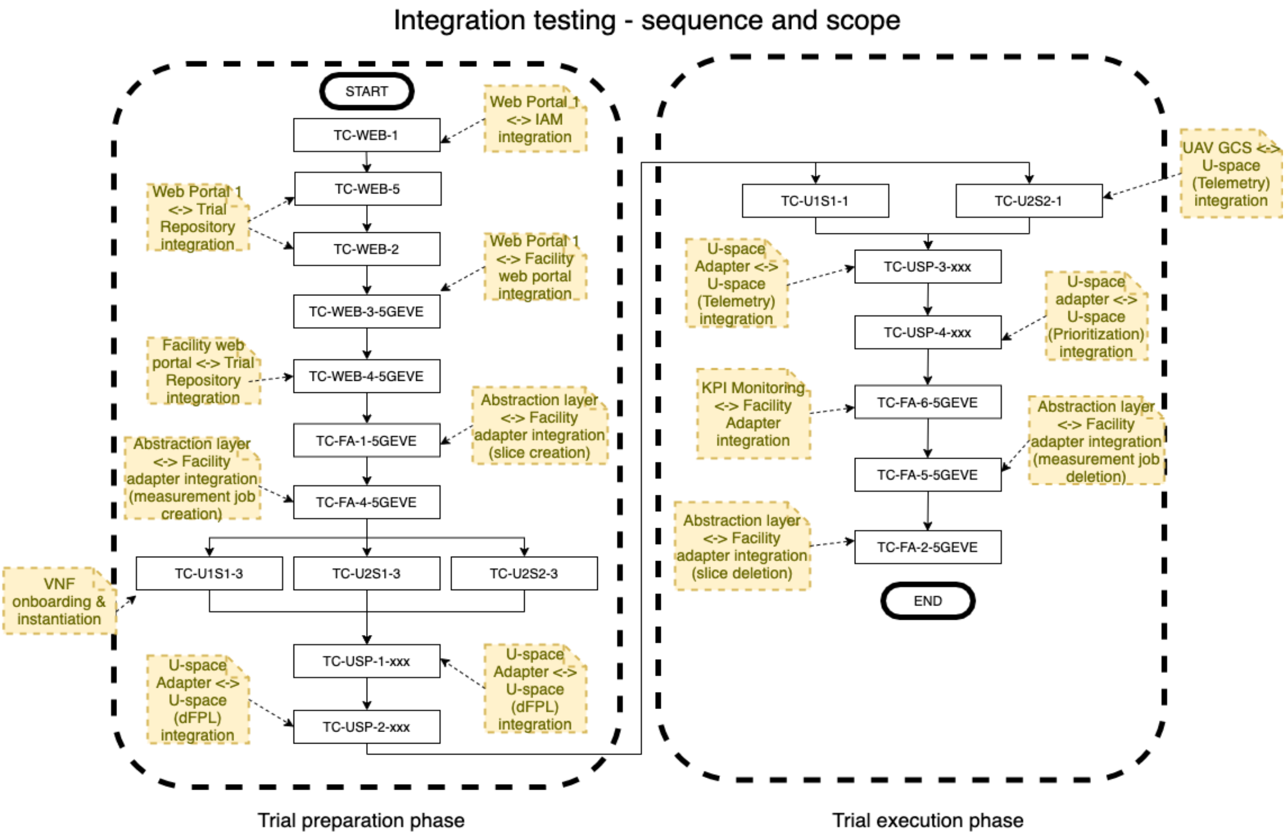


Figure 50. Integration Release 1 testing and sequence scope

Index of test cases and results of the EURECOM pretrials on 17-Jun-2021 are described in the Table 5 below.

Table 5. Test cases and results of the EURECOM pretrials on 17-Jun-2021

Nr	Index of test cases	Result
1	TC-WEB-1 – Login into Web portal 1	Completed successfully
2	TC-WEB-5 – Save/retrieve/modify UAV to/from Trial Repository (Web Portal 1)	Completed successfully
3	TC-WEB-2 – Save/retrieve trial configuration to/from Trial Repository (Web Portal 1)	Completed successfully
4	TC-WEB-3-5GEVE – Redirect from Web Portal 1 for NST preparation	Completed successfully
5	TC-WEB-4-5GEVE – Save/retrieve trial configuration to/from Trial Repository (Facility Web portal)	Completed successfully
6	TC-FA-1-5GEVE – Create slice (5G-EVE)	Completed successfully
7	TC-FA-4-5GEVE – Create measurement job (5G-EVE)	Completed successfully
8	TC-U1S1-3 – Onboard and instantiate CAFA Tech UgCS Platform (CUP)	Completed successfully
9	TC-U2S1-3 – Onboard and Instantiate CAFA Tech UgCS Platform (CUP) and Airbus MCS (Mission Critical System) Platform	Completed successfully
10	TC-U2S2-3 – Onboard and Instantiate UL-CCP	Not used on 17-Jun-2021
11	TC-USP-1-DRR – Submit dFPL	Not used on 17-Jun-2021

Nr	Index of test cases	Result
12	TC-USP-1-FRQ – Submit dFPL	Not used on 17-Jun-2021
13	TC-USP-2-DRR – Receive res/req from U-space	Not used on 17-Jun-2021
14	TC-USP-2-FRQ – Receive res/req from U-space	Not used on 17-Jun-2021
15	TC-U1S1-1 – Send telemetry data from CAFA Tech UgCS to U-space	Not used on 17-Jun-2021
16	TC-U2S2-1 – Send telemetry data from UL-CCP to U-space	Not used on 17-Jun-2021
17	TC-USP-3-DRR – Receive telemetry data from U-space	Not used on 17-Jun-2021
18	TC-USP-3-FRQ – Receive telemetry data from U-space	Not used on 17-Jun-2021
19	TC-USP-4-DRR – Receive new Geofencing notification from U-space	Not used on 17-Jun-2021
20	TC-USP-4-FRQ – Receive new Geo-fencing notification from U-space	Not used on 17-Jun-2021
21	TC-FA-6-5GEVE – Receive KPI data	Completed successfully
22	TC-FA-5-5GEVE – Delete measurement job	Completed successfully
23	TC-FA-2-5GEVE – Delete slice	Completed successfully

UMS utilised their simulation testbed to conduct some preliminary tests at EURECOM. Two companion personal computers (CPCs) were shipped to EURECOM prior to the trials. CPCs were connected to 5G-enabled smartphones provided by EURECOM. Vehicle to Vehicle (V2V) communication over EURECOM's MEC infrastructure and the communication to our central control platform when running it on our server in Belgium were tested successfully. However, during the preparation for these trials UMS identified certain unique preferences for deploying all our modules on EURECOM's MEC infrastructure. As UMS current deployments on other MEC infrastructures in 5G!Drones and other commercial solutions use a different setup, UMS will need to make some adaptations to accommodate this. UMS are currently investigating potential solutions to modify our application in order to be able to deploy our modules on EURECOM's MEC infrastructure for the physical trials at EURECOM.

In summary, it should be noted that the EUR remote tests on 17-Jun-2021 were the first time that the WP2 Trial controller enablers were tested (although to a limited extent, as planned after Integration Release 1). It provided valuable input for Integration Release 2 and WP2 enablers developments.

3 Enablers, principles and KPIs for conducting trials

The purpose of this chapter is to offer an overview of WP2 and WP3 enablers and integration releases and principles and KPIs, which are similar for all scenarios.

3.1 Overview of Trial controller development plan in 2021-2022

WP2 focuses on the development of a trial controller that allows the vertical to describe the scenario to be trialled on the top of the 5G facilities. The trial controller is also responsible for enforcing the trials and managing their lifecycles. WP2 covers a number of enablers, which are the following:

- Web Portal 1: which exposes the functionalities of the system and allows describing operation fight level of the scenario;
- Web Portal 2: allows to describe the network level of the scenario. Web Portal 2 is therefore facility-dependent;
- Trial validator: is used to validate the scenario to be trialled;
- Repositories: which serves for hosting different information about the scenario to be trialled;
- LCM: which is a central component of the trial controller that manages the trial throughout its lifespan;
- Trial enforcement: whose responsibility is to enforce the trial on the top of the target facility;
- U-space adapter: which serves as an interface to the U-space;
- KPI component: allows to collect, analyse and visualize the measured KPIs from the performing trials.

The development plan for WP2 enablers is summarized in the Table 6 below.

Table 6. Current development plan for WP2 enablers as of 30-Jun-2021

Enabler	Current development plan
Web Portal 1	• M20 – Adding and management of the users, basic dashboard, adding the UAV, communication with the repositories. • M21 – Defining the flight plan, basic dashboard presentation and actions. • M22 – Sending trial for approval, managing responses from Trial Validator. • M23 – Executing mission (simulations).
Web Portal 2-EUR	• The first release is available since September 2020. • A new release is expected when the Web Portal 1 and LCM of 5G!Drones will be finalized. The new release will adapt the code to the new NBI of LCM and connected to Web Portal 1.
Web Portal 2-NCSRD	• Release 1 available in January 2021. • Release 2 available at the end of March 2021.
Web Portal 2-UO	• First release: End of February 2021 (basic layout, user registration and management, user roles, TSD creation, DB backup functionality). • Second release: Collects Slice Metadata, RAN info and KPI list, shows basic Slices information in dashboard, New Slice/TSD from saved template.
Web Portal 2-AU	• The first release has been presented in December 2019 (feature: describing the scenario at UAV level). • The second release has been presented in October 2020 (feature: extending the description of the scenario to the network level). • The next release will integrate the communication to the LCM (August 2021).
Trial validator	• 4 releases, end of the month – February 2021 – May 2021.
Repositories	• First version is released in December 2020. • This module is live, and updates are performed when required.

Enabler	Current development plan
LCM	• Three monthly main release (January/February/March 2021). • Maintenance releases will then be issued when needed.
Trial enforcement	• Release 1: April 2021. • Release 2: September 2021.
U-space adapter	• The first version has been released in December 2020. • Current plan: ongoing coordination and implementation.
KPI component	• The first version has been released in December 2020. • Current plan: integration with other components to receive data and with LCM/dashboards.

3.2 Overview of WP3 UAV enablers development plan in 2021-2022

The aim of WP3 is to design and implement the missing components that will allow 5G facilities and vertical services to support the target use cases. The development plan for WP3 enablers is summarized in the Table 7 below.

Table 7. Overview of WP3 enablers development plan 2021-2022

Enabler	Current development plan
IoT data collection module (AU)	• Work in progress • M24 – first version
Virtual flight controller (AU)	• The first release is already available
Alerion's GCS (ALE)	• Implemented • Initial tests of expected to be conducted during pretrials (M24)
Data processing (ALE)	• Architectural design completed • Development: In progress • M28: first release
Sensor data streaming (ALE)	• Application design completed • Core development completed • Security aspects: in progress • M24: Initial tests during pretrials
Hydradrone (ALE)	• Software design & dev: completed • Hardware Design: in progress • M28: Test of Hydradrone V1
Telemetry for UTM (FRQ, DRR)	• Status: Work in progress, expected by M26
Drone Flight Plan to UTM (FRQ, DRR)	• Status: Work in progress, expected by M26
Geozone information (Mission Prioritization) support (FRQ, DRR)	• Status: Work in progress, expected by M26
Hepta's Data Cloud (HEP)	• Status: In testing
Hepta's GCS (HEP)	• Status: Work in progress, expected by M27
Hepta's drone with tether (HEP)	• Status: Testing finished, Ready to use
Payload – Lidar for 3D mapping (HEP)	• Status: Ready to use
Interface with AP (HEP)	• Status: Work in progress, V1 is Ready to be used, V2 expected by M27
Sensor data streaming (HEP)	• Status: Ready to use
Data processing (HEP)	• Status: work in progress, expected by M27
INVOLI Central Server (INV)	• V1 ready since October 2020
INVOLI's KIVU/LEMAN tracker (INV)	• Status: ready to use since October 2020 • Expected by September 2021
K-1090 receiver (INV)	• V1 ready since October 2020

Enabler	Current development plan
Nokia drone (NOK)	• Status: ready to use
UWB-based drone positioning system (NOK)	• Status: Ready to use
Geolocation of an UAV based on signal strength from 1 BS (ORA)	• Status: work in progress • Release date: M33
Optimal trajectory of UAV Base Station (ORA)	• Status: work in progress • Release date: M32
Virtual flight controller (UO)	• Status: work in progress • Release date: September 2021
Positioning analysis application (UO)	• Status: work in progress • Release date: M26
Data collection and mapping (UO)	• Status: work in progress • Release date: M26
UL-ACE (UMS)	• Status: work in progress • Alpha release date: March 2021
UL-CCP (UMS)	• Status: work in progress • Alpha release date: March 2021
UMS Video Analysis	• Status: work in progress • Alpha release date: March 2021
UMS Wi-Fi Access Point	• Status: work in progress • Alpha release date: March 2021
UgCS C2 cloud native application enhanced by CAFA Tech (CAFA CUP)	• Status: Ready since January 2021
4K Video streaming system from drone to MEC/edge server (CAF)	• Status: work in progress • Release date: M32
CAFA Tech Video analyser (VideoLyzer)	• Status: work in progress • Release date: M32
CAFA Tech Field GIS C2 system for Police operations and Drone Logistics	• Status: work in progress • Release date: M32
3D map for visualising QoS of 5G (CAFA Tech Analyzer)	• Status: work in progress • Release date: M32
CAFA Tech cellular drone (Pixhawk platform-based) supporting onboard 5G commands via 5G module	• Status: work in progress • Release 1 date: August 2021 • Release 2 date: February 2022

3.3 Overview of integrations releases in 2021-2022

There are in total 4 integration releases planned, which will assure that Trial Controller system is ready to fulfil 5G!Drones requirements:

- Release 1: Integration validation release;
- Release 2: Trial Controller release;
- Release 3: KPI release;
- Release 4: Use case release.

Each of the release is described in more details in following subsections.

Activities planned within each of those releases can be of 2 main types:

- Tests, which would require end to end testing environment availability including selected trial controller components, additional applications (enablers), facilities, UAVs, etc.;
- Tests, which could be executed in simulated or limited capability environment in terms of required availability of UAVs able to flight, access to facilities, etc.

End to end tests, due to the huge logistic effort and limited resource and suitable time slots, will be synchronized with planned trials and showcases. The other tests, which do not require end to end availability, will be planned to be executed in other suitable time.

For the reasons mentioned above, in this document we focus only on planning of end-to-end tests related to integration tasks and its relation to trials plan, whereas all release planning is covered in details in the deliverable D4.2.

Integration validation release (Release 1)

It is planned for the period of M22-M27. Main goals of this release:

1. To ensure that all Trial Controller components in scope are interconnected as required with appropriate technologies (e.g. RESTful API, message bus, publish/subscribe, etc.) and required infrastructure is provided;
2. To ensure that all 3rd party external enablers' integration requirements are captured, fulfilled and validated;
3. To propose/validate deployment methodology;
4. To propose/validate (integration) testing automation tools/processes.

Potential end to end tests would involve most probably only facility partners and would cover:

- Tests of NS enforcement;
- Basic tests of generating and receiving KPI data streams from facility and forwarding it through Abstraction layer to KPI Monitoring module of Trial Controller;
- Tests of fetching, onboarding and activating of example VNFs.

Trial Controller release (Release 2)

It is planned for the period of M28-M31. Potential on-site tests should be synchronized with trials in October 2021. The main goal is to perform end-to-end tests of key Trial Controller processes based on the assumed to be available fully functional releases of all Trial Controller components.

KPI release (Release 3)

It is planned for the period of M32-M33. The main goal is to perform end-to-end tests (including facilities and UAVs) of all KPIs with designed KPI tools (e.g. dedicated scripts) and processes to validate them and expected results. Activities of this release assume very extensive use of whole, end to end infrastructure including all components and enablers.

Use case release (Release 4)

It is planned for the period of M36-M37, but it should be synchronized with trials in May-September 2022. It is a final release confirming full ability to perform trials/execute defined use case scenarios:

1. To ensure all service level enablers are developed;
2. To ensure all use cases are defined in their final form;
3. To ensure all use case components are tested.

3.4 Trials evaluation objectives, KPIs, measurement methodology and tools

This subchapter describes trials evaluation objectives, measurement methodology and tools planned to use on trials.

3.4.1 Overview of the trial's evaluation objectives

The purpose of the executed feasibility tests and pretrials was primarily to validate the integration activities and evaluate the feasibility to execute the target demonstrations. A phased approach, with early, 1st year feasibility trials, and pretrials in 2021, ensures that all aspects that need tuning and optimisations are identified timely and acted upon as part of the on-going development and integration work-packages. While in the first year the focus has been to ensure that the basic infrastructure components are properly in place, the trial's interest in subsequent pretrials is shifted towards successful integration and validation of measurable objectives. Overall, the list of evaluation objectives identified are described in the Table 8 below together with their respective business impact.

Table 8. Evaluation objectives for the trials

#	Objective	Business impact
1	Vertical applications containers working in MEC or Edge servers.	Drone verticals can install their cloud native applications on the 5G MEC/Edge, which reduces the need to forward the entire data stream to a central server, especially when using video analytics, which is a significant gain both in respect to the application latency as well as in bandwidth consumed. On average, mobile data costs about 1 EUR to transfer 1 GB of data over a mobile network. Automatically operating drones produce approx. 1 TB of data in 30 days (30 GB × 30 days).
2	Trial Controller is working.	Involving the 5G!Drones test execution environment is considered a significant aid to automate the verification of UAV 5G use cases and abstract the underlying infrastructure complexities.
3	U-space adapter and UTM services are working and accessible.	Seamless integration through the 5G!Drones components to interact with U-space services, complements in an end-to-end manner the experimentation process of 5G UAV use cases and bridges the 5G and U-space ecosystems.
4	Cybersecurity minimum requirements are fulfilled.	Security is an important consideration, and specific requirements for the 5G!Drones platforms are already defined and prioritized. It is possible to measure their implementation by counting the fulfilled requirements.
5	Verification of Target KPIs, measurement process and metrics collection points.	Identified KPIs per use case have target values and accuracy. The purpose of the 5G!Drones platform is to provide the means to collect and validate these KPIs, and as such the verification of proper operation of the measurements collection is very important.
6	Access to collected KPIs for post-analysis.	The availability of data collected from the 5G!Drones facility (IT and 5G network, Trial Controller, U-space, Drones 5G UEs) during the experiments execution is necessary to allow post-processing for the KPIs calculation as well as transparency for the end results and is an important characteristic of the 5G!Drones platform.

Specifically, distilling from the project requirements [1], work of the previous project [6], and recommendations from 5G-PPP [7]-[9], the measurable objectives of the 1st Round trials have been identified in the Table 9.

Table 9. Target network KPIs to be measured in trials

#	Network KPI	Description	Relevant metrics and tools
K1	Coverage	5G network coverage for whole route to control the flight over 5G at height level up to 30 m AGL. It is feasible to use 5G network to conduct drone flight.	• Reference Signal Received Power (**RSRP**): Indicates the average power received from a single Reference signal. • Reference Signal Received Quality (**RSRQ**): Indicates quality of the received signal as a ratio of power and interference.

<table>
<tr><th>#</th><th>Network KPI</th><th>Description</th><th>Relevant metrics and tools</th></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td></td><td>Received Signal Strength Indicator (RSSI): Indicates the power of received radio signal.
Signal to Interference plus Noise Ratio (SINR): Indicates the theoretical upper bounds of channel capacity.</td></tr>
<tr><td colspan="2">Using industry best practices[1], the KPI is technically decomposed as follows:
<table>
<tr><td>Excellent</td><td>-44 dBm > RSRP > -85 dBm</td><td>0 dB > RSRQ > -10 dB</td></tr>
<tr><td>Good</td><td>-85 dBm > RSRP > -105 dBm</td><td>-10 dB >= RSRQ > -14 dB</td></tr>
<tr><td>Fair/Bad</td><td>-105 dBm >= RSRP > -140 dBm</td><td>-14 dB >= RSRQ > -40 dB</td></tr>
</table>
<table>
<tr><td>Excellent</td><td>-50 dBm > RSSI > -70 dBm</td><td>20 dB > SINR > 12 dB</td></tr>
<tr><td>Good</td><td>-70 dBm > RSSI > -80 dBm</td><td>12 dB >= SINR > 7 dB</td></tr>
<tr><td>Fair/Bad</td><td>-80 dBm >= RSSI > -100 dBm</td><td>7 dB >= SINR > 0 dB</td></tr>
</table></td></tr>
<tr><td rowspan="2">K2</td><td rowspan="2">Throughput</td><td>Throughput is a KPI characterizing the capability of data transfer of a connectivity link under specific network conditions. It refers to data (payload) successfully transferred within a given time period from a data source to a data sink. This KPI is a factor of a vast number of parameters and conditions, including the System Under Test (SUT) and the use requirements. Especially for 5G networks, it is a slice-dependent performance indicator [6].</td><td>Based on the direction (uplink/downlink) and the respective payload (TCP or UDP traffic) we consider the following metrics as necessary per use case:
Upload UDP Rate (bps): Max./Avg./Min. values for UDP traffic
Download UDP Rate (bps): Max./Avg./Min. values for UDP traffic
Upload TCP Rate (bps): Max./Avg./Min. values for TCP traffic
Download TCP Rate (bps): Max./Avg./Min. values for TCP traffic
These metrics can be collected from either points of the link that is measured, depending on the measurement tool capabilities. It is common to see a client (primary) and server (secondary) configuration, and as such, it is important to denote the collection points of the reported measurement. Typically, the measurements at the site of the client (primary), which are usually installed in the end-user equipment (UE) are indicative of the perceived end-user performance.</td></tr>
<tr><td colspan="2">As noted, target values can differ based on the application requirements and system capabilities that become more specific per user scenario. In principle two options can be considered, “System-related” target values, that relate to the nominal targets that the equipment vendor specifies, as well as “Use case-related” values, that describe the “Required Rate” targets as provided by the use case analysis. Customarily, as an initial verification of the proper 5G system installation and configuration the system related KPIs need to be firstly met. In the subsequent sections each trial site reports on the deployment setup and Nominal Maximum Upload and Download metrics that can be supported by the deployment tested. The list below depicts some basic principles for the evaluation of the measurements collected, with the following formalisation:
Rate = The throughput metric under test (Upload UDP Rate or Upload UDP Rate or Download TCP Rate or Download TCP Rate) collected from a specific source (Client/Primary and Server/Secondary endpoint).
Nominal Rate = It is specific to the deployment characteristics per trial site and equipment that is reported separately in subsequent sections.</td></tr>
</table>

[1] https://www.telecomhall.net/t/standard-range-for-signal-strength-quality/8364

#	Network KPI	Description	Relevant metrics and tools
		Excellent	***System Related*** Max. Rate == Max. Nominal Rate of the SUT Equipment Average Rate >= 90% Max. *Nominal* Rate ***Use Case Related*** Min. Rate >= Required Rate
		Good	Max. Rate = 90% of *Nominal* Rate of the SUT Equipment Average Rate = Required Rate
		Fair/Bad	Average Rate < 90% of *Nominal* Rate of the SUT Equipment Min. Rate < Required Rate
K3	E2E Round Trip Time	The "Round Trip Time 3GPP KPI" is considered for the user plane traffic as the time it takes to transfer a given piece of information from the end-user device (UE, IoT device, etc.) (here-in transmitting node) up to the end providing the data service or application (herein receiving node), to process the piece of data at the receiving node, and to transfer an acknowledgement status back to the transmitting node [6].	• **RTT** (ms): For this metric, the traffic source (the UE) sends c the destination, the latter responding with an ICMP ECHO_RESPONSE. This test case employs "ping" as a tool to generate the traffic stream.
		The Round Trip Time is highly dependent on the deployment characteristics per site. It contains the full, acknowledged communication between the target UE and the application components and as such it is primarily use case specific. **Each trial site needs to report on the Required RTT of the use case to support.**	
		Excellent	Max. RTT <= Required RTT
		Good	Average RTT <= Required RTT
		Fair/Bad	Min. RTT > Required RTT
K4	Delay	The time it takes to transfer a given piece of information from a source to a destination, from the moment it is transmitted by the source to the moment it is received at the destination (in this link direction only) over the SUT.	• **Delay** metric (seconds) is measured on the Network, Transport Layer, and Data-Link Layer of the communication link utilizing socket-based communications under the implementation supported by each individual tool to measure the time delay taken for a packet to reach from source to destination.
		The directional delay metric is highly dependent on the deployment characteristics per site. It contains the one-directional, bi-directional, or un-acknowledged communication between the denoted endpoints and as such it is primarily use case specific. It is a unidirectional or bidirectional delay measurement that is collected from the client (primary) or server (secondary) source, as necessary per case. Each trial site reports on the Required Latency of the use case it needs to support in subsequent sections. Below table is an indicative target for the results evaluation.	
		Excellent	Max. delay <= Required delay
		Good	Average delay <= Required delay
		Fair/Bad	Min. delay > Required delay
K5	Application/VNF performance	Measure the resources consumption of the application running as a VNF (Virtualized Network Function) and described in the Network Slice Descriptor of the 5G infrastructure.	• **VNF CPU**: The real-time CPU consumption of each VNF that is running on the underlying physical infrastructure. • **VNF GPU**: The real-time GPU consumption of each VNF that is running on the underlying physical infrastructure. • **VNF RAM**: The real-time memory consumption each VNF that is running on the underlying physical infrastructure.

#	Network KPI	Description	Relevant metrics and tools
			• **Vnf_bw_tx**: The amount of data sent by the VNF per time unit. • **Vnf_bw_rx**: The amount of data received by the VNF per time unit.
		These metrics are measured through the Virtualised Infrastructure Manager Monitoring tools (VIM) and is very specific to the underlying technology, the (over) provisioning resource allocation policy applied by the infrastructure provider as well as the specific VNF technical characteristics. In this sense there can be no uniform proposition on acceptable target values, as the careful balance between resources starvation and waste is very use case-specific. Respective conclusions shall therefore be discussed individually per trial execution.	
K8	RAN throughput	The throughput computed in the Radio part of the network. This is the effective throughput experienced while running the scenario (without generating extra traffic).	• **PDCP Transfer Rate**: The difference between the number of bytes at the PDCP layer at time t and t-Δt divided by Δt. It is monitored for both UL and DL directions.
		Excellent	Min. Uplink/Downlink Rate >= Uplink/Downlink Required Rate
		Good	Average Uplink/Downlink Rate = Uplink/Downlink Required Rate
		Fair/Bad	Min. Uplink/Downlink Rate < Uplink/Downlink Required Rate
K9	RAN reliability	Reliability is the probability that an item under test will perform its intended function for a specified interval under stated conditions. For the RAN equipment, the reliability of radio communication is measured in terms of the ability to deliver packets without errors and losses.	• **RAN packet loss**: The rate of lost data packets experienced at the Radio access network while running the scenario. When the number of retransmissions at the MAC layer exceeds the Maximum number of retransmissions, the data chunk is assumed lost.
		RAN packet loss rate = Number of lost data packets/Total Number of packets.	
		Excellent	Max. Rate < (1 – Required Reliability Rate)
		Good	Avg. Rate ≤ (1 – Required Reliability Rate)
		Fair/Bad	Min. Rate > (1 – Required Reliability Rate)
K10	Service creation time	The time needed to build/deploy the application components (VNFs) and create the Network Slice at the target facility infrastructure, as described in the relevant Network Slice Descriptor (NSD).	• **Slice Creation Time**: The slice creation time is computed by measuring the difference between the arrival time of the creation request and the time when the slice is created and in running state.
		Excellent	Slice Creation time < Required Deployment time
		Good	Slice Creation time = Required Deployment time
		Fair/Bad	Slice Creation time > Required Deployment time

The technical methodology used to collect and verify above KPIs is described in the Table 9 above. As general guidelines, the following principles are considered:

- Measurements need to be collected automatically, in any available format, either as log files or image snips and be available for post processing;
- The KPI calculation shall omit significant terms according to statistical analysis practices;
- At least N > 2 iterations of the metrics collection process shall be run for each metric.

Metrics, measurement tools and methodology are described in the Table 10 below.

Table 10. Metrics, measurement tools and methodology

<table>
<tr><th>Metric</th><th>Tools and measurement methodology</th></tr>
<tr><td rowspan="4">RSRP, RSRQ, RSSI, SINR</td><td>Available tools</td></tr>
<tr><td>The metrics are collected through a UE or CPE trying to access the 5G network with either of the below alternatives:
1. Android out-of-the-box applications, publicly available at the various Play Stores such as:
a. NetMonitor[2] and
b. LTE Discovery[3].
2. Custom applications that leverage the Android API. In the scope of the project the following tools are considered:
a. COSMOTools documented in the deliverable D2.3 [10].
3. Enterprise tools, such as:
a. Nemo Handy is an application for solely Android-based systems developed by the Keysight Technologies company [11]. It enables measuring wireless diagnostics information of air interface and mobile application quality-of-service (QoS) and quality-of-experience (QoE). For the project purposes, Nemo Handy is used mainly for measurement and monitoring radio signal coverage metrics.</td></tr>
<tr><td>Measurement methodology</td></tr>
<tr><td>The considered measurement methodology includes following guidelines:
• Execute stationary tests from N focal points at the trial site and get baseline measurements.
• Repeat tests executing the flight plan, and get stationary measurements on location updates (either in X or Y axis) every 10 m.
When using the Nemo Handy:
• The test execution duration is on average 30 s to get the needed data and also can be until to stop the measurement manually at the application.
• Metrics such as RSRP, RSRQ, RSSI, and SINR are measured each second by default for the duration of test execution.</td></tr>
</table>

[2] https://play.google.com/store/apps/details?id=com.parizene.netmonitor&hl=en_SG

[3] https://play.google.com/store/apps/details?id=net.simplyadvanced.ltediscovery&hl=en&gl=US

<table>
<tr><th>Metric</th><th>Tools and measurement methodology</th></tr>
<tr><td rowspan="4">Upload TCP Rate Download TCP Rate</td><td>Measurement tools</td></tr>
<tr><td>The following tools can be used for collecting the metrics:
• iPerf3[4]/Magic iPerf[5]: A TCP-based traffic stream is created between the source and the destination. The source is typically the UE (executing the nPerf mobile app) or CPE and the destination is an iPerf3 server than can be located at either the Mobile Edge, a Private or Public Cloud.
• Ookla Speedtest[6]: With this tool, throughput between a client (typically a 5G UE) and an external Ookla Speedtest server over the Mobile network, using the Ookla methodology.
• nPerf[7] Speedtest: Similar to the Ookla tool using the nPerf servers.
• Open5GENESIS throughput testing probes: Probes installed inside the UE and permits OpenTAP[8] to use SSH and initiate the iPerf3 tool.
• Qosium is a real-time passive network performance measurement solution developed by the Kaitotek company from Finland [12]. Qosium measures any traffic passing through the network interface, which is set to monitor by the Qosium Probes (i.e. measurement agents). Qosium measures two-directions network QoS performance from a real application's point of view. Qosium Probe measures all the metrics from the existing traffic, and it calculates the throughput based on all data passed through the monitored network interface using the packets captured at data-link layer. Hence, upload and download TCP rate can be collected by using Qosium Probes listening received and sent traffic. The Qosium tool is documented in the deliverable D2.3 [10] and it is currently used in the 5G-TN facility of the University of Oulu.</td></tr>
<tr><td>Measurement methodology</td></tr>
<tr><td>• When using a public cloud (Ookla/nPerf) destination server:
  ○ Select the nearest available server to the trial site's location. This might affect the proper selection of Ookla or nPerf server to run the tests. This is due to the fact that parameters (such as the TCP window size) controlling the transfer are not optimized for the increased latency that comes from an increase in distance.
  ○ Run the test using at least 60 s execution, as these tools progressively increase speed as targets get reached.
  ○ Execute tests on Multiple Connection Mode.
  ○ Perform of N ≥ 2 iterations of the test.
• When running iPerf3 tests:
  ○ Duration of a test execution at least two (2) minutes (-t 120).
  ○ Records measured over 10-second intervals within an iteration with at least 25 iterations (-i 10).
  ○ To reduce impacts of TCP slow-start algorithm, the first 20 s of a measurement are discarded (-O 20).
  ○ Use Parallel Streams to determine maximum rate reached (-P = 5|10]).
  ○ Carefully choose the appropriate buffer size (-l option) to work with the MSS size of TCP to reduce the TP penalty by the inefficient fragmentation. A recommendation is to use 1470 (-l 1470).
• When running Qosium:
  ○ Duration of test execution is until to stop the measurement.
  ○ Upload and download TCP rates are measured each second by default for the duration of test execution.
  ○ Additional Qosium configurations can be found in the Table 11.</td></tr>
<tr><td></td><td>Measurement tools</td></tr>
</table>

[4] https://iPerf.fr/iPerf-download.php

[5] https://play.google.com/store/apps/details?id=com.nextdoordeveloper.miPerf.miPerf&hl=en&gl=US

[6] https://www.speedtest.net/about/knowledge/test-methods

[7] https://www.nperf.com/en/

[8] https://www.opentap.io/

Metric	Tools and measurement methodology
Upload UDP Rate Download UDP Rate	The following tools can be used for collecting the metrics: • iPerf3[9]/Magic iPerf[10]: A TCP-based traffic stream is created between the source and the destination. The source is typically the UE (executing the nPerf mobile app) or CPE and the destination is an iPerf3 server than can be located at either the Mobile Edge, a Private or Public Cloud. • Qosium is a real-time passive network performance measurement solution developed by the Kaitotek company from Finland [12]. Qosium measures any traffic passing through the network interface, which is set to monitor by the Qosium Probes (i.e. measurement agents). Qosium measures two-directions network QoS performance from a real application's point of view. Qosium Probe measures all the metrics from the existing traffic, and it calculates the throughput based on the data passed through the monitored network interface using the packets captured at data-link layer. Hence, upload and download UDP rate can be collected by using Qosium Probes listening received and sent traffic. The Qosium tool is documented in the deliverable D2.3 [10] and it is currently used in the 5G-TN facility of the University of Oulu.
	Measurement methodology

	• When running iPerf3 tests:
	  ○ Duration of a test execution at least two (2) minutes (-t 120).
	  ○ Records measured over 10-second intervals within an iteration with at least 25 iterations (-i 10).
	  ○ Carefully choose the appropriate buffer size (-l option) to work with the MSS size of UDP to reduce the TP penalty by the inefficient fragmentation. A recommendation is to use 1330 (-l 1330).
	  ○ Set the target bandwidth to N bps as default is 1 Mbps. Each trial site needs to appropriately define N based on the nominal max.
	  ○ Consider setting the buffer size that datagrams are received in (-w 10M).
	• When running Qosium:
	  ○ Duration of test execution is until to stop the measurement.
	  ○ Upload and download UDP rates are measured each second by default for the duration of test execution.
	  ○ Additional Qosium configurations can be found in the Table 11.

RTT	**Measurement tools**
	The possible tools to measure RTT are: • ping command, executed in the UE user plane. • nPerf: that Indicates the delay a small packet of data requires to make a round-trip from the 5G UE to the nPerf server, located at the public internet. • Open5GENESIS latency testing probes: Probes installed inside the UE and permits OpenTAP to use SSH and initiate the ping tool.
	Measurement methodology

	On the testing methodology, the following can be reported:
	• When running ping command:
	  ○ Aim for more than 60 packets transmission.
	  ○ Considering using 32 B and 1500 B packet sizes.
	• When using a destination server that is in the public cloud (Ookla/nPerf):
	  ○ Select the nearest available server to the trial site's location. This is due to the fact that parameters (such as the TCP window size) controlling the transfer are not optimized for the increased latency that comes from an increase in distance.
	  ○ Run the test using at least 60 s execution.
	  ○ Perform of N ≥ 2 iterations of the test.

	Measurement tools

[9] https://iPerf.fr/iPerf-download.php

[10] https://play.google.com/store/apps/details?id=com.nextdoordeveloper.miPerf.miPerf&hl=en&gl=US

Metric	Tools and measurement methodology
Delay	The following tools can be used for collecting the metrics: • EURECOM tool: A client-server application running on Unix hosts that uses the time function of the operating system to measure the socket-based connection between the end-points. The client uses the time function to get the current timestamp, sends it to the server and receive it back in an ACK message. The client will use the timestamp contained in the ACK to compute the delay. • Qosium is a real-time passive network performance measurement solution developed by the Kaitotek company from Finland [12]. Qosium measures any traffic passing through the network interface, which is set to monitor by the Qosium Probes (i.e. measurement agents). Qosium Probes measure uplink and downlink directions network Delay between two specific measurement points. The delay metric is measured on the data-link layer, and it is calculated based on the time it takes to transfer data packets from a source primary point to a destination secondary point. Qosium Probe measures all the metrics from the existing traffic, and it calculates the delay based on the data passed through the monitored network interface. Hence, the delay metrics are collected by using Qosium Probes listening received and sent traffic. The Qosium tool (documented in the deliverable D2.3 [10]) is currently used in the 5G-TN facility of the University of Oulu.
	Measurement methodology
	On the testing methodology, the following can be reported: • When running EURECOM tool: ○ Run the test during the complete trial. ○ If you are using the tool, while running a scenario, then use a small amount of data (100 B). • When running Qosium: ○ The delay metrics are measured each second by default for the duration of test execution. ○ Additional Qosium configurations can be found in the Table 11.
VNF CPU and GPU **VNF RAM** **VNF Bandwidth Rx** **VNF Bandwidth Tx**	**Measurement tools**
	These measurements are collected from the tools available from the monitoring tools of the relevant infrastructure manager. For the 5G!Drones the following tools are relevant for collecting these measurements: • CAdvisor (Container Advisor) [13] collects, aggregates, processes, and exports information about resource usage and performance characteristics of running docker containers. • OpenStack Libvirt Exporter [14]: a software tool that connects to the OpenStack compute nodes and retrieves active VM metrics. • Prometheus node exporter [15]: Prometheus is a widely utilised monitoring tools that can collect performance measurements of the host environments.
	Measurement methodology
	The metrics are collected by the monitoring tools continuously with their default configuration.
PDCP Transfer Rate	**Measurement tools**
	FlexRAN [16] is flexible and programmable Software Defined Radio Access Network (SD-RAN) platform that separates the RAN control and data planes. It is built on the top of OAI [17]] platform. It exposes RAN level statistics [18] for different eNodeB layers.
	Measurement methodology
	The metrics are collected by the monitoring tools continuously with their default configuration.
RAN Packet Loss	**Measurement tools**
	FlexRAN [16] is flexible and programmable Software Defined Radio Access Network (SD-RAN) platform that separates the RAN control and data planes. It is built on the top of OAI [17]] platform. It exposes RAN level statistics [18] for different eNodeB layers.
	Measurement methodology
	The metrics are collected by the monitoring tools continuously with their default configuration.

Metric	Tools and measurement methodology
Slice Creation Time	**Measurement tools** The time function of the operating system on which the entry point of the facility is running. This latter saves the time when the slice creation request was received. After the slice is created and running, the saved time is subtracted from the current time to get the slice creation time. **Measurement methodology** The metric is collected automatically by adding the process to the facility entry point.

The Qosium tool methodology specifications are described in Table 11the Table 11 below.

Table 11. Qosium tool methodology specifications

Metric	Tools and measurement methodology
	Measurement methodology

Traffic bps (Upload & Download TCP and UDP rates)	Methodology to collect throughput-related metrics using Qosium.
	• Install and execute Qosium Probes on systems based on Linux, Android, or Windows.
	• Before starting the measurements, set the "Probes," "Topology," "Measurements," and "Results" features using the user interface of Qosium Scope.
	• To measure the throughput of specific traffic like video streaming it is required to add some commands in the "Manual Filter" field of the "Measurement" feature in Qosium Scope.
	• After to complete all required configurations to perform measurements among two points, can be started the measurement from Qosium Scope controller.
	• Qosium setup enables to collect the next throughput-related metrics for sent and received traffic of Primary and Secondary measurement point:
	  ○ Traffic (bps) of Primary Point (Sent – Upload).
	  ○ Traffic (bps) of Primary Point (Received – Download).
	  ○ Traffic (bps) of Secondary Point (Sent – Upload).
	  ○ Traffic (bps) of Secondary Point (Received – Download).
	• While measurements are running, the throughput-related metrics as part of all average results measurements are sending simultaneously to the Qosium Storage database.
	• The measurement is performed until the user stops it at the user interface of Qosium Scope.

Delay seconds/ milliseconds (UL & DL)	Methodology to collect delay metrics using Qosium.
	• Install and execute Qosium Probes on systems based on Linux, Android, or Windows.
	• Install and execute the Precision Time Protocol daemon (PTPd) on Linux and Android-based devices to get high accurate synchronization (to run PTPd, check the annex).
	• Before starting the measurements, set the "Probes," "Topology," "Measurements," and "Results" settings using the user interface of Qosium Scope.
	• To measure the latency of specific traffic like video streaming it is required to add some commands in the "Manual Filter" field of the "Measurement" feature in Qosium Scope.
	• After to complete all required configurations to perform measurements among two points, can be starter the measurement from Qosium Scope controller.
	• Qosium enables to collect the next latency-related metrics including delays for both directions, upload, and download:
	  ○ Delay Received (seconds/milliseconds);
	  ○ Delay Sent (seconds/milliseconds);
	  ○ Delay Received, max. (seconds/milliseconds);
	  ○ Delay Sent, max. (seconds/milliseconds);
	  ○ Delay Received, min. (seconds/milliseconds);
	  ○ Delay Sent, min. (seconds/milliseconds).
	• While measurements are running, the latency-related metrics as part of all average results measurements are sending simultaneously to the Qosium Storage database.
	• The measurement is performed until the user stops it at the user interface of Qosium Scope.

3.4.2 Trial evaluation targets for the trials

3.4.2.1 5GENESIS Athens trial evaluation targets

At the Athens UC4:SC1, the following evaluation objectives are set as described in the Table 12 below.

Table 12. Athens UC4:SC1 trials objectives

Athens UC4:SC1 trials objectives		
#	**Objective**	**Technical description**
1	Vertical applications containers working in MEC or Edge servers.	**COS-NCSRD sites Trial #1** For the COS-NCSRD site, the 5G network is deployed between the two campuses, considering the 5G-core at the NCSRD campus and the RAN at the COS campus, together with the edge deployment. The following Application Components are installed in the Private Cloud infrastructure at COSMOTE/OTE Academy, which stands as the MEC site for the Athens Trial site and they shall be used for the execution of the trials: • C2 application/GCS Software; • Network Latency emulator (Netem/DummyNet). **MoE-NCSRD sites Trial #2** For the MOS-NCSRD site, the 5G network is deployed between the Egaleo stadium and the NCSRD campus, where the 5G-core is deployed at the NCSRD campus and the RAN at the Egaleo stadium, together with a local edge deployment. The following Application Components are installed at the edge: • C2 application/GCS Software provided by CAFA Tech; • U-space adapter for UTMs provided by DroneRadar, Frequentis; • Video Streaming application by CAFA Tech; • C2 application/Unmanned Life Central Command Platform (UL-CCP) software provided by UMS; • Unmanned Life Video analytics (UL-VA) application by UMS.
2	Trial Controller is working.	For the trials executed at the 5GENESIS Athens platform (5G-PPP ICT-17 Platform), the functionalities of the Trial Controller are provided by the Open5GENESIS suite, which supports the experiment automation needed for the successful execution of the trials, as well as the data visualization of the results. The Open5GENESIS experimentation suite installed at the NCSRD site of the Athens Trial Site is used to execute the trials, initiate the experiments and collect the results.
3	U-space adapter is working.	**COS-NCSRD sites** The U-space adapter installed at the NCSRD site of the Athens Trial Site or at the edge (for the MoE-NCSRD trial setup) is used to communicate with the UTM components as necessary, during the preparation and the execution of the trials.
4	Cyber security minimum requirements are fulfilled.	The experimentation components, as well as the connectivity between the trial sites meet the minimum security requirements, such as encrypted communication tunnel between the sites, user authorization for accessing the experimenter site, etc.
5	Verification of Target KPIs.	The following KPIs are the target of the Athens experiments: K1: Coverage; K2: Throughput; K3: RTT. The verification of the latency KPI will be verified, showing the impact of using the edge computing and the 5G-LBO in order to reduce the latency for sensitive services/applications, such as delivering the C2-over-5G and the virtualised GCS component.
6	Access to collected KPIs for post-analysis.	The collected data of the experiment are automatically collected during the experiment execution and stored in a time-series database, from where post-

		analysis, such as visualization, is performed. Further post analysis is feasible with direct access to the stored data.

As an outcome of the trials, the following metrics shall be evaluated described in the Table 13 below.

Table 13. UC4:SC1 targets, metrics, trials, tools and parameters

Athens UC4.SC1 metrics, targets and parameters		
Metrics	**Targets**	**Tool & parameters**
RSRP, RSRQ	In Athens trials the use of RSRP, RSRQ will be performed by attaching a 5G CPE/UE to the UAV that will monitor the RSRP, RSRQ during the C2-over-5G flight, in order to assess the feasibility piloting the drone under different network conditions. The target of using this KPI is to evaluate the impact of the quality reception to the UAV flight.	• NetMonitor • COSMOTools
UDP Upload and Download Rate	At the OTE Academy demo site, the NOKIA radio equipment is a 2×2 MIMO and the maximum According to the vendor, for the specific configuration and TDD pattern selected (NR TDD DDDSUUDDDD (4+2+4), the nominal values are 650 Mbps for downlink and 55 Mbps for uplink. These are expected for both TCP and UDP metrics. At the NCSRD-MoE setup of the 5GENESIS platform, the Amarisoft 5G SA 2×2 MIMO setup has achieved peak UL 368 Mbps and DL 35 Mbps. The target DL values (real assessed throughputs in the field), in order to achieve better performance than the currently commercially available LTE network is > 50 Mbps and the UL to be > 20 Mbps.	• COSMOTools, using private-edge server located at the OTE Academy site • nPerf, Speedtest using 10G public servers located in Greece
TCP Upload and Download Rate		
RTT	The max. RTT that the application mandates for the proper operation must be < 30 ms.	• COSMOTools • Ping using a private-edge server located at the OTE Academy site
VNF CPU VNF RAM VNF Bandwidth Rx	The target resources utilisation should be less than 75% of the allocated resources: • 2 vCPUs, 4 GB RAM for C2 application/GCS Software 2 vCPUs, 4 GB RAM for U-space adapter; • 4 vCPUs, 8 GB RAM for Video Streaming & Analytics applications; • 4 vCPUs, 8 GB RAM 3D map processing applications; • 8-core CPU, 16 GB RAM, 80 GB disk space, internet connectivity for UL-CCP; • 8-core CPU, 32 GB RAM, 8 GB RAM for GPU, 80 GB disk space, CUDA 11.0 drivers, GPU pass through mode, internet connectivity for UL-VA.	• CAdvisor • OpenStack Libvirt Exporter [14] • Prometheus node exporter

3.4.2.2 5G-EVE Sophia-Antipolis trial evaluation targets

For Use Case – scenarios UC1:SC1, UC2:SC1, UC2:SC2 in the EURECOM, the following evaluation objectives are set as described in the Table 14 below.

Table 14. UC1:SC1, UC2:SC1, UC2:SC2 trials objectives

5G-EVE Sophia-Antipolis UC1:SC1, UC2:SC1, UC2:SC2 trial objectives		
#	**Objective**	**Technical description**
1	Vertical applications containers working in MEC or Edge servers.	The MEC containers are deployed in EURECOM OpenShift cluster. The Trial Enforcement module sends the NST to the abstraction layer, which will interact with the facility to deploy the containers. OpenShift has the ability to create replicates containers, so if a container goes down it will be replaced automatically. The vertical applications to be deployed are: • C2 application/GCS Software provided by CAFA Tech; • C2 application/Unmanned Life Central Command Platform (UL-CCP) software provided by UMS; • Unmanned Life Video analytics (UL-VA) application by UMS.
2	Trial Controller is working.	The Trial Controller will be hosted outside the facility and interacts with the abstraction layer API hosted at Aalto university. The latter will route the Trial Controller requests to the appropriate facility adapter.
3	U-space adapter and services are working and accessible.	The facility does not interact with the U-space adapter.
4	Cyber security minimum requirements are fulfilled.	The communication between the facility and the abstraction layer is going through an SSH tunnel accessible only from Aalto university, which is hosting the abstraction layer. The web portal 2 communication is based on HTTPS protocol.
5	Verification of Target KPIs, measurement process and metrics collection points.	The following KPIs are the target of the French experiments: K2: Throughput; K3: Delay; K5: VNF performance; K10: Slice Creation Time. Details on the measurement targets and tools to be used can be found in below table.
6	Access to collected KPIs for post - analysis.	The KPIs are sent by the abstraction layer to the KPI Management module hosted at Frequentis during all the trial duration.

As an outcome of the trials, the following metrics shall be evaluated described in the Table 15 below.

Table 15. UC1:SC1, UC2:SC1, UC2:SC2 targets, metrics, tools and parameters

UC1:SC1, UC2:SC1, UC2:SC2 use case/trial site metrics, targets and parameters		
Metrics	**Targets**	**Tool & parameters**
VNF CPU, GPU	VNF CPU > 80% of allocated CPU with a little number of peaks reaching 100%. The allocated resources: • 2 vCPUs, 4 GB RAM for C2 application; • 1 vCPU, 1 GB RAM for MCS application; • 8-core CPU, 16 GB RAM, 80 GB disk space, internet connectivity for UL-CCP; • 8-core CPU, 32 GB RAM, 8 GB RAM for GPU, 80 GB disk space, CUDA 11.0 drivers, GPU pass through mode, internet connectivity for UL-VA.	CAdvisor and Prometheus
VNF RAM	VNF RAM > 90 % of allocated RAM	CAdvisor and Prometheus
VNF Bandwidth Rx	VNF Bandwidth Rx ≤ 200 Mbps. Around 500 kbps per video stream and per user for SD stream (640 px × 480 px) at 15 fps for MCS application. Around 5 Mbps per video stream and per user for FHD stream (1920 px × 1080 px) at 60 fps for MCS application.	CAdvisor and Prometheus
VNF Bandwidth Tx	VNF Bandwidth Tx ≤ 200 Mbps. Around 500 kbps per video stream for SD stream (640 px × 480 px) at 15 fps for MCS application. Around 5 Mbps per video stream for FHD stream (1920 px × 1080 px) at 60 fps for MCS application.	CAdvisor and Prometheus
Slice Creation Time	It depends from the service size (how many VNFs and their size).	Facility entry point
Delay	Delay < 50 ms.	EURECOM script

3.4.2.3 5G-TN Oulu trial evaluation targets

For use case – scenarios UC1:SC2/UC2:SC3/UC3:SC1:sub-SC1/UC3:SC1:sub-SC2/UC3:SC1:sub-SC3/UC3:SC3 in the campus of the University of Oulu, the following evaluation objectives are set as described in the Table 16 below.

Table 16. UC1:SC2/UC2:SC3/UC3:SC1:sub-SC1/UC3:SC1:sub-SC2/UC3:SC1:sub-SC3/UC3:SC3 trials objectives

University of Oulu use case scenarios trials objectives		
#	**Objective**	**Technical description**
1	Vertical applications containers working in MEC or Edge servers.	The following Application Components are installed in the Private Cloud infrastructure at 5G-TN at the University of Oulu: • Video streaming application at the MEC server; • Map analysis application (CAFA Tech Analyzer); • C2 application (CAFA Tech CUP).
2	Trial Controller is working.	The Trial Controller installed at the 5G-TN facility of the University of Oulu is used to execute the trials, initiate the experiments and collect the average results of specific KPI measurements.
3	U-space adapter and services are working and accessible.	The U-space adapter installed at the 5G-TN facility of the trial site at University of Oulu is used to communicate with the UTM components as necessary, during the preparation and the execution of the trials.

4	Cyber security minimum requirements are fulfilled.	The communication between the 5G-TN facility at the University of Oulu and the X-Network of Aalto University is configured using the Internet Key Exchange (IKE) and Internet Protocol Security (IPSec) by Virtual Private Network (VPN), SSL encryption, and X.509 public-key certificate exchanges for authentication. On the basis of this secure configuration, the Abstraction Layer hosted at X-Network can communicate with the facility parsers hosted at 5G-TN. Furthermore, for the REST API responsible to provide the measurements from the 5G-TN to the KPI monitoring Component hosted at Frequentis, it is used the Token Authentication and HTTPS protocol.
5	Verification of Target KPIs, measurement process and metrics collection points.	For these use case scenarios, the following KPIs are the target of the Oulu experiments: K1: Coverage (RSRQ, RSRP, RSSI, SINR); K2: Throughput; K4: Delay; The details on the measurement targets and tools to be used can be found in the Table 17 below.
6	Access to collected KPIs for post-analysis.	During the trials, the KPIs measurement data is sent through the facility parsers and Abstraction Layer to the KPI Endpoint REST API of KPI Monitoring component and then to the Elasticsearch system hosted at Frequentis. All the measurements collected by Qosium are stored automatically in the Qosium Storage database at 5G-TN facility. This database also uses the time scale database extension to store the measurements in time-series data scale for better management and further post-analysis of them.

University of Oulu use case scenarios metrics, targets and parameters are described in the Table 17 given below.

Table 17. UC1:SC2/UC2:SC3/UC3:SC1:sub-SC1/UC3:SC1:sub-SC2/UC3:SC1:sub-SC3/UC3:SC3 targets, metrics, tools and parameters

University of Oulu Use case scenarios metrics, targets and parameters		
Metrics	**Targets for use cases scenarios**	**Tool & parameters**
RSRQ, RSRP, RSSI, SINR	The radio signal strength metrics like RSRP, RSRQ, RSSI, and SINR will be collected from the drone onboard 5G module or the mobile phone attached to the UAV during the flight. This will enable the evaluation of the feasibility of piloting the drone under different network conditions. Thus, the metrics in question will enable assess the impact of the quality reception to the UAV flight during the trials in the area at the University of Oulu. The specific use case scenarios that require RSRP, RSRQ, RSSI, and SINR metrics are UC2:SC3, UC3:SC1:sub-SC1, UC3:SC1:sub-SC3.	• Nemo Handy or • Qosium Probes or • iPerf or • nPerf
Upload UDP Rate Download UDP Rate Upload TCP Rate Download TCP Rate	At the 5G-TN facility, the Nokia radio equipment works with 4×2 MIMO, at TDD n78 frequency band, 60 MHz of bandwidth, and it can achieve the peak data rates of 550 Mbps for downlink and 40 Mbps for uplink. 5G NR sites are connected using 10 Gbps links to the core and network server cluster. 1. C2: 100 kbps for UL and DL; 2. UL data rate video streaming from UAV to MEC/Edge server: > 30 Mbps (UC1:SC2/UC2:SC3/UC3:SC1:sub-SC1/UC3:SC3);	Qosium Scope, Qosium Probes, and Qosium Storage

	3. Control messages of collision avoidance LIDAR from mobile phone on UAV to operator: >= 120 Mbps (UC3:SC1:sub-SC2); 4. Payload video streaming data rate from mobile phone on UAV to operator: >= 100 Mbps (UC3:SC1:sub-SC2); 5. Streaming LIDAR laser mapping data rate from mobile phone on UAV to operator: >= 120 Mbps (UC3:SC1:sub-SC2); 6. Sensor control data rate from mobile phone on UAV to MEC server: >= 50 Mbps (UC3:SC1:sub-SC3); 7. UL video streaming data rate from mobile phone on UAV to MEC server for Processing: >= 9 Mbps for HD and >= 25 Mbps for 4K (UC1:SC2/UC3:SC3).	
Delay	1. Delay of control messages between mobile phone on UAV and 5G Network (e.g. Network Slice): <= 10 ms (one way) (UC1:SC2/UC3:SC3); 2. Delay of TCP and UDP traffic of onboard 5G module or onboard mobile phones to 5G Network: delay <= 50 ms (UC2:SC3/UC3:SC1:sub-SC1/UC3:SC3); 3. C2 delay between software pilot and UAV in sending control & command messages: <= 10 ms (UC3:SC1:sub-SC2/UC3:SC1:sub-SC3); 4. Collision avoidance LIDAR delay for LIDAR streaming among UAV and Operator: <= 10 ms (UC3:SC1:sub-SC2).	Qosium Scope, Qosium Probes, and Qosium Storage

3.4.2.4 X-Network Aalto University trial evaluation targets

The Aalto University target trial objectives are described in the Table 18 given below.

Table 18. UC1:SC3, UC3:SC2 trials objectives

Aalto University UC1:SC3, UC3:SC2 trials objectives		
#	**Objective**	**Technical description**

1	Vertical applications containers working in MEC or Edge servers.	The following applications will be hosted at the edge server of the facility:
		• UC1:SC3:
		  ○ C2 application/GCS Software provided by CAFA Tech;
		  ○ Video server application.
		• UC3:SC2:
		  ○ C2 service;
		  ○ IoT data collection service.

2	Trial Controller is working.	Some functionalities of the trial controller will be tested, including planning and automatic deployment.
3	U-space adapter and services are working and accessible.	The U-space adapter is located at Frequentis premises. The facility interacts with it using APIs.
5	Cyber security minimum requirements are fulfilled.	• Aalto University hosts different parts of the trial controller, in addition to the abstraction layer. The access to the machines hosting these components is secured and only provided to the development team. The IP addresses of the machines are only known to the consortium members. • For the facility components, they are not accessible from outside. Only a set of APIs are provided and securely accessible via the abstraction layer.

	Verification of target KPIs, measurement process and metrics collection points.	The collected KPIs are pushed to the KPI component.

As an outcome of the trials, the following metrics shall be evaluated as described in the Table 19 below.

Table 19. UC1:SC3, UC3:SC2 targets, metrics, tools and parameters

UC1:SC3, UC3:SC2 Use case/trial site metrics, targets and parameters		
Metrics	**Targets**	**Tool & parameters**
VNF CPU **VNF RAM** **VNF bandwidth**	The target resources utilisation should be less than 75% of the allocated resources (2 vCPUs, 4 GB RAM for the different services).	Based on Prometheus
Slice creation time	< 1 min.	Measured by the slice orchestrator
RTT	RTT < 100 ms.	Ookla (to a server located in Helsinki) Ping (to a server located locally)
UE throughput	Aalto University makes use of a commercial gNodeB that operates at 60 MHz (3640 to 3700 MHz) band n78. The peak data rates of 550 Mbps for downlink and 40 Mbps for uplink.	Ookla (to server located in Helsinki) nPerf (to a server located locally)

3.5 Regulation of UAV flights in EU and specific conditions

The objective of this section is to present the UAV Regulation, especially with respect to European Commission Implementing Regulation (EU) 2019/947 [3] entered into force. Since the 31-Dec-2020, it has replaced each EU state's existing laws with respect to drone's operations. In this way, there are some things that must be taken into account with respect to the operation as well as the administrative procedures.

Registration Requirements

A drone operator/owner must register himself with the National Aviation Authority (NAA) of the EU country he/she resides, and this procedure must be done regardless of the number of drones he/she owns. Once registered, a "drone operator registration number" is provided and this number needs to be displayed with a sticker on all the drones he/she own, including those privately built. This unique registration number will be valid in all other EASA member State. Operator/owner is exempt to register if the drone:

- weighs less than 250 g and has no camera or other sensor able to detect personal data; or
- even with a camera or other sensor, weighs less than 250 g, but is a toy.

Operational Requirements

This new regulation framework takes a risk-based approach and defines three operation categories depending on the level of risks of the operations: **OPEN**, **SPECIFIC** and **CERTIFIED**. Besides, consumer drone manufacturers must label their product with a CE class identification label (C0, C1, C2, C3, C4, C5 and C6) depending on their weight, speed. C0 to C4 are reserved for the OPEN category while C5 to C6 for the SPECIFIC one.

The OPEN category addresses operations in the lower risk bracket. This category is subdivided into three further subcategories called A1, A2 and A3. Operational risks in the OPEN category are considered low, and therefore no authorisation is required before starting a flight. A summary of the OPEN category is shown below in the Table 20.

Table 20. Summary of the “Open” category in EC Implementing Regulation 947/2019 [3]

<table>
<tr><th colspan="2">Operation</th><th rowspan="2">Remote pilot competency</th><th colspan="3">UAS</th></tr>
<tr><th>Subcategory</th><th>Area</th><th>Class</th><th>MTOM</th><th>Electronic ID</th></tr>
<tr><td>A1: Fly over people</td><td>Can fly over uninvolved people (not over crowds).</td><td>Consumer info, online training and test</td><td>C1</td><td>< 900 g</td><td rowspan="4">Yes + unique serial nr.</td></tr>
<tr><td>A2: Fly close to people</td><td>Can fly at a safe distance from uninvolved people.</td><td>Consumer info, online training and test, theoretical test in a centre recognised by the aviation authority</td><td>C2</td><td>< 4 kg</td></tr>
<tr><td rowspan="3">A3: fly far from people</td><td rowspan="3">Should fly:
1. In an area where it is reasonably expected that no uninvolved people will be endangered;
2. Keep a safety distance from urban areas.</td><td rowspan="3">Consumer info, online training and test</td><td>C3</td><td rowspan="3">> 25 kg</td></tr>
<tr><td>C4</td></tr>
<tr><td>Privately built</td><td>If required by zone of operations</td></tr>
</table>

The SPECIFIC category covers riskier operations, where safety is ensured by the drone operator obtaining an operational authorisation from the national competent authority before starting the operation. To obtain the authorisation, the drone operator is required to conduct a safety risk assessment, which will determine the requirements necessary for safe operation of the drone(s).

In SPECIFIC category, operator either:

- applies for an operational authorization (planned activities as well as a risk assessment and detailed mitigation measures must be presented), or
- operates under a declaration according to one of the standard scenarios published by EASA in 2019 [19]. However, standard scenarios will be officially operational since December 2021.

In the CERTIFIED category, the safety risk is so high that certification of the drone operator and the aircraft is required to ensure safety, as well as the licensing of the remote pilot(s).

By European Commission Implementing Regulation (EU) 2019/947 “The rules and procedures for the operation of unmanned aircraft” [3] article 4, paragraph 1f regulates: Open category: (f) during flight, the unmanned aircraft does not drop any material. The plan is to fly with CAFA Tech private built 5G drone with paracetamol medicine. When the drone reaches its destination, the drone lands on the Delivery Box and the drone then releases paracetamol. Then drone will start new mission with take-off from Delivery Box. So UC1:SC3 trial is an Open category flight.

Article 3(a) UAS operations in the “open” category shall not be subject to any prior operational authorization, nor to an operational declaration by the UAS operator before the operation takes place.

Article 4, paragraph 2. UAS operations in the “open” category shall be divided in three sub-categories in accordance with the requirements set out in Part A of the Annex.

The annex *UAS operations in the “open” and “specific” categories*, part A *UAS operations in the “open” category* establishes: UAS operations in subcategory A3 UAS operations in subcategory A3 shall comply with all of the following conditions: (…) (2) be conducted at a safe horizontal distance of at least 150 m from residential, commercial, industrial or recreational areas. Aalto, Oulu, EURECOM, NCSRD, OTE Academy, Egaleo stadium testing areas are close to the buildings, but the national transition period must be considered.

A transition period has been defined giving all EU member states and stakeholders time to adhere to the new rules and regulation from the 31-Dec-2020 to 01-Jan-2023. Concretely, drone without class identification label can fly in OPEN category under the following conditions (limited OPEN category):

- Weight < 500 g, not over people, pilot competency determined by the NAA;
- Weight < 2 kg, 50 m or more from people, pilot training equivalent to subcategory A2;
- Weight < 25 kg, areas free from people, distance >= 150 m from properties, pilot training equivalent to subcategory A3.

Countries Particular Cases

In case of France, the DGAC (CAA) has defined new standard national scenarios that can be used in France, as well as the conditions applicable to missions that do not fit within the framework of European regulations. Existing S1, S2 and S3 national scenarios continue to exist almost identically, in a declarative way. The only operational difference with the previous rules concerns the lowering of the maximum flying height to 120 m. Hence, and according to what was described above, experimental flights in France can be conducted:

- according to one of the three national standard scenarios in which case, a declaration to the DGAC is needed. This declaration must be done before the 02-Dec-2021 and will allow operators to conduct flights using one of the three national standard scenarios until the 02-Dec-2023. After the 02-Dec-2021, only declarations regarding the new specific standard scenarios will be admitted.

or

- in SPECIFIC CATEGORY for which the UAS operator wishing to fly in must request an authorization from the competent authority of the country where the operator is registered. The operator then submits to the DSAC (France) a copy of the authorization obtained, together with the list of the sites in which the operator will conduct the flights as well as the mitigation measures considered based on these operating locations. The DSAC evaluates the scenario and then confirms or not to the operator and to the competent authority of the country of registration that the operation can begin without delay.

The Finnish government has decided to apply a transitional period. It allows drone flights in Finland to be operated under Finnish regulations until 31-Dec-2021 by those drone operators who were registered in the Finnish CAA (Traficom) before 30-Dec-2020.

3.6 UTM regulation and developments in the EU

In March 2021, the European Aviation Safety Agency's (EASA's) Committee for the application of common safety rules in the field of civil aviation approved the proposed EU U-space regulatory package. In April 2021, the official Commission Implementing Regulation (EU) 2021/664 on a regulatory framework for the U-space was released [4]. Its entry into force is planned for January 2023.

The regulation defines the roles and the responsibilities of the different stakeholders involved, centred around:

- U-space service providers (USSP);
- Common Information service providers (CISP);
- Drone operators;
- Air Navigation Service Providers (ANSPs);
- Authority.

Member states will be responsible for designating so called U-space airspace, portions of airspace where drone operations will be allowed to take place with support of U-space services. To which extend this U-space airspace is designated, is fully up to the member state.

Providing U-space services will require certification, USSPs will have to provide at least four mandatory U-space services to achieve certification, the mandatory services are depicted in the Figure 51 below in dark blue.

Figure 51. U-space services

- Network Identification will enable to identify drones. It is a precondition to other services, as it not only deals with the actual registration of drone, but additionally includes position data. It is primarily a service for the in-flight phase.
- Geo-Awareness enables drone operators to plan missions. It combines relevant static and dynamic data, typically to be visualised on mission planning tools – mostly relevant in the pre-flight phase.
- Flight Authorisation is a service providing approvals to drone operators. It includes so called strategic deconfliction, ensuring that planned drone operations do not overlap in 4D – space and time. The service is relevant both in pre- and in-flight phases, as approvals could be withdrawn due to changed conditions in the air situation.
- Traffic Information ensures common situational awareness, it provides information on all air traffic nearby a drone operators mission, including manned aviation.
- Optional services are Weather Information and Conformance Monitoring. Weather information lays out the required weather data support safety, conformance monitoring provides awareness on compliance with the flight authorisation. Flights leaving their declared area of operation will cause relevant stakeholders to be alerted.

Even though conformance monitoring is an optional service per regulation, it is widely considered to be a must have service in real operational scenarios.

At the time of writing (July 2021), work is ongoing on AMC/GM (Acceptable Means of Compliance and Guidance Material), further detailing out expected behaviour, performance and requirements. These materials are expected to be published by EASA in autumn 2021. U-space levels are shown in the Figure 52 below.

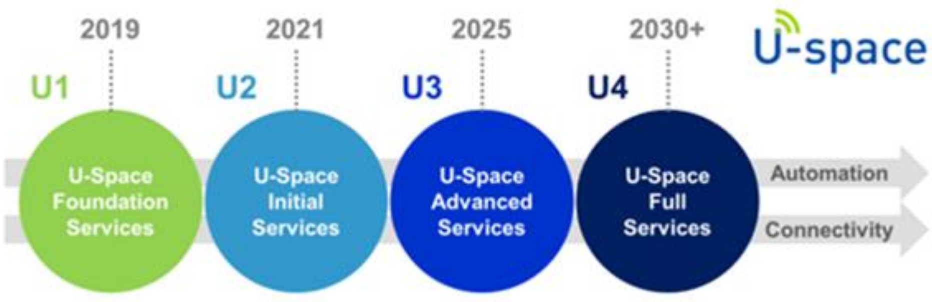


Figure 52. U-space levels (Source: Eurocontrol – U-space Services Implementation Monitoring Report – 2020-1-2)

The U-space regulation is the first regulatory step, mostly dealing with U1 und U2 level services. Advances services will follow over time (see Figure 52), driven by increase in traffic and operational experience with the initial regulation.

An indication on which services could be regulated/required next, or, made mandatory by member states already now, can be found in the U-space service levels widely used in ongoing European research.

Next steps will likely target further integration of unmanned traffic into the existing aviation ecosystem, evolving from the current approach based on so called dynamic reconfiguration of airspace (closing airspace dedicated U-space airspace for unmanned traffic if required by the air situation).

EC Implementing Regulation 2021/665 [20] describes the requirements for ANSPs and other air traffic management functions in regard to U-space collaboration. Basically, it states that air traffic management has to provide relevant AIM data and coordinate dynamic reconfiguration of U-space.

EC Implementing Regulation 2021/666 [21] is describing requirements for manned aviation operating within U-space. It describes that within a designated U-space also manned aircraft have to make their position known to USSPs.

3.7 Use of 5G devices on board UAVs – regulation in the EU

In the EU level there are no restrictions for using cellular communication (mobile networks) for drones. CEPT Electronic Communications Committee (ECC) Report 309 “Analysis of the usage of aerial UE for communication in current MFCN harmonised bands” (03.07.2020) [5] deals with the use of mobile frequencies in unmanned aircraft systems. The ECC reports are not binding and do not impose specific conditions on Member States of the Conference of European Postal and Telecommunications Administrations (CEPT). On the basis of the report, an ECC decision will be drawn up and will be sent to member states and stakeholders to get feedback (expected on second half of 2022). A decision on the use of these areas should be completed by the end of 2022.

In Finland, Traficom Regulation 15 AR/2021M [22] sets in paragraph: Use of radio transmitters on board airborne aircraft: Radio transmitters must not be used on board airborne model aircraft, unmanned aircraft or other aircraft, unless allowed in accordance with the special provisions on use defined in article 7-11. With the consent of mobile operators, Traficom may also exceptionally grant a radio licence that enables using mobile devices on board aircraft when flying at low levels. The mobile network frequencies specified in the radio licence may be used for command-and-control links, payload connections or calls. To add 5G UE to the drone, a separate permit must be applied for from Traficom. The permit application process is described on the Traficom website [23].

3.8 Safety requirements

General rules and instructions are described in the Table 21 below.

Table 21. General safety requirements

ID	Name	Description
S1	Ground crew	Ground crew for blocking area (100 m × 200 m parking area) during flight time. Visual contact between Ground crew and drone pilot and trial lead.
S2	Safety vests for all participants	5G!Drones safety vests.
S3	Safety briefing	Critical pre-flight safety briefing as part of Air Safety Coordinator duties.
S4	Trial detailed entered to air navigation map	Filing flight area into the app (such as Aviamaps) to alert officials.
S5	Handheld radios	Up to 6 Walkie-talkies for enhanced communication during trials.
S6	Emergency Response Plan	Emergency and contingency plan to ensure we are prepared in case something was to go wrong.
S7	Pre-flight checklist	Detailed pre-fight checklist to go through and approve onsite.

3.9 Schedule for preparations, technical tests, execution and conclusions

This subchapter describes the activities before, during, and after the tests. As exact dates are difficult to set in advance for about a year, the letter D is used on the timeline as the date of the trials. D-1 denotes the day before day D, respectively. A separate plan will be agreed between the participating partners for each scenario. The trial must involve at least 2 partners. The preparation and conduct of the trial for each scenario is led by the scenario leader. The drone operator is responsible for the permit to fly, but must be notified by the scenario leader at least 60 days in advance of the time and location (coordinates with accuracy 5 m) where the tests are to be performed.

Schedule for preparations is described in the Table 22 below.

Table 22. Schedule for preparations

Date	Topic	Description	Responsible
D-60	Deciding when to conduct physical trial	The decision is made for each scenario separately.	Participating partners
D-50	5G Network parameters	Frequencies for 5G and IoT, then partners can adapt relevant 5G modem.	Facility owner
D-35	Deciding when to conduct remote tests	Parameters for CAFA Tech, then CAFA Tech can choose relevant IoT sensors.	Participating partners
D-30	5G Network coverage and DL/UL in main Testing area and in Reserve area	To choose locations for trials (Main testing area and Reserve area).	Facility owner
D-30	Notification about Specific category flight	Notification to the local CAA to conduct Specific category flights.	Drone operator
D-30	Apply for permission to add 5G UE onboard a drone	Permission from Finnish Traficom (Finnish Radio Communication Authority) to add 5G UE onboard a drone.	Drone operator
D-28 until D-7	Technical tests	Technical tests and final preparations. 5G network coverage measurements in Main area and in Reserved area.	Participating partners
D-5	Rehearsals	Rehearsals will be conducted remotely. Rehearsals include all steps of field tests.	Participating partners

Schedule for execution of trial on D-day is described in the Table 23 below.

Table 23. Schedule for execution of trial on D-day

Date	Topic	Description	Responsible
D	Network coverage check	5G network coverage measurements in Main area and in Reserve area.	Facility owner
D	Set up Command post, communication, laptops	Set up tent and 230 V electricity and all computers and communication and drone with 5G UE. Testing communication and systems.	All
D	Safety briefing	Safety briefing and send out Ground Crew for blocking area during flight.	Air Safety Coordinator
D	Drone flights	Drone flights.	Drone operator
D	After Action Review and tasks allocation	To collect initial feedback and results. To agree how to collect results and media files and how to compile the report.	All
D+1	Reserve day	One additional day should be reserved for trials if technical or weather obstacles occur on the main D day.	

Schedule for drafting the report is described in the Table 24 below.

Table 24. Schedule for drafting the report

Date	Topic	Description	Responsible
D+1 until D+3	Results collection	All results will be uploaded to MS Teams dedicated folder.	All participants
D+5	Drafting the report	1st draft of the report for all participants.	All participants
D+7	Telco meeting to present initial results	For all consortium.	All participants
D+10	Drafting the report	2nd draft of the report for all consortium.	All participants

3.10 Communication activities

The information, photos and videos collected during the Trials support the communication and dissemination activities of the 5G! Drones project. The schedule is shown in the Table 25 below.

Table 25. Schedule for communication activities

Time	Topic	Description
D-30	Preparations	Detailed media plan with all tools and persons responsibilities.
D-28	Invitations to stakeholders	Invitations to stakeholders who agreed with participants.
D-3	Technical rehearsals	To conduct rehearsals with all devices and test online streaming and sharing for 5G!Drones partners.
D	Field tests media collection and online sharing	To take photos, videos, screencasts. To share video feed from the test site for all consortium partners.
D+2	Collection of materials	To collect materials from all partners.
D+7	Conclusions, website news, overview video and photos for all partners	To edit photos and videos.

4 Detailed trials plans based on the scenarios

Trials will take place at four facility partner locations in EURECOM, NCSRD, Aalto University, University of Oulu. WP2 and WP3 enablers have been added for each trial, the development and integration of which must be finally completed by the end of Integration Release 4. Given that changes in EU regulations, UAV enablers developments, 5G! Drones facilities, Trial Controller developments may occur in the next 12 months, the detailed plans of the trials may change.

Trials are scheduled to be performed in two rounds as described in the Table 26 below:

- 1st Round from July to October 2021 to test Integration Release 1 and Release 2 components.
- 2nd Round from June to September 2022 to test the complete solutions of the 5G!Drones project.

Table 26. Trials time schedule of 2021-2022

Trials round	Date	Aalto	Oulu	EURECOM	Athens
1st Round trials with Release 1 "Integration validation release" and Release 2 "Trial Controller release"	July-October 2021	Physically	Physically	Physically	Physically
Showcasing trial in Tallinn, Estonia	May 2022				
2nd Round Trials with Release 3 "KPI Release" and Release 4 "Use Case Release"	June-September 2022	Physically	Physically	Physically	Physically

4.1 EURECOM trials in Sophia-Antipolis

In the EURECOM facility, there will be executed three trials: UC1:SC1, UC2:SC1 and UC2:SC2.

4.1.1 Locations and aviation restrictions map

Link to the Google Maps: **https://goo.gl/maps/ABukkS72SY9kFuj88**

Coordinates: 43.61453270828758, 7.071041266913765

Due to fact that EURECOM 5G base station cannot provide enough 5G network coverage for Parking slot area (Reserv area) the Trials main area is planned near the EURECOM 5G base station as shown in the Figure 53 below.

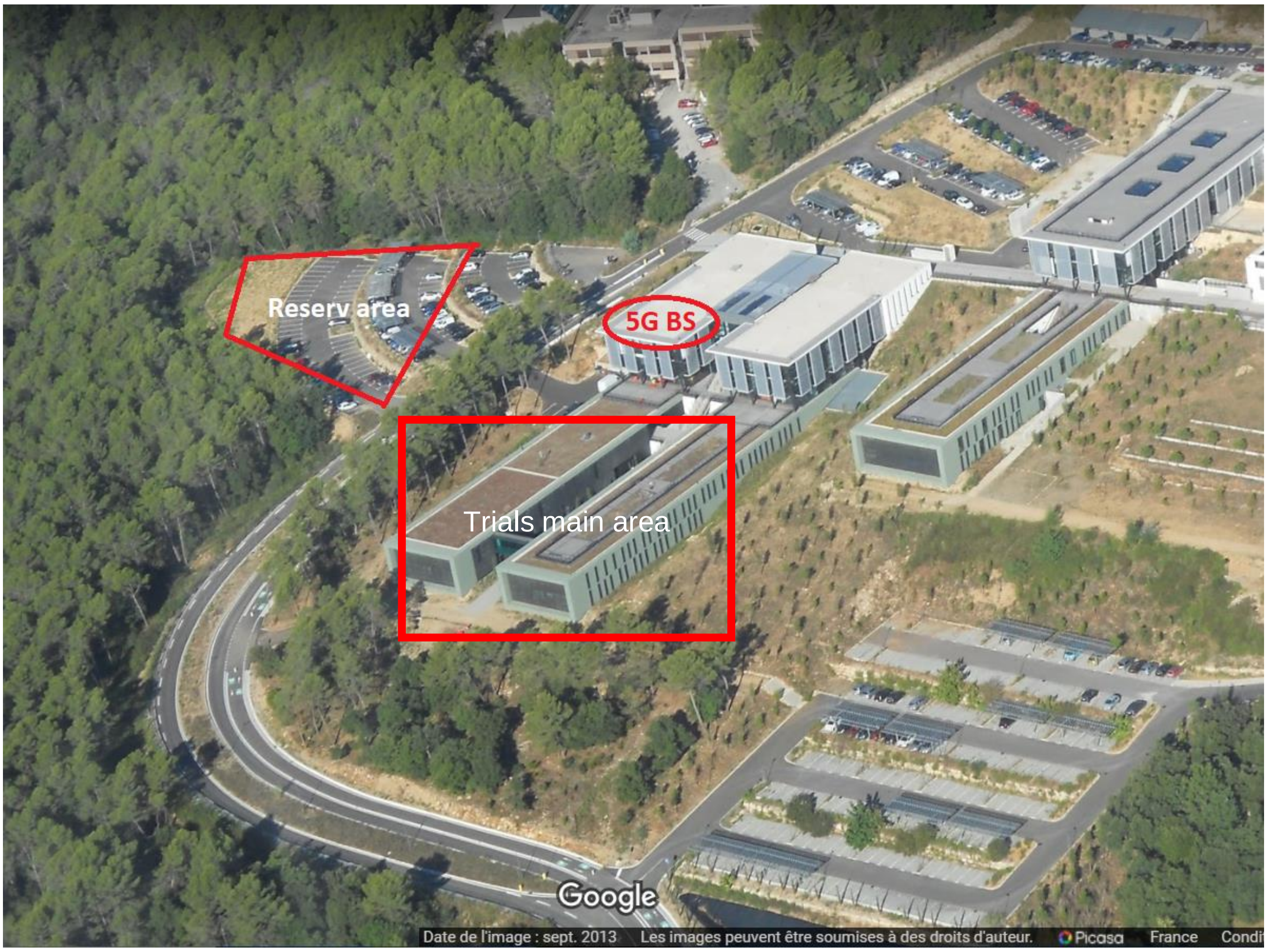


Figure 53. EURECOM Sophia-Antipolis site trials site map screenshot from Google Maps

Screenshot of EURECOM campus on the air navigation map from geoportail.gouv.fr described in the Figure 54 shows that only parking slot is without any flight restrictions. For drone flights at other locations, it is necessary to apply for a permit from the French CAA.

Figure 54. Screenshot of EURECOM campus in Sophia-Antipolis on the air navigation map geoportail.gouv.fr

4.1.2 Available frequencies and bandwidth parameters in facility 5G network

Table 27. Available frequencies and bandwidth parameters in the 5G network of EURECOM

Name	Frequency in MHz	Bandwidth in MHz
Band n78	3400	10
Band n38	2600	20

4.1.3 UC1:SC1 UTM Command & Control application

The main focus of UC1:SC1 tests are the services provided by U-space, Trial Controller and Facility to the Ground Control Station deployed by UAV Operator in the EDGE server. The intent is to assure, that everything is under control before and during a mission. The plan is to simulate the problems, which can appear, like addition of the forbidden zone, incoming bad weather alert or connectivity problem. In case of such event, the mission can continue or will be terminated, according to the defined rules. The most important requirement is that everything is happening in a controlled manner.

It is planned to add the INVOLI's LEMAN tracker, which will report independently of the on-board drone system its position, direction, altitude and speed. This is the additional safety backup, which is considered to be required in the real BVLOS operations in medical delivery missions. The INVOLI's K-1090 receiver connected either through 5G test network or 4G commercial network will deliver to the U-space service the actual airspace traffic in the area of the test as shown in the Figure 55 below.

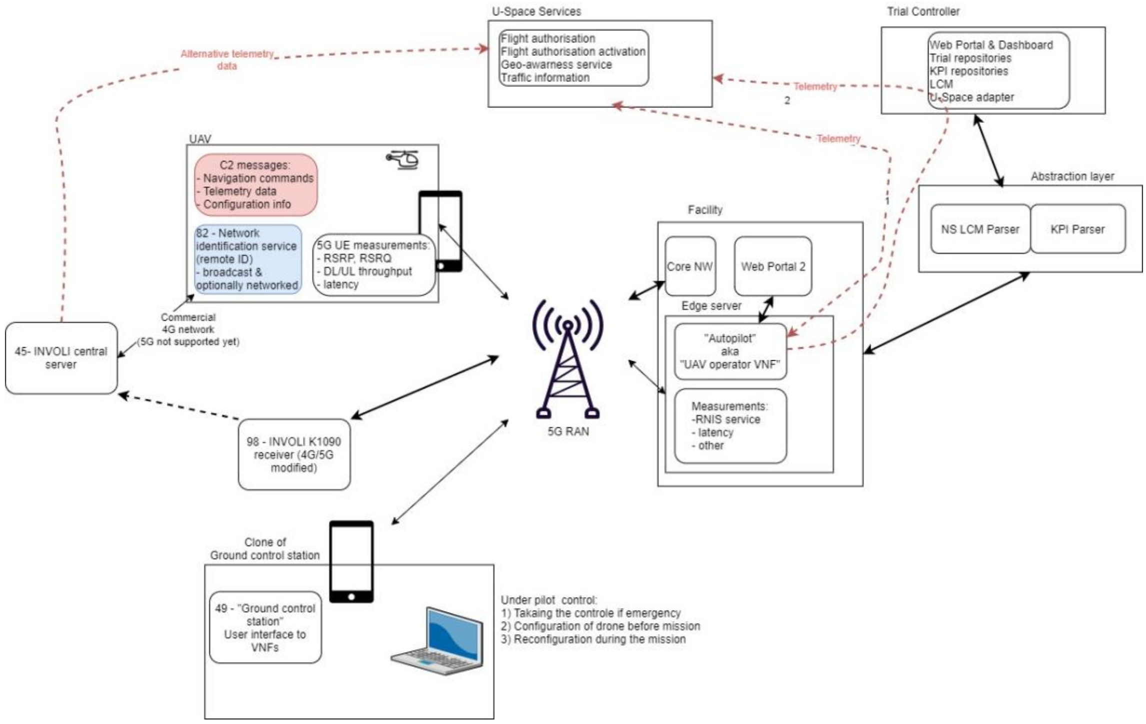


Figure 55. Description of UC1:SC1 trials' architecture

U-space – Trial Controller related tests <u>before the trial date</u>:

- U-space cancels dFP before given start time: 1 week/1 day/6 hours/2 hours. Objective: to verify that cancellation triggered form U-space side is properly transferred from U-space and handled by Trial Controller.

- UAS Operator cancels dFP before given start time: 1 week/1 day/6 hours/2 hours. Objective: to verify that cancellation triggered by UAS Operator is transferred from Trial Controller and handled by U-space.
- Before test is started, U-space adds the restriction area, which is partially intersecting with dFP. Objective: to verify that the restriction is visible to UAS operator/pilot/GCS and he/it can respect restriction or change the dFP operation area.
- Incoming weather alert from supplementary service provider – warning or critical. Objective: to see if it is well handled by Trial Controller. Timing: before test.
- Time to approve the dFP request in case of VLOS request for Open A0-A3. Objective: to measure time needed for the automated case handling between Trial Controller and U-space.
- Time to approve the dFP request in case of specific request (i.e. BVLOS). Objective: to measure time needed for semi-manual or manual case handling between Trial Controller and U-space.

U-space – Trial Controller-related tests during trial:

- Activation of the trial @U-space. Before starting the trial, Pilot needs to activate it in the U-space. To measure: the response time for activation and success/fail status.
- During the on-going test, U-space adds the restriction area, which is partially intersecting with dFP. Test objective 1: if UAV is outside of this area, it is not allowed to enter it. Test objective 2: if it is inside, the best alternative will be selected to resolve the conflict.
- During the on-going test, U-space adds the restriction area, which is entirely including the dFP area. Test objective: the proper handling of this fact by Trial Controller – fast termination of the on-going dFP.
- Incoming weather alert from supplementary service provider – warning or critical. Test objective: to see if it is well handled by Trial Controller.
- Warning/alert in case the UAS goes out of the defined dFP operation boundaries – to the buffer and beyond buffer zone. Test objective: to test the system in case of non-conformance situation and how conformance is restored.

Trial Controller tests:

- Verification of all UAS-related logs, which should be stored by Trial Controller. Test objective: to verify if all logs are stored, accessible and not corrupted.
- Handling of the loss of the one of C2 connection link (5G radio link loss) by Trial Controller/Facility. Objective: Define the algorithm of handling such situation in Trial Controller/Facility/UAS.

5G network measurements:

- Logs from different 5G infrastructure elements: 5G RAN and Core Network
- EDGE logs: latency, RNIS service, application specific logs, infrastructure logs

5G mobile measurements:

- 5G UE measurements: RSRP, RSRQ, CQI, DL/UL throughput, BLER or FER, latency

Tactical deconfliction:

- Two drones are approaching each other until the moment they are so close that the alert is raised by U-space. Objective: how alarm is raised from U-space, other modules and how is it transferred to GCS and UAV.

4.1.4 UC2:SC1 Monitoring a wildfire

The 5G!Drones partners conducted remotely UC2:SC1 Wildfire pretrials in June 2021 to test Release 1 “Integration validation release” solutions and WP2/WP3 enablers and to collect inputs for 5G!Drones next developments and actions.

Detailed mapping to the facility of UC2:SC1 Monitoring a wildfire

We consider a scenario that a team of fire fighters, equipped with their mission critical communication system, performs a coordinated operation in a forest fire scene with the aid of a fleet of drones. Drones can support rescue operations in limited time. The best solution is combining drones with firefighters. Firefighters can provide area where they need aerial live video feed to get overview from larger area. 5G cellular drone provides video feed from operational area. 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.

Components used in trial

1. eNodeB, EPC: are already deployed at the facility. It can be seen as Physical Network Function (PNF). EURECOM is providing these elements.
2. Cellular drone: to be deployed when the trial is ready. They should include the C2 link and video streaming from the drone. Provider: CAF.
3. Mission Critical Service: a virtualized service running on a virtual machine. Provider: AIR.
4. C2 system at the EDGE for controlling cellular drone flight. Provider: CAF.

Connectivity

1. C2 link service should be connected to the UEs data plane traffic, via traffic redirection to be done at the EPC, and another connection is needed to the Internet to communicate with UTM.
2. MCS platform should be connected to the UEs data plane traffic to share multimedia and data streams between all the UEs. Another connection is needed to the Internet to communicate with command centre (in charge of tactical operation (defining subscribers, rights, communications, etc.) and to load maps tiles.

Architecture

Architecture of trials is shown in the Figure 56 below.

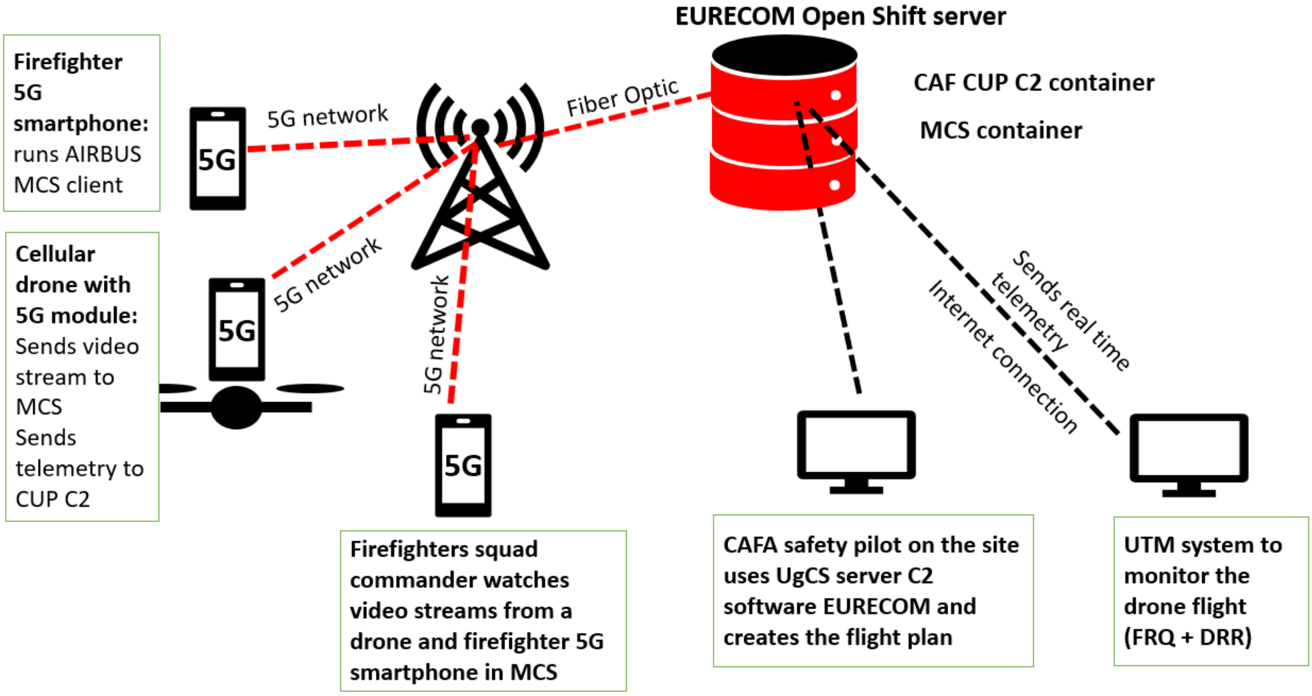


Figure 56. Description of UC2:SC1 trials' architecture

4.1.5 UC2:SC2 Disaster recovery

This use case scenario is a "disaster recovery" simulation in which UAVs are used to simultaneously and autonomously provide on-demand network connectivity and video footage of the affected area. UAVs can interconnect and communicate with ground stations over direct D2D links, allowing for the rapid deployment of a wireless backhaul in situations where capacity is needed on an expedited basis. These UAVs can then bridge the signal for backhaul interconnect to provide ultra-reliable, low-latency wireless connectivity to end-users in need. These networks allow both victims and emergency workers to communicate when it is most important.

This scenario will make use of two UAVs (hereafter referred to as the network UAV and the video UAV). Both UAVs will be augmented by a small on-board computer (UL-ACE) and managed by a software pilot (UL-CCP) hosted at MEC. Initially, the video UAV will patrol the affected area, streaming video to services hosted at MEC. These services will analyse the video stream for potential humans on-site. Once a human is detected in the video stream, the network UAV will be autonomously dispatched to the detection coordinates in order to provide ad-hoc network connectivity to the end-user in the disaster area. The network connectivity will be provided via a Wi-Fi access point, although this can optionally be substituted for a 4G small cell (if available).

This service will require two Docker containers deployed on the MEC infrastructure. The first provides the C2 link service (UL-CCP) for controlling and coordinating between the UAVs in use. The second VNF provides video stream reception and analysis. Both VNFs require two connections – one to the internet and one to the UEs (i.e. the video and network UAVs). The external network connection is required to communicate with externally hosted services such as UTM and the 3020 LifeX Solution.

The Figure 57 below provides the architectural schematic of the UC2:SC2 setup.

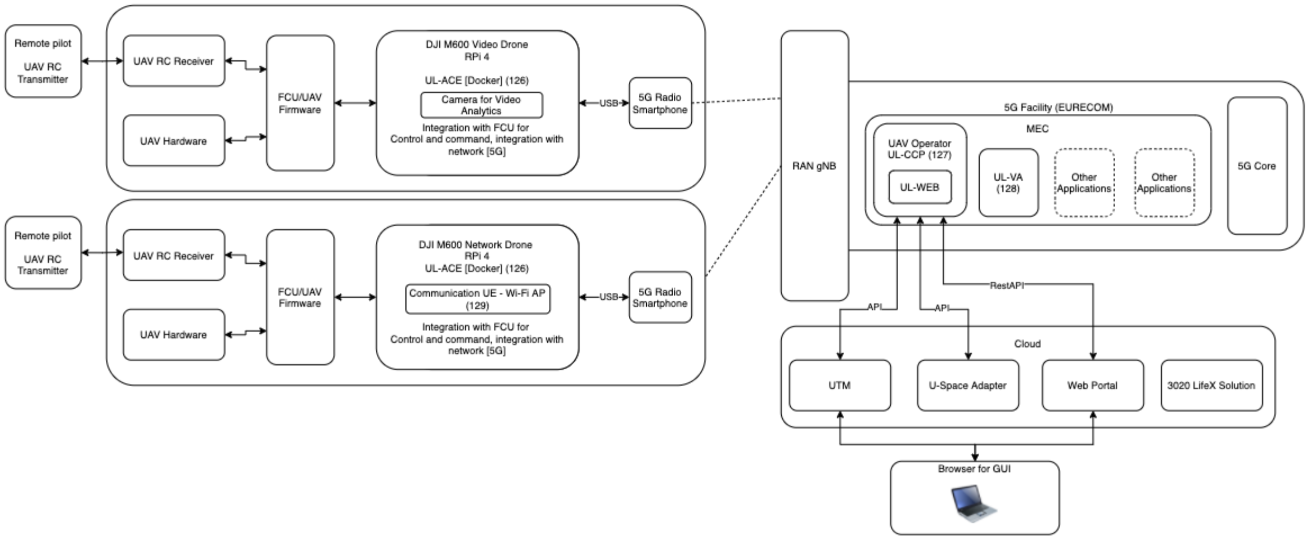


Figure 57. Description of UC2:SC2 trials' architecture

Trial Components:

1. UAV Components: 2 × DJI M600 Pro, Video Streaming Camera, Wi-Fi Access Point, 5G Smartphones (with USB tethering). Providers: HEP, UMS, EUR
2. UAV Operator Components: UL-ACE, UL-CCP, UL-VA. Providers: UMS
3. UTM Components: Support for dFPL (drone Flight Plan), Situational awareness (airspace perspective) service to submit dFPL. Provider, U-space telemetry endpoint. Providers: FRQ, DRR
4. 5G Components: 5G Network, MEC Infrastructure. Provider: EUR
5. Other Components: 3020 LifeX Solution. Provider: FRQ

Frequentis LifeX solution proof-of-concept activity

The 3020 LifeX solution developed by Frequentis is a public safety product suite for emergency management. In the context of UC2:SC2, Frequentis will be performing a standalone proof-of-concept activity to validate their technology.

During the trial, a person in distress (PiD) will send out a SOS signal to the Frequentis LifeX Dispatcher client (similar to 911). The dispatcher will then relay the information to the LifeX system hosted on the U-space. LifeX system is a control centre for management of operations that will verify this information and provide the relevant first responder(s) with the location of the PiD for immediate dispatch.

As we will be emulating the scenario, UML could act as the artificial first responder during the trial. This activity will be fully managed by Frequentis and will not interfere with the primary activities of the trial. Details of implementation are yet to be charted out. The objective is to test and validate this technology so it can be adapted to help people requiring assistance during emergencies in real-life scenarios.

A preliminary version of the planned/proposed architecture scenario is shown in the Figure 58 below.

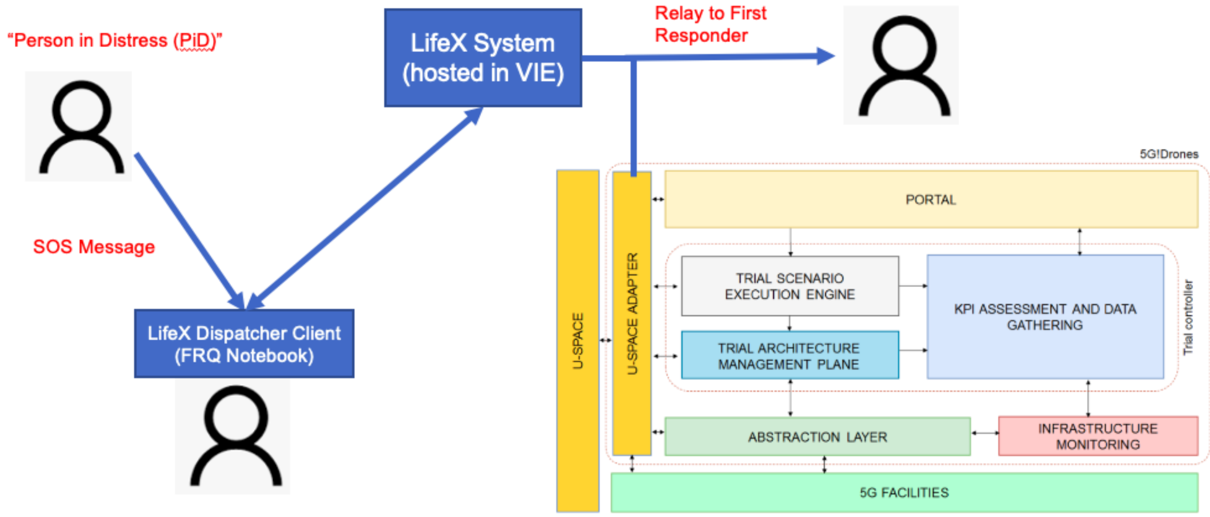


Figure 58. Architecture of Frequentis LifeX System tests

4.2 Trials in the Aalto University campus

In Aalto university campus will be conducted UC1:SC3 and UC3:SC2 trials. The test area has been selected close to the 5G Base station (BS) to ensure a strong enough 5G coverage to perform the tests as shown in the Figure 59 below.

4.2.1 Locations and aviation restrictions map

Link to the Google Maps: https://goo.gl/maps/YhgYzFSaiqQXTqRy7

Coordinates: 60.18787005218471, 24.819457034055493

Figure 59. Aalto University trials site map screenshot from Google Maps

The air navigation map Aviamaps.com shows that in Aalto University campus is maximum flying height 120 m as shown in the Figure 60 below. Link to the Aviamaps: **https://aviamaps.com/map?drone#p=15/60.18784/24.81875**

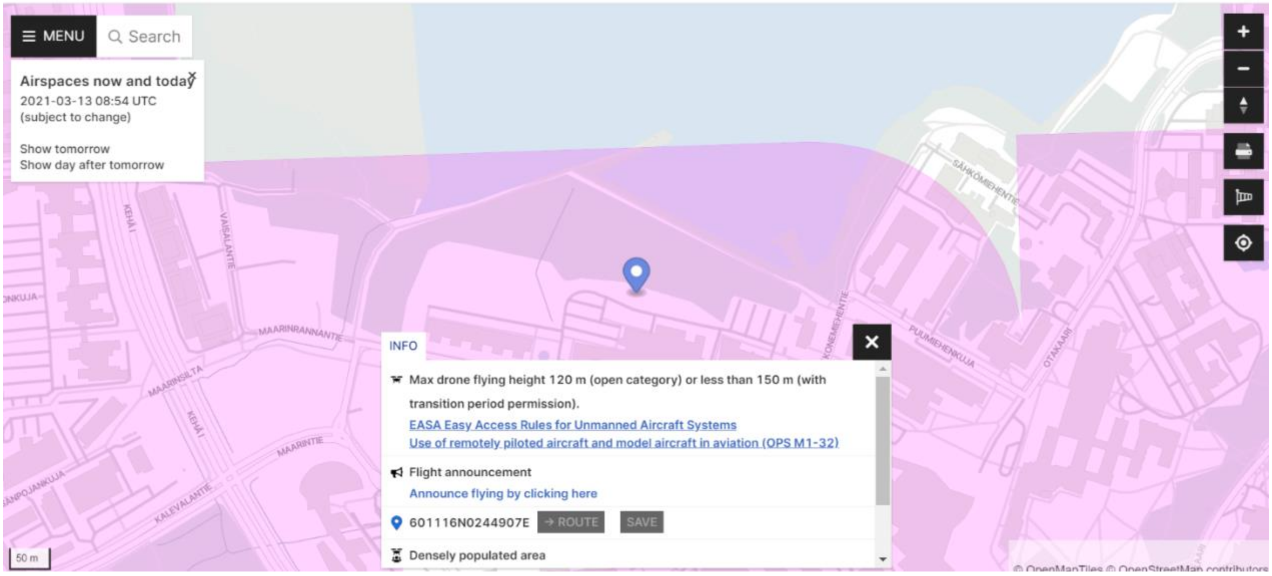


Figure 60. Screenshot of the Aalto University campus on the air navigation map Aviamaps.com

4.2.2 Available frequencies and bandwidth parameters in facility 5G network

Table 28. Available frequencies and bandwidth parameters in the 5G network of the Aalto University

Name	Frequency in MHz	Bandwidth in MHz
Band n28	3640-3700	80

4.2.3 UC1:SC3 UAV logistics

Architecture and description

The purpose of this scenario is to demonstrate how UAVs thanks to 5G network capabilities can provide logistics solutions. The 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 through CAFA Tech Field GIS C2 system for Drone Logistics. The delivery is conducted by CAFA Tech drone, which is the drone built by CAFA Tech based on the PX4 Drone Vision Kit. When the drone reaches its destination, there are inaccuracies with GNSS (Global Navigation Satellite System) signals. Therefore, the operator of the drone logistics company (actually the CAFA Tech operator) takes over the control of the drone. The operator uses the video stream from the drone camera and uses the gamepad to conduct the landing of the drone to the Delivery Box. Video transmission and drone remote control take place over a 5G network. When the drone lands on the Delivery Box the drone then releases paracetamol thanks to drone's electrical hook mechanism. During the flight virtual Air Traffic Control (ATC) operator monitors UTM system and CAFA Tech drone flight thanks to U-space integration via CAFA Tech UgCS C2 system.

The architecture is described in the Figure 61 below.

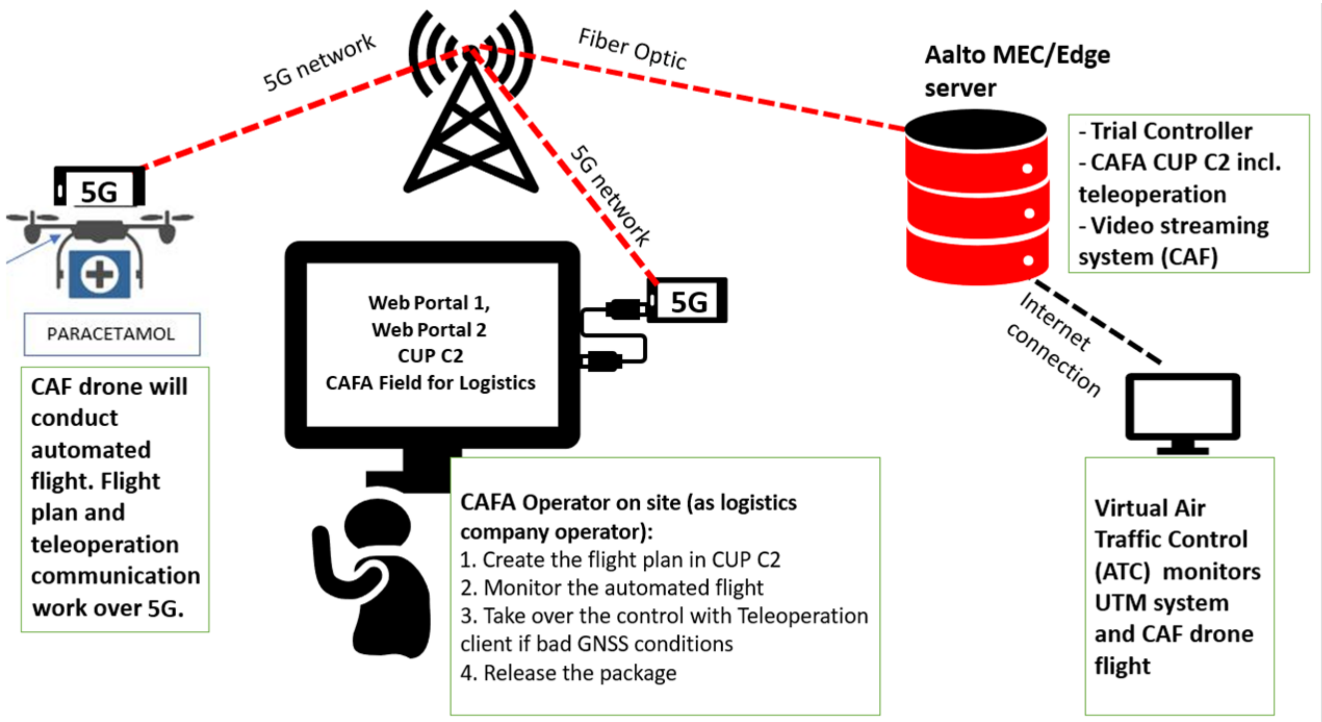


Figure 61. Description of UC1:SC3 trials' architecture

4.2.4 UC3:SC2 UAV-enhanced IoT data collection

Architecture and description

In this scenario UAVs will be used to provide IoT services from height. Each UAV will be equipped with a set of IoT devices to measure different parameters such as temperature, humidity, etc. The drones will be controlled by a software pilot ensuring C2 services, while the data collected by the drones will be processed by a dedicated service. For this end, the facility will make use of its cloud/edge server to host the application services (the software pilot and the IoT data processing services).

Components used in UC3:SC2:

- eNodeB, gNodeB, Core network: are already deployed at the facility. It can be seen as Physical Network Function (PNF). Aalto University is providing these elements.
- UE Drone: which is a drone with 5G connectivity (which is provided by using a phone). The drone is also equipped with a set of IoT devices to capture data while it is flying.
- C2 link service: represented by the software pilot of Aalto University.
- IoT data processing services: represented by the service of Aalto University used to query, collect and store IoT data.

During the trial, it is planned to test the whole scenario with the WP2 Trial controller and WP3 enablers integrated during the relevant Integration Release of 5G!Drones project. The architecture is described in the Figure 62 below.

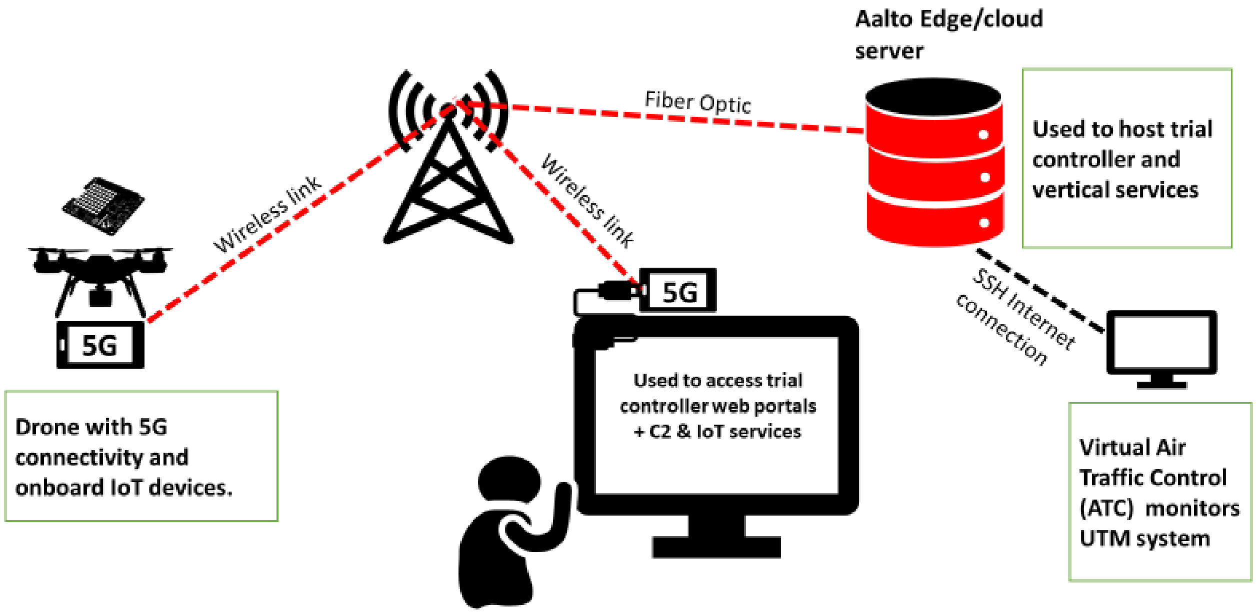


Figure 62. Description of UC3:SC2 trials' architecture

Aalto University complies with the regulations related to flying drones in Finland. The department of communication and networking (COMNET) of the university is taking care of requesting the necessary permits from the Finnish Transport and Communications Agency (TRAFICOM). The UAVs operated by Aalto University are already registered. Furthermore, Aalto University has also acquired the permit to mount a 5G modem on the top of its UAVs.

In the Aalto University Otaniemi campus, there are no areas where flying an unmanned aircraft is restricted. Nevertheless, occasional or temporary flight restrictions may occur. The temporary flight restrictions will be declared beforehand (the university maintains an internal page on the necessary information about operating drones).

4.3 Trials in the University of Oulu campus

In University of Oulu 5G facility will be conducted 5 trials: UC1:SC2, UC2:SC3, UC3:SC1, UC3:SC3.

4.3.1 Locations and aviation restrictions map

Location of Trials: Botanical Garden of the University of Oulu as shown in the Figure 63 below.

Link to Google Maps: **https://goo.gl/maps/hM81qf1pfu7VpuDs9**

Coordinates: 65.063435, 25.463098

Figure 63. Oulu trials site map screenshot from Google Maps

Air navigation restrictions for drone operations are described in Aviamaps application and shown in the Figure 64 below. Link to the Aviamaps query:
https://aviamaps.com/map?drone#p=15/60.18784/24.81875

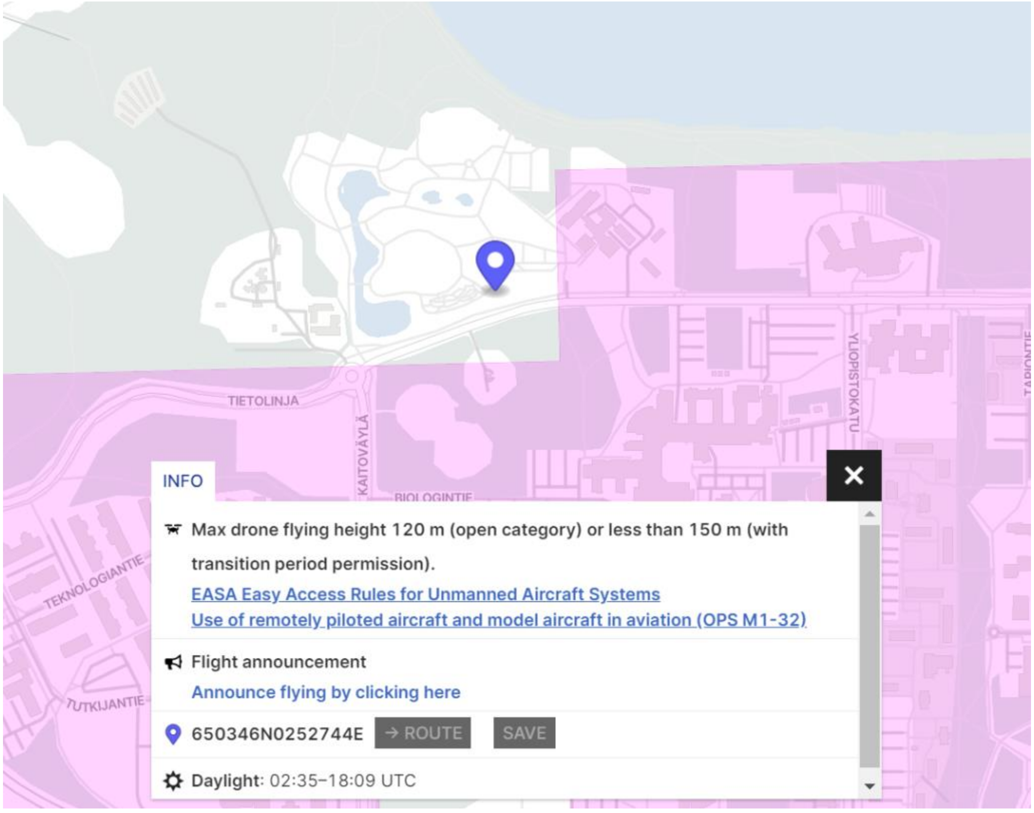


Figure 64. Screenshot from the air navigation map Aviamaps.com

4.3.2 Available frequencies and bandwidth parameters in facility 5G network

Table 29. Available frequencies and bandwidth parameters in the 5G network of the University of Oulu

Name	Frequency in MHz	Bandwidth in MHz
LTE Band 1	2100	10
LTE Band 40	2300	20
LTE Band 7	2700	10+5
Band n78	3500	60

4.3.3 UC1:SC2 3D Map and supporting visualization/analysis software for UTM

This use case will demonstrate, how drone-based laser scanning and video image stream is combined to map the environment. Further, it will contain a 3D visualisation with VR support that can be used for visualising multiple drone operation (and UTM) in real time remotely.

Architecture has 3 main components, one for Virtual Reality user interface, running in PC with high performance GPU and VR headset. The second component is software that creates a 3D world model, combining prior information generated from data downloaded from UTM system, real-time information of drone movements on the area, and real-time updates generated from real-time measurements of the drones. The third component is sensors' integration software that combines the sensors' data from drones, filter the date and reconstruct size optimized objects representing the real operation environment. The architecture is described in the Figure 65 below.

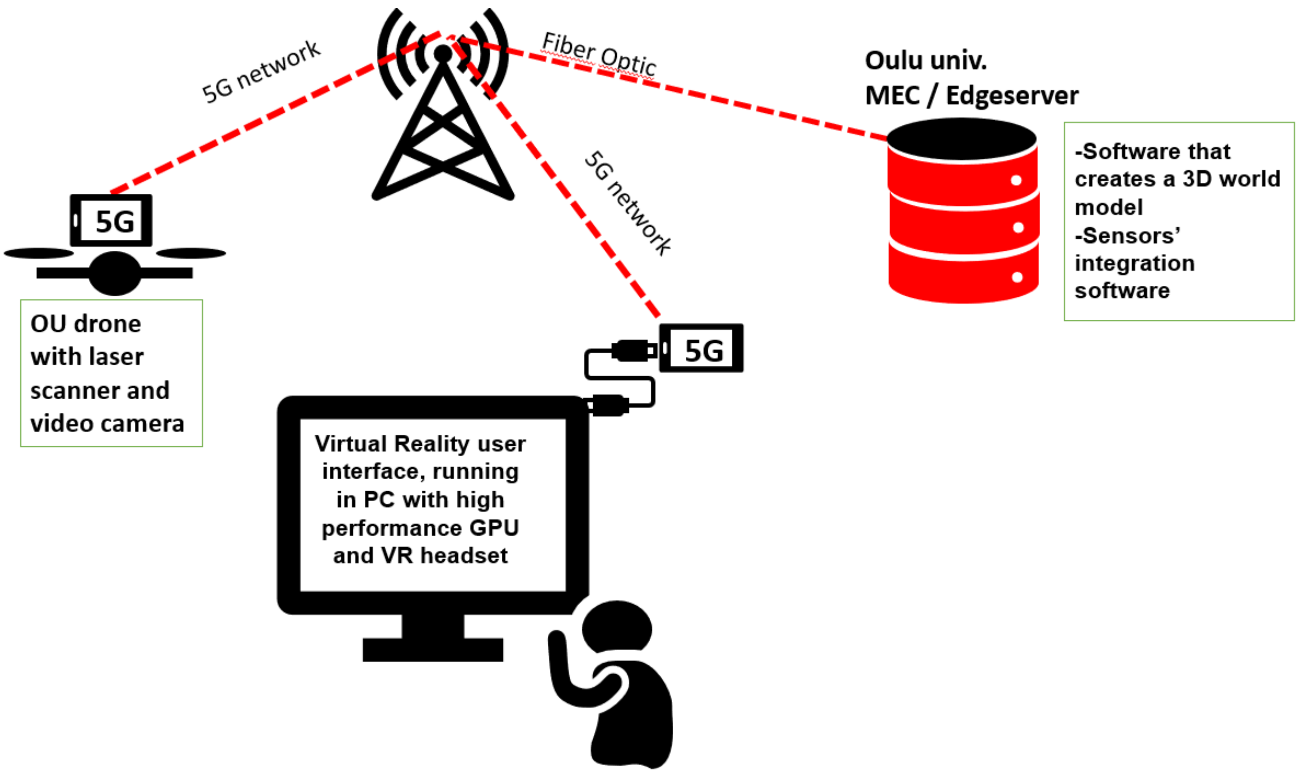


Figure 65. Description of UC1:SC2 trials' architecture

In the Virtual Reality user interface, along with physical objects in the environments that are represented, also non-visual information can be visualized. This can be, for example, spatial signal quality measurements represented as "cloud" and colours on measurements coordinate.

During the demonstration, non-real-time (generated from UTM system and a prior map) and real-time (generated by drone sensors) objects from environment are visualized in virtual reality user interface. User can see flight paths in VR and adjust flight path points. When path is defined, user can execute flight and follow the progress as true location of the drone is replicated to virtual world on same coordinate. Along the flight, optionally some 3D detected objects are visualised during flight as well as optional non-visual information like signal strengths on measurement location.

The demonstration will be performed using a custom drone developed by the OU team, as well as using the developed Cable Drone device. The Cable Drone is a device that is using a cable to move between two locations. It allows safe and precise movement, repeatability and long-time tests.

To realize repetitive and carefully controlled testing, a Cable Drone facility will be constructed. With it both indoor and outdoor experiments can be done.

4.3.4 UC2:SC3 Police including counter-UAS

Architecture and description of the scenario

This use case will demonstrate how remotely piloted UAV and video analytics can be used for police tasks, including counter-UAS activities using 5G communication. The police are preparing for a VIP visit. The police also uses a drone that automatically flies and streams video to the video analyser software at the command centre. The video analysing software, CAFA Tech VideoLyzer, installed on MEC, uses videos and photos provided by the drone. As a part of the VIP visit, a temporary No Fly Zone (NFZ) and restricted ground area are established.

During the visit, the police drone flies on autonomous mode. The police drone streams continuously the video feed to the MEC server where at the same time, computer vision software CAFA Tech VideoLyzer works. CAFA Tech VideoLyzer detects a suspicious activity (person or drone on restricted area). The police operator then changes Police drone control from automated mode to teleoperation mode and flies near the suspicious person and affects the person to stop the illegal activity.

The description of the architecture of UC2:SC3 is described in the Figure 66 below.

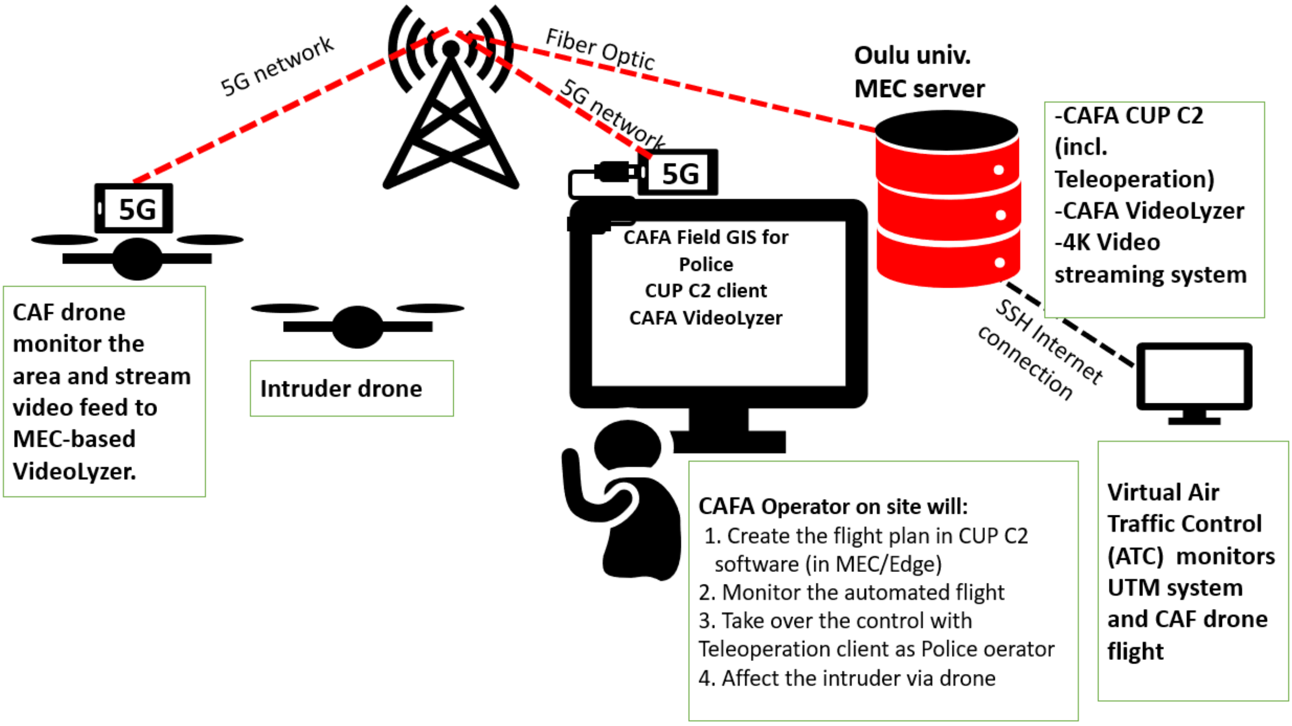


Figure 66. Description of UC2:SC3 trials' architecture

4.3.5 UC3:SC1:sub-SC1: 3D mapping of 5G QoS

Architecture and description of the scenario

This use case will demonstrate how 5G QoS mapping is done using 5G MEC based on software for measuring 5G QoS the communication company ordered from a drone company for the 3D mapping of 5G QoS. At first, the drone operator takes 50-80 photos, which are then processed to point cloud. Point cloud is used for creating 3D map. Then 5G base station icon will be placed on the 3D map.

The CAFA Tech cellular drone then carries 5G UE to measure the quality of 5G coverage from various positions with 3D coordinates (x, y, z). During flight the operator and safety pilot monitor the automated flight. Measuring results are transferred to the server and then results visualised on the CAFA Tech 3D Analyzer. The architecture is described in the Figure 67 below.

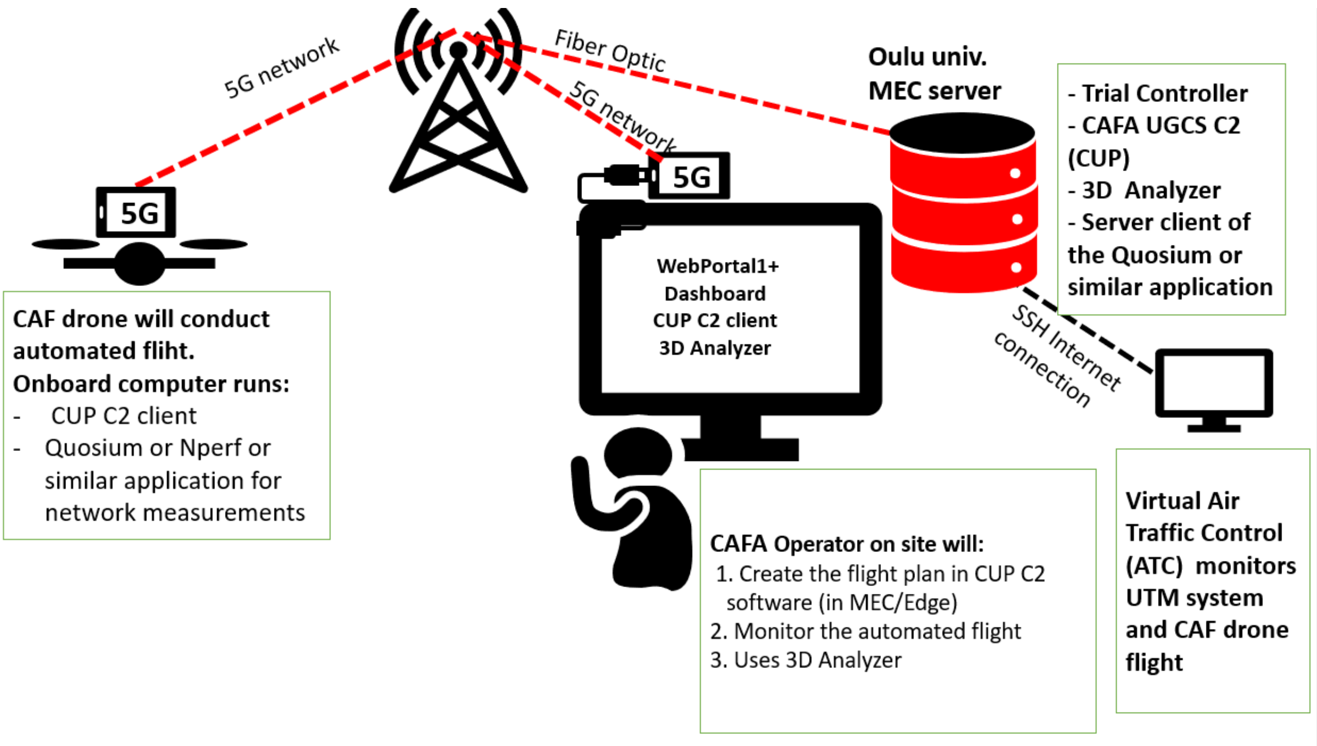


Figure 67. Description of UC3:SC1:sub-SC1 trials' architecture

4.3.6 UC3:SC1:sub-SC2 Long range powerline inspection

Architecture and description of the scenario

The purpose of this sub-scenario is to demonstrate how UAVs could be used in well-connected 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 if there is a power outage due to a storm.

The planned trial will focus on BVLOS operations and data intensive payload transmitting. The UAV will be connected to 5G network and will be flying semi-autonomously. The UAV is equipped with one LIDAR for collision avoidance, one LIDAR for infrastructure inspection and one camera for high resolution imaging. A mock-up power line course will be prepared and actual-looking power line elements searched in the trials.

Captured images will be sent to Hepta's cloud-based infrastructure inspection software uBird for analysis. Image processing results can be seen by the UAV operator in near real time via uBird's User Interface. Captured point cloud will be streamed to the UAV operator for real-time viewing and to the edge server for further processing.

The operator will control the drone over 5G connection via a dedicated C2 VNF in the 5G edge server. Additionally, the drone will have redundant C2 links over 4G and an additional safety pilot in LOS with 868 MHz remote control as shown in the Figure 68 below.

Additionally, to the sensor data, link latencies, UL and DL speeds, signal quality parameters, on board computer metrics, UAV telemetry and weather conditions will be logged during the trial.

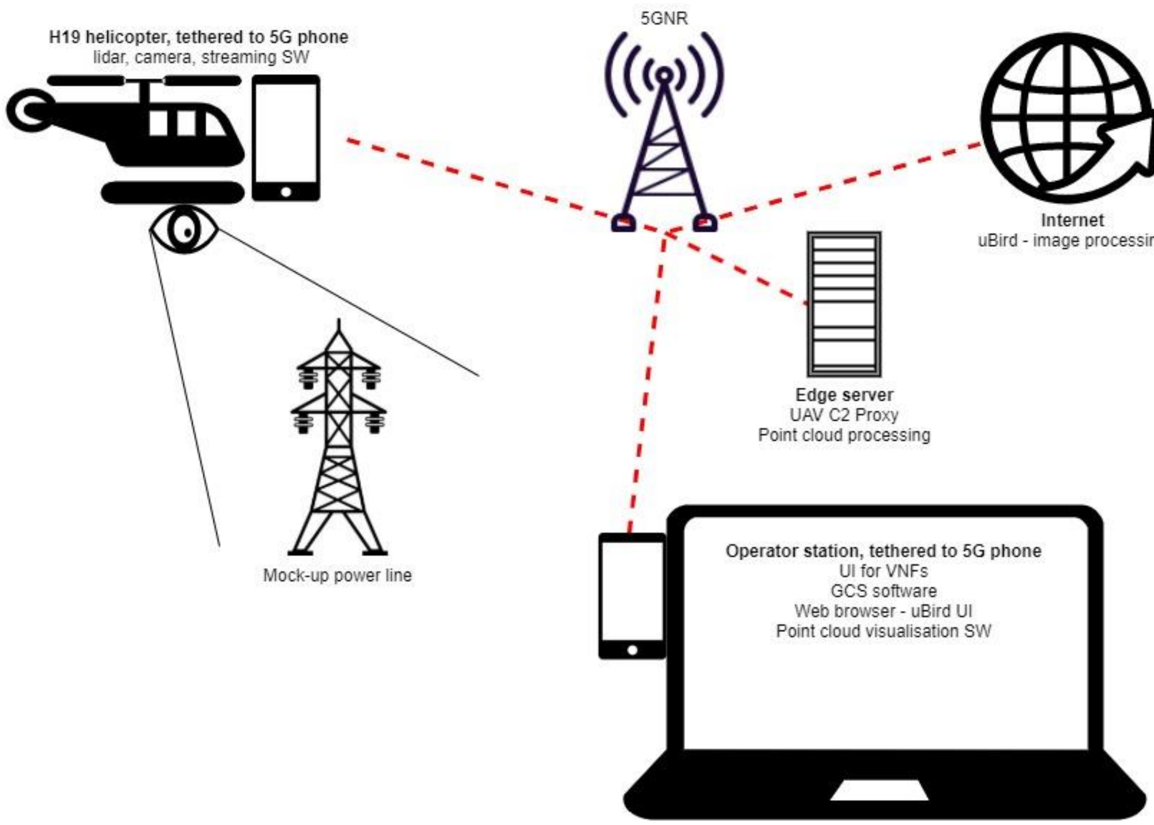


Figure 68. Description of UC3:SC1:sub-SC2 trials' high-level architecture

The flights are planned to take place over University of Oulu Botanical Gardens.

4.3.7 UC3:SC1:sub-SC3 SAR operations on the lake

Architecture and description of the scenario

This use case will demonstrate how 5G can be used for SAR operations in large body of water. During missions, our Hydradrone may operate in both flight and navigation mode, alternating between each of them depending on the mission specifications. For trial sessions, missions are expected to be carried out at the botanical garden, more precisely, around the small lake within the garden. Depending on the OU 5G coverage, trial sessions can be extended to Kuivasjärvi Lake, in the north of the University.

During the missions, data will be captured by different sensors onboard the drone, which will be streamed through 5G eMBB network slice to the Data processing application running at the edge. Next, the processed data (essentially, bathymetric data) will then be sent to the GCS running locally in ALE laptop in order to visualize the analysed data. Commands for controlling the Drone operation are expected to be sent through 5G uRLLC link. As shown in the Figure 69 below.

During the tests, 5G network parameters as well as other KPIs will be measured.

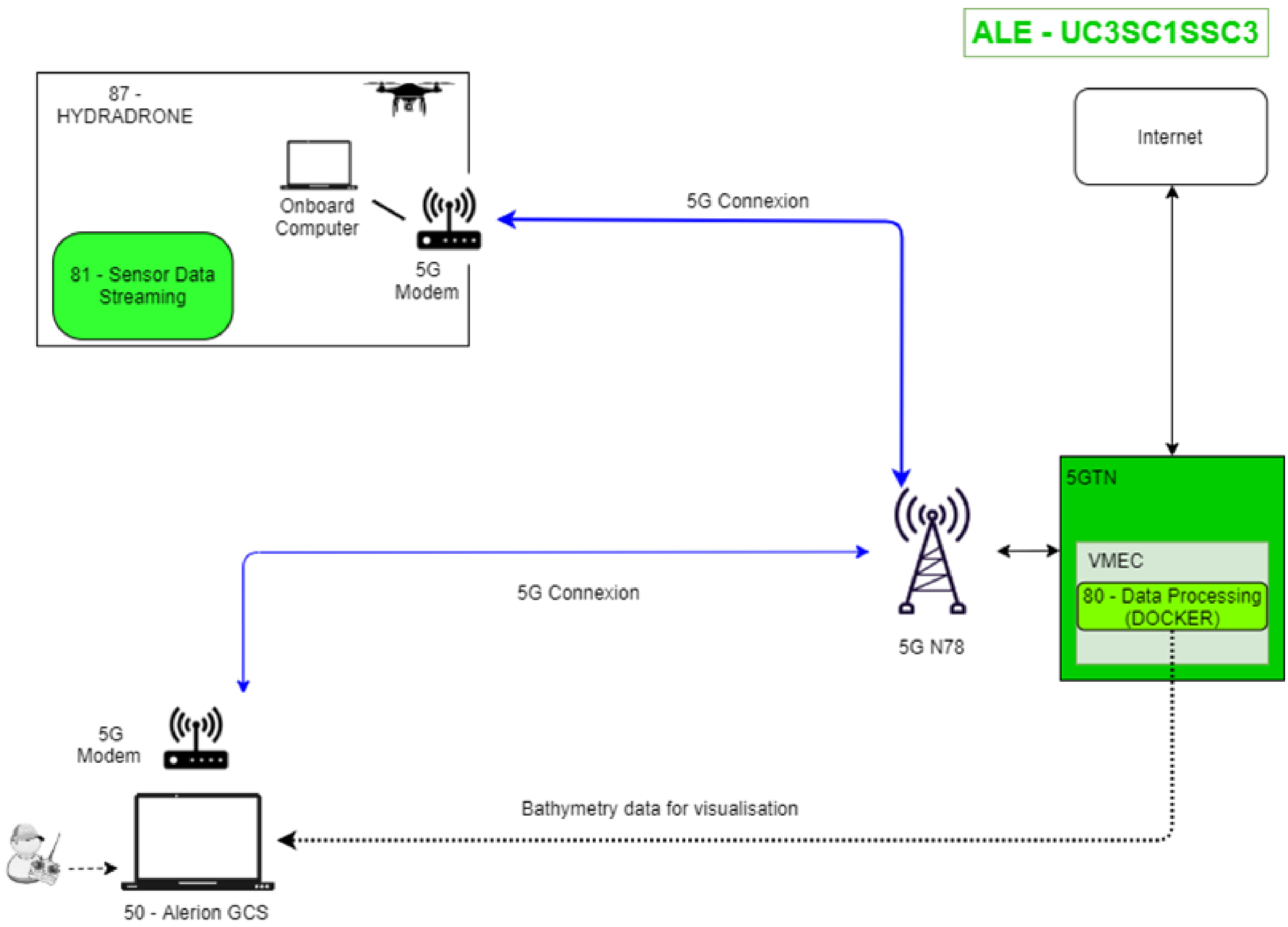


Figure 69. Description of UC3:SC1:sub-SC3 trials' architecture

4.3.8 UC3:SC3 Location of UE in non-GPS environments

Architecture and description of the scenario

The purpose of this scenario is to demonstrate how UAVs could obtain position information in situation where Global Navigation Satellite System (GNSS) is compromised. Example of this kind of situation could be flying indoors or nearby to high buildings.

As stated in D1.1, 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 also needed by the UTM. The secondary objective for the use case is to create a database for future positioning algorithms development. During the scenario deployment plenty of different sensory information will be collected in a synchronized manner and stored to a database as shown in the Figure 70 below.

In this scenario UE will collect 5G RF data. Then the data is used to train neural network, which will then provide alternative position for GPS. As the neural network is used for this scenario, the training needs to be done again if same system is moved to another location. In addition, the 5G radio must stay in same position with same settings as in the training phase. Usually this is not a problem, because the basic assumption is that once the radio has been installed, it will not be altered.

Positioning must be done close to the 5G radio for it needs data from the radio. Position information is not meant to be used for drone navigation, so the accuracy does not have to same accuracy as the integrated GPS. Assumed accuracy will be closer to 10 m than 1 m. At best this method could be used as backup position for the drone to hover above GSC until it is taken down manually. Naturally this method becomes more valid and precise if more than one 5G cell is available. When the position is more accurate it could be used to provide position for drone when it is taking off and landing

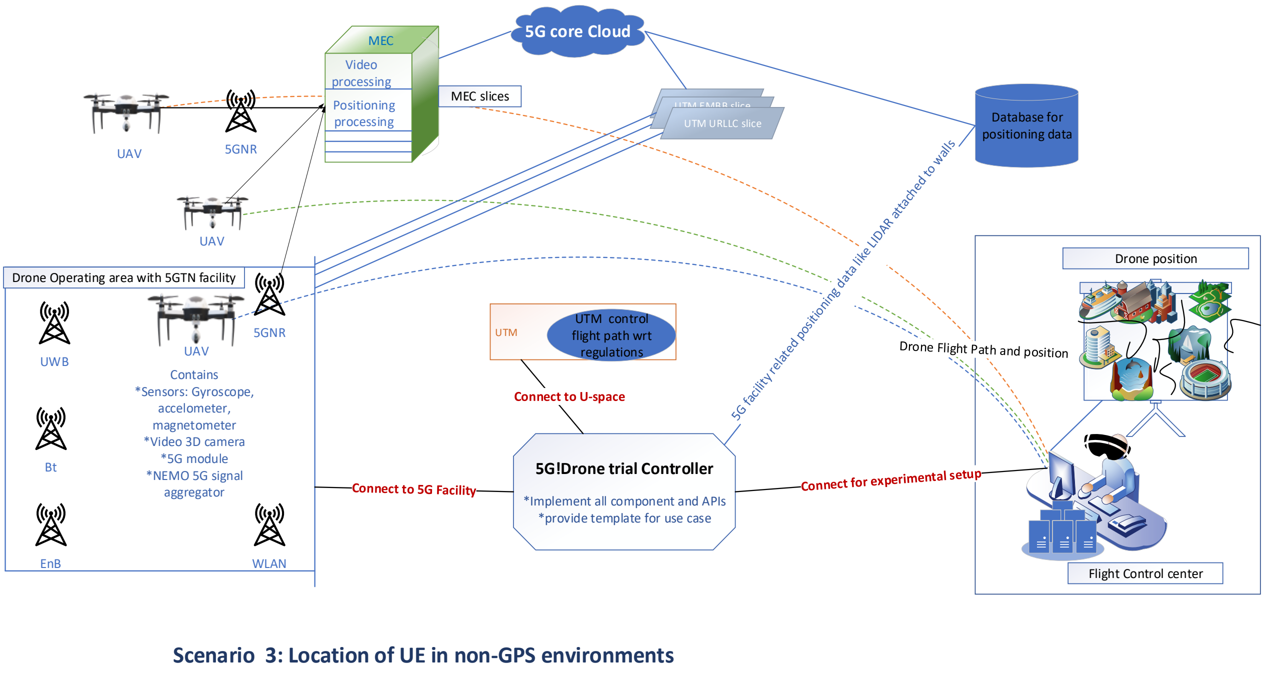


Figure 70. Description of UC3:SC3 trials' architecture

In the trials data will be collected for neural network. Data is collected with UE that on-boarded to a drone. The UE will collect data with Nemo outdoor. Pretrials are done together with University of Oulu and NOK and thus data can be possible collected also with cable drone.

Initially the Preliminary testing is done in Nokia premises. Then all the needed SW and HW are transferred to University of Oulu premises.

The pretrials consists of four phases as seen in the Figure 71 below. The phases are collecting the dataset, training the neural network, test the neural network and verify the accuracy.

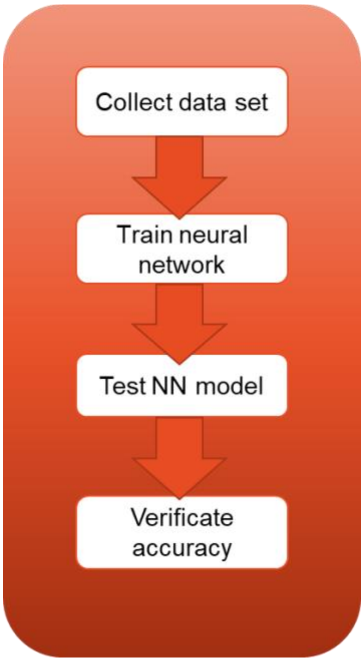


Figure 71. UC3:SC3 trial flowchart

In the Dataset collecting phase either actual drone or cable drone can be utilised. The dataset is later used to train the neural network, but in addition to that, data will be stored for further researches. Due to this, data, which might not be used for this pretrial, should be collected with various sensors if possible. Dataset, which will be used in this pretrial, consists of ground truth data and measurement data. Dataset is collected using Nemo outdoor from Keysight. Ground truth will be GPS position obtained from the RTK GPS, which can have up to one-centimetre accuracy outdoors. Measurement data consist of at least RSRP data from the 5G radio, but also if possible, from faster output. These data are collected simultaneously with timestamps either locally to company computer or uploaded to cloud.

Training the network is done by feeding it ground truth position and 5G parameters to the network. Then the network will gradually learn “hidden mathematical formula”, which will give out longitude and latitude based on the RSRP value it will receive. As of writing this report, the chosen neural network will be Artificial neural networks, which is running with Python. Training a neural network typically needs a lot of samples for it to work properly. For this reason, plenty of samples must be collected with multiple measurements. Guiding amount would be at least thousand samples. For this pretrial about 10 000 samples will be collected. In this sense cable drone is very convenient, because it can collect a lot of data compared to flying drones in the same amount of time. If the 5G radio does not change the network should stay the same and thus more training data could be collected over time when simultaneously doing other cases.

Testing the neural network means tuning the network, but also testing different variants of neural networks. Hidden layer of the network should be tweaked by someone who has good expertise in machine learning, because neural networks are known to be difficult by their nature. In this phase the amount samples are refined if needed.

The last part for the pretrial is to verify the accuracy of the neural network model. By this phase the algorithm is tuned as good as possible. This is done by making measurement flight inside the training area. Positioning can be visualised after post processing in the map application to show difference between the calculated path and actual coordinates. If the model calculation is fast enough and Nemo outdoor results can be upload to cloud, then the results could potentially be visualised in real time.

The pretrial will be conducted in the University of Oulu botanical garden. Before the trials 5G radio will be installed to University of Oulu premises and it will point to garden direction. The actual and more defined position in the map for the pretrial will be chosen later, based on the radio heading and beam coverage.

4.4 Athens trials of UC4:SC1 – Connectivity extension and offloading during crowded events

The trials of the UC4:SC1 are planned to be executed at different domains, namely the COS campus, the Egaleo stadium and the NCSRD campus. Each trial will focus on a different objective, highlighting the advances that are realised by complementing the 5GENESIS experimentation platform with 5G!Drones components, such as the U-space adapter, the Portal 1, etc.

4.4.1 Locations and aviation map data

Location 1: OTE Academy (COS campus) on Google Maps shown in the Figure 72 below.

Coordinates: 38.0493518229469, 23.788459469511736

Google Maps link: **https://goo.gl/maps/wd2SDq45c1oNmMgU7**

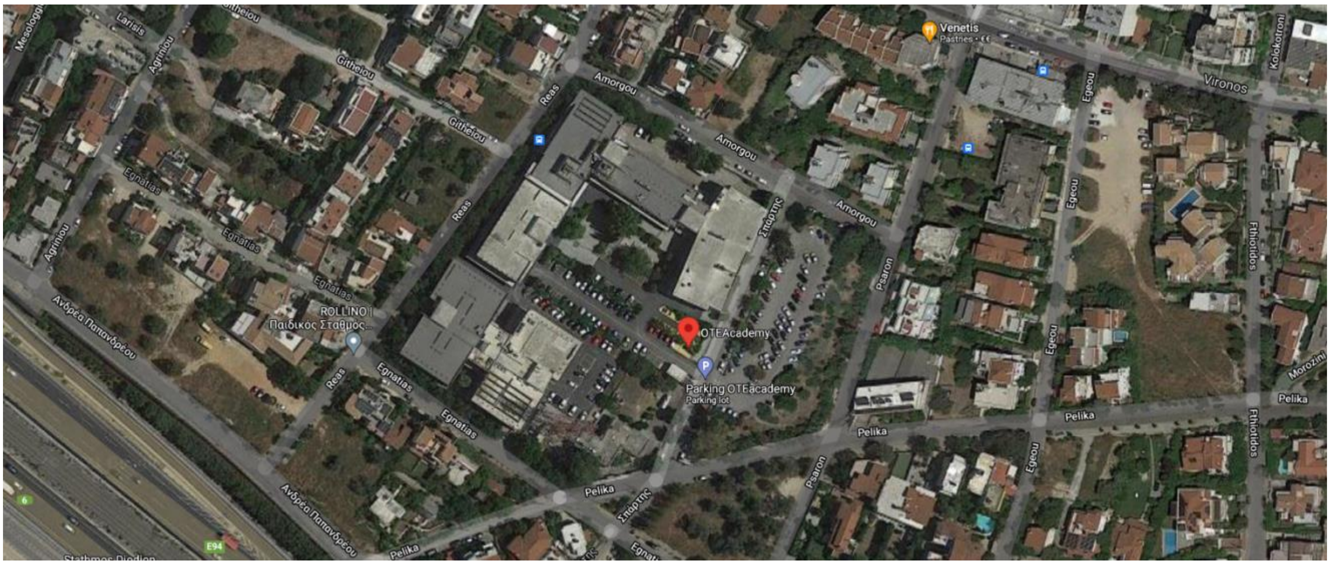


Figure 72. Location of the OTE Academy

Screenshot of the air navigation map of OTE Academy location indicates that there are flight restrictions shown in the Figure 73 below.

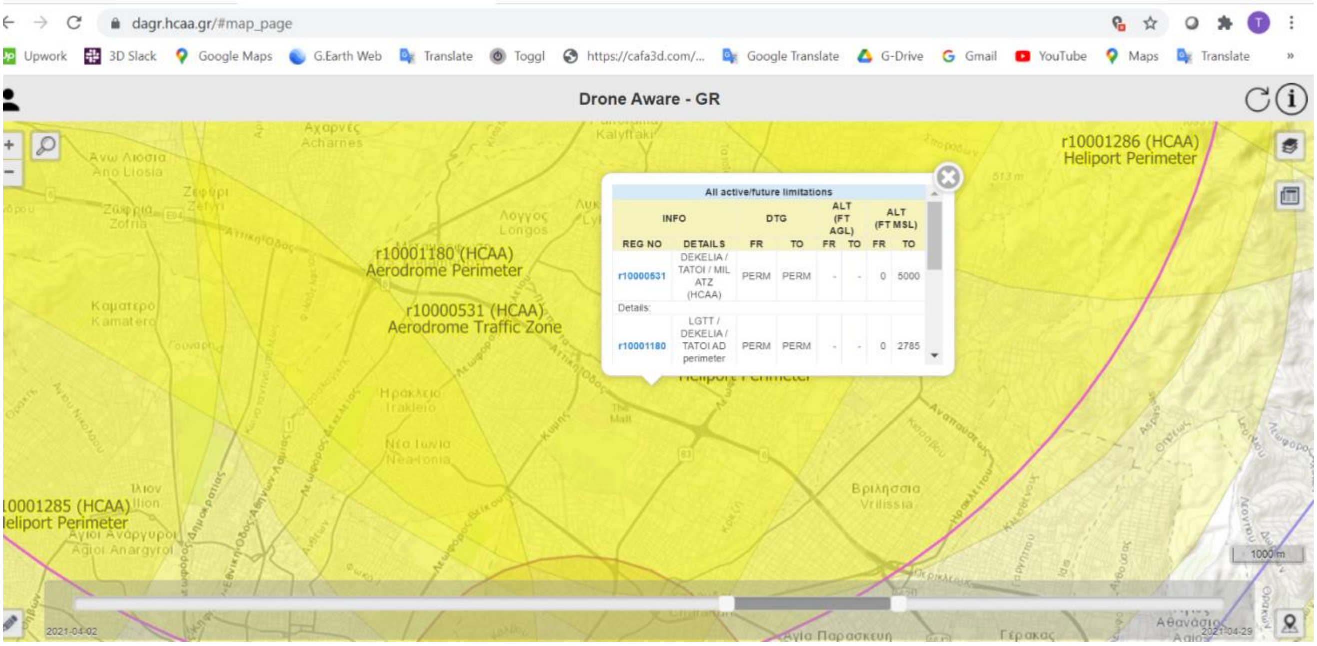


Figure 73. Screenshot from Hellenic Civil Aviation Authority map

Location 2: National Centre for Scientific Research “Demokritos” (NCSRD campus) on Google Maps shown in the Figure 74 below.

Coordinates: 37.99952898820401, 23.819995947612373

Google Maps link: **https://goo.gl/maps/5ny81BPMX1KnxCvk6**

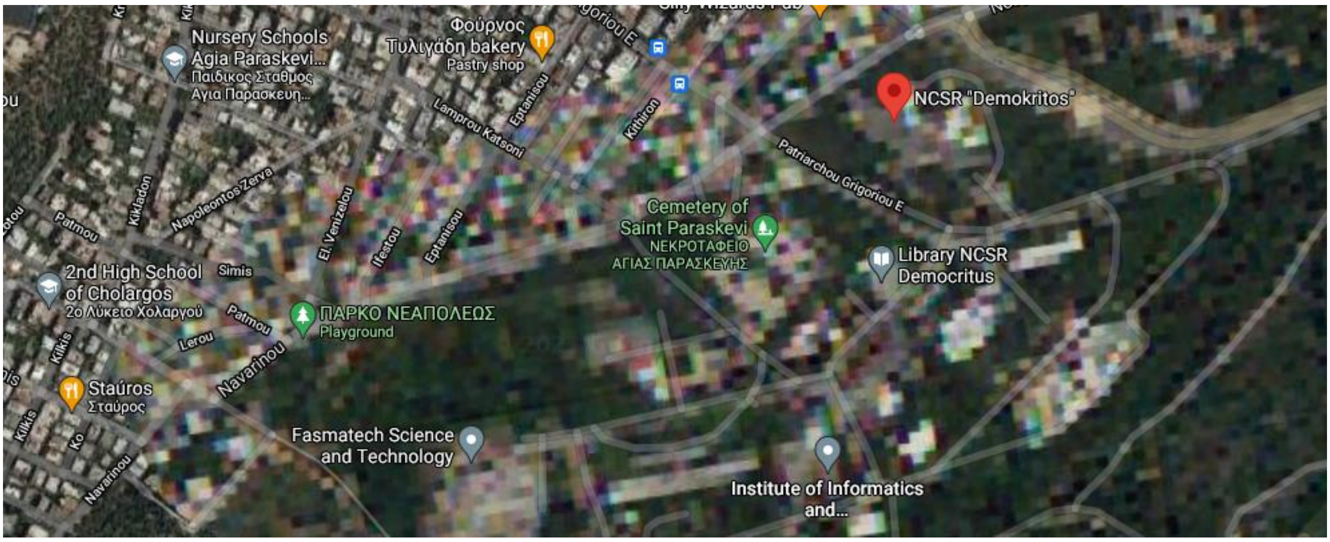


Figure 74. National Centre for Scientific Research “Demokritos”

Screenshot of the air navigation map indicates that there are no flight restrictions on NCSRD campus area as shown in the Figure 75 below.

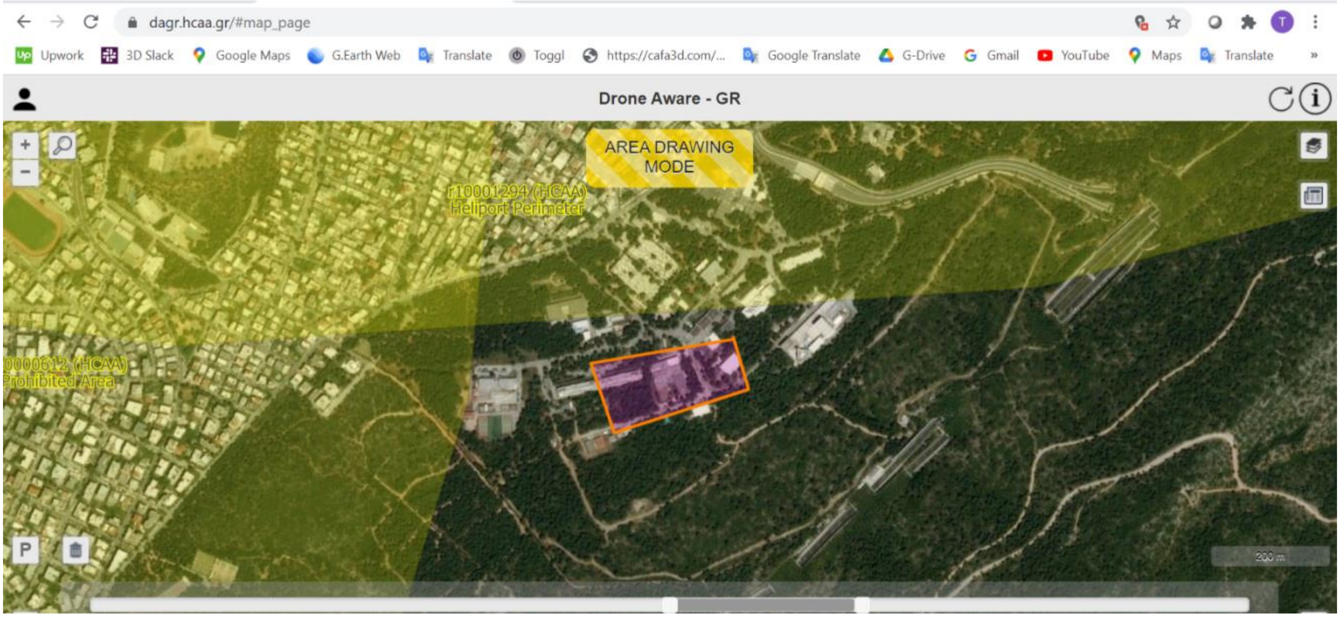


Figure 75. Screenshot from Hellenic Civil Aviation Authority map

Location: Stavros Mavrothalassitis Stadium

Coordinates: 37.987165264082236, 23.675983811180572

Google Maps link: **https://goo.gl/maps/C57SDnrtmTB5r1r58**

Screenshot of the map is shown in the Figure 76 below.

Figure 76. Stavros Mavrothalassitis Stadium in Egaleo

The screenshot of the air navigation map of Stadium of Municipality of Egaleo location indicates that there are flight restrictions as show in the Figure 77 below.

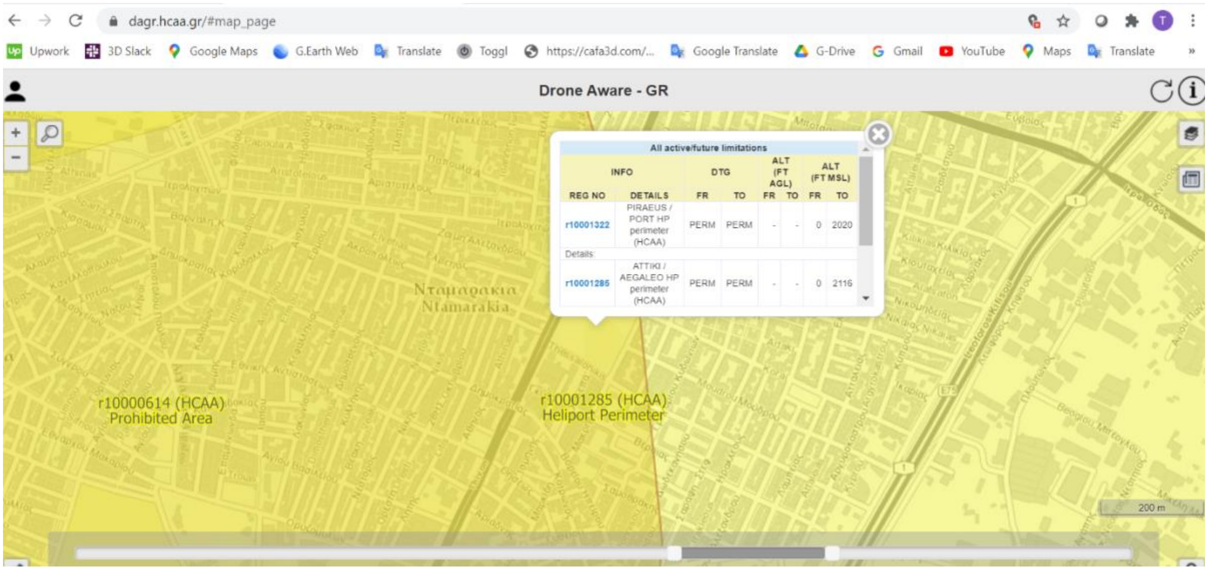


Figure 77. Screenshot from Hellenic Civil Aviation Authority map

4.4.2 Available frequencies and bandwidth parameters in facility 5G network

Table 30. Available frequencies and bandwidth parameters in the 5G network of NCSRD

Name	Frequency (MHz)	Description	Remarks
Band n78	3300-3800	5G NR	User plane
LTE Band 7	2600-2700	LTE Anchor for 5G NSA 3x deployment option	Control plane
Band n78	3300-3800	5G NR (academic frequencies)	User plane

4.4.3 Trials descriptions

4.4.3.1 Athens platform trial – July 2021 on top of 5GENESIS platform (COS-NCSRD sites)

Automated experimentation by Open 5GENESIS framework is described in the Figure 78 below:

The UAV flight is manual with C2 over 5G and experiment execution is automated with the 5GENESIS platform.

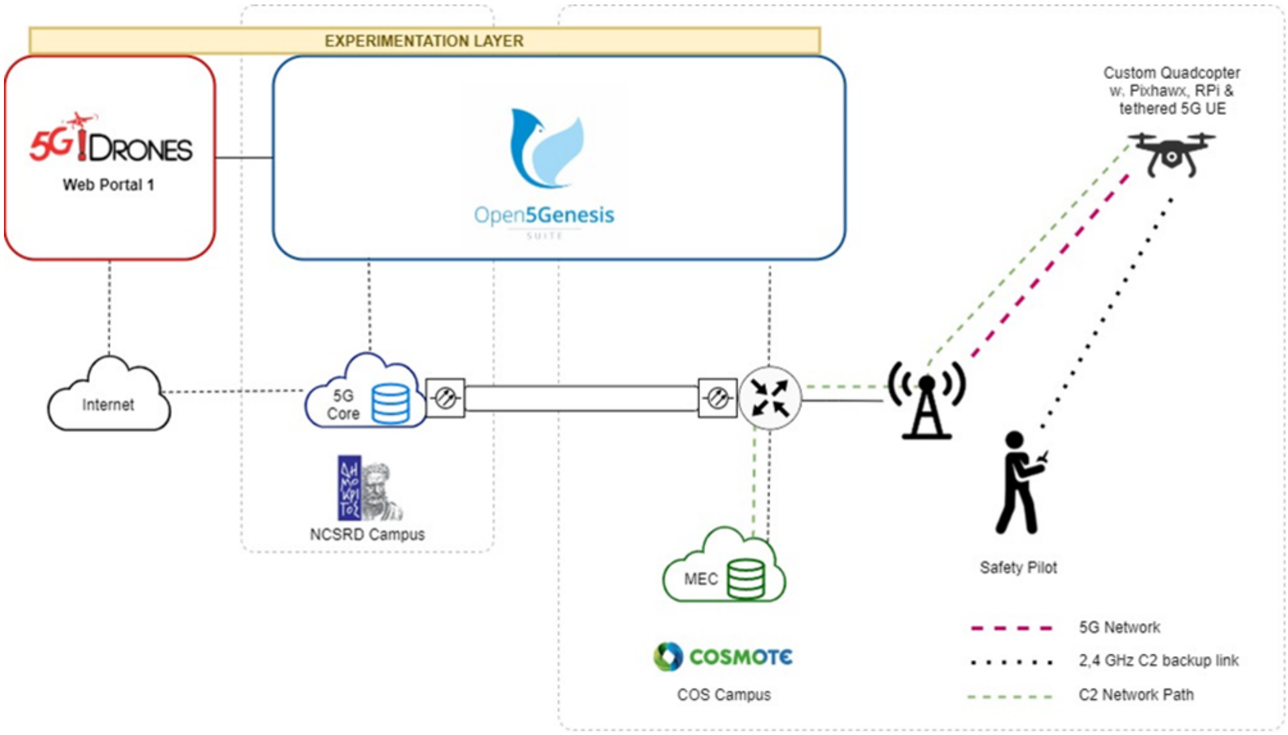


Figure 78. Architecture of Athens Platform Trial – July 2021 on top of 5GENESIS platform

The Pilot will control the Drone over the 5G network. Simultaneously, experiment execution will take place by utilizing the 5GENESIS platform and network performance measurements such as latency and throughput will be triggered from the 5GENESIS portal (Web Portal 2). The different experiment steps will be controlled exclusively by the 5GENESIS Automation Framework, including the Lifecycle Manager, the OpenTap sequencer and the relative probes that will be preinstalled on a companion computer placed on the drone.

Automatic UAV flight with C2 over 5G with Ground Control software deployed at MEC is described in the Figure 79 below.

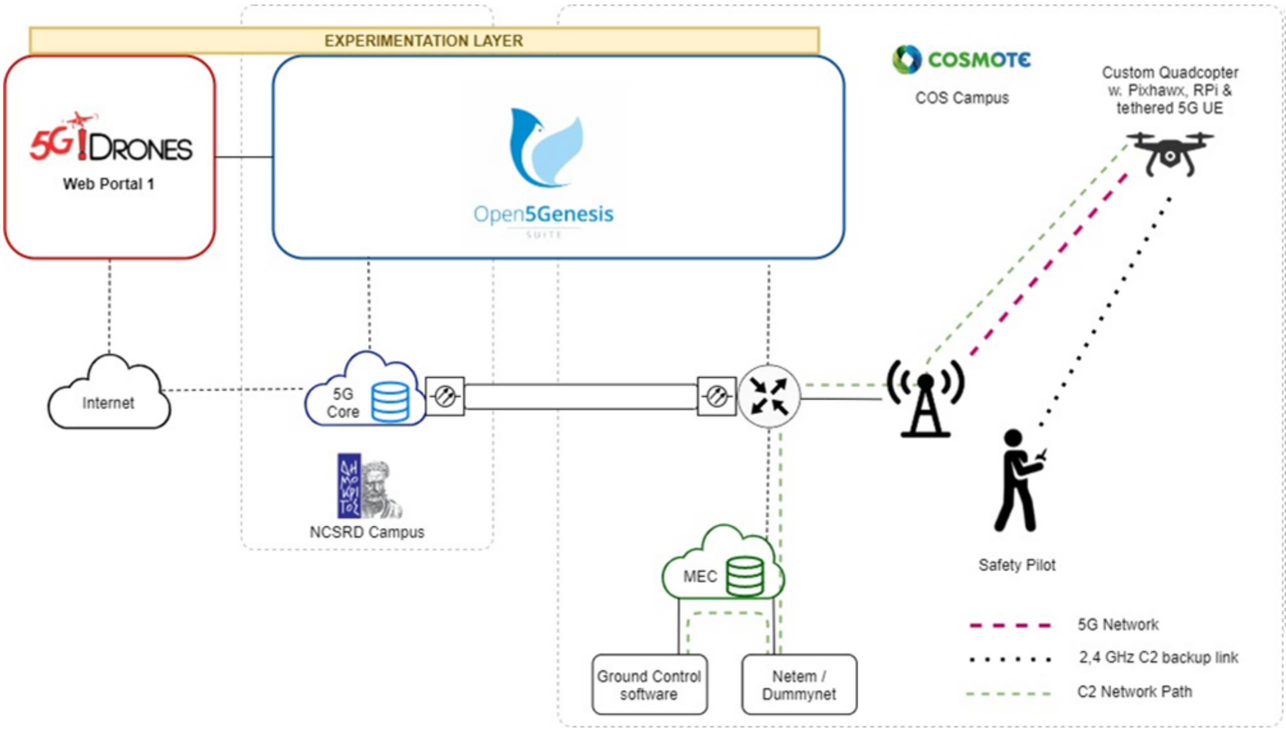


Figure 79. Automatic UAV flight with C2 over 5G with Ground Control software deployed at MEC

A predefined set of commands will be sent from OpenTap (the sequencer used by the 5GENESIS Automation Framework) to the Drone. “Send” and “Receive” timestamps will be captured and compared on each side in order to calculate latency for each command.

Additional non-5GENESIS experiments

Signal strength measurement with Android app & heatmap creation is shown in the Figure 80 below.

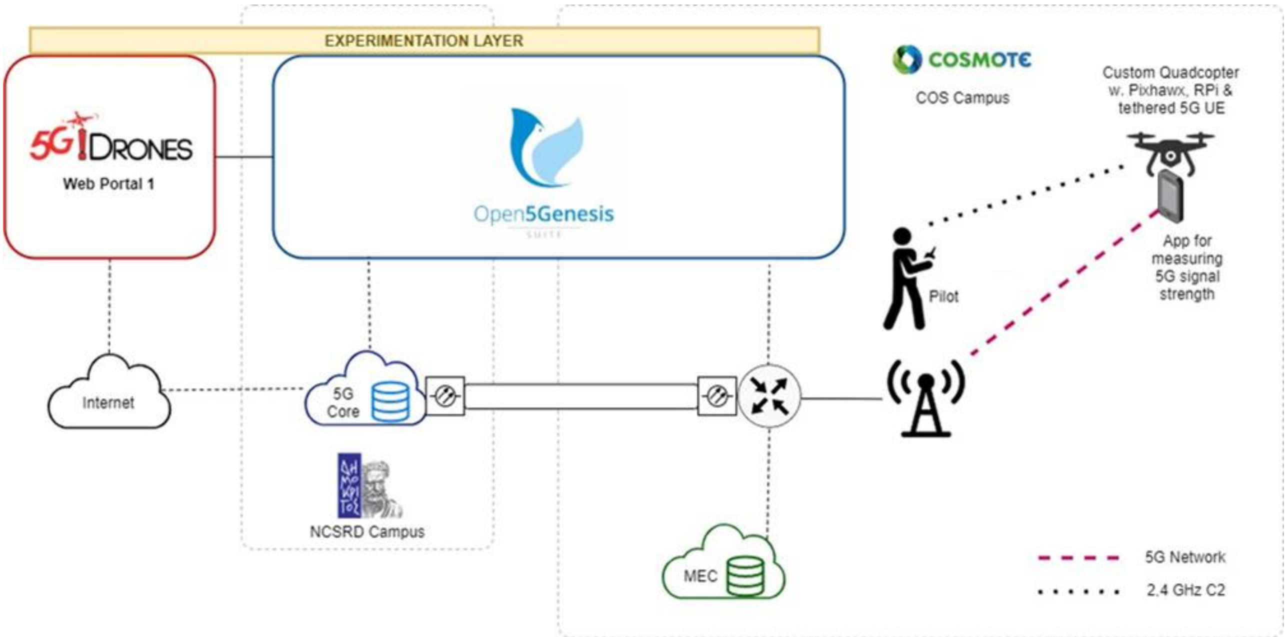


Figure 80. Signal strength measurement with Android app and heatmap creation

The flight will be manually handled over RF while the Drone will carry a Mobile Phone with an app that will store signal strength measurements across the flight. The measurements will be visualized directly on the 2D map used by the app and also stored for later use in order to produce a 3D heatmap with the signal strength. Stream video from Drone camera to service deployed at the EDGE is described in the Figure 81 below.

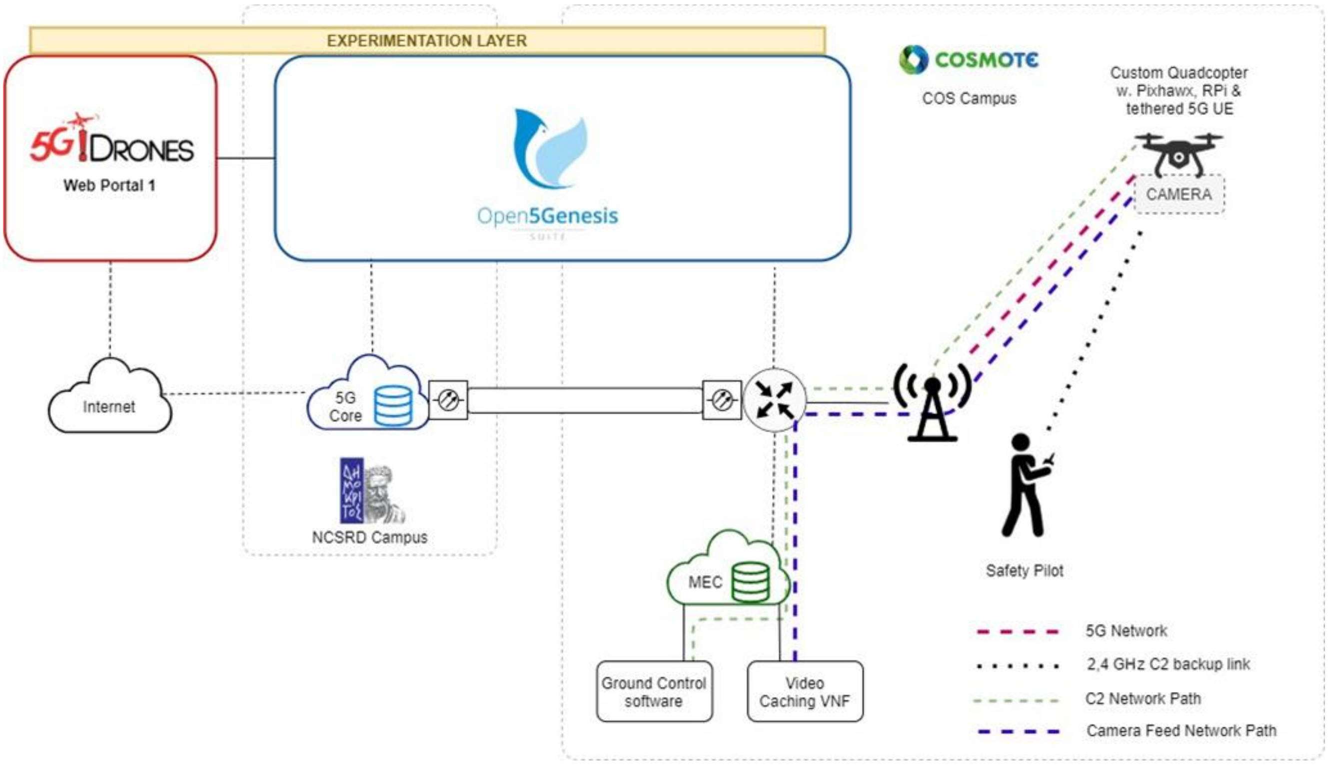


Figure 81. Stream video from Drone camera to service deployed at the EDGE

A predefined flight will start from Ground Control Software while the Drone will be equipped with a plugin camera. The camera will stream to a capture service on the EDGE using the 5G Network.

4.4.3.2 Trials in 2022 (Egaleo site)

Detailed mapping to the facility of UC4:SC1 – Connectivity extension and offloading during crowded events

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. Solution’s capabilities include autonomous flight planning and navigation, live-video streaming, utilising 5G User Equipment (UE) to provide ad-hoc connectivity to people as shown in the Figure 82 below.

The trials will be performed at the Egaleo stadium where the deployed infrastructure and the necessary components will be utilized in UC4:SC1. These components, thoroughly described in the next section, are comprised by the 5G system, the UAS deployed in the Edge cloud, the UTM deployed off-site, the Streaming server deployed in a private cloud and three drones, one per each task (patrolling, infrastructure, streaming HD video). In the variant that will be tested during the trials, the drone will be carrying a 5G base station (gNodeB) and will have an RF backhaul link to the ground 5G Core. This approach aims to expand the connectivity to the stadium, in case that a crowded event takes place or other stadium patrolling services require a dedicated private connectivity.

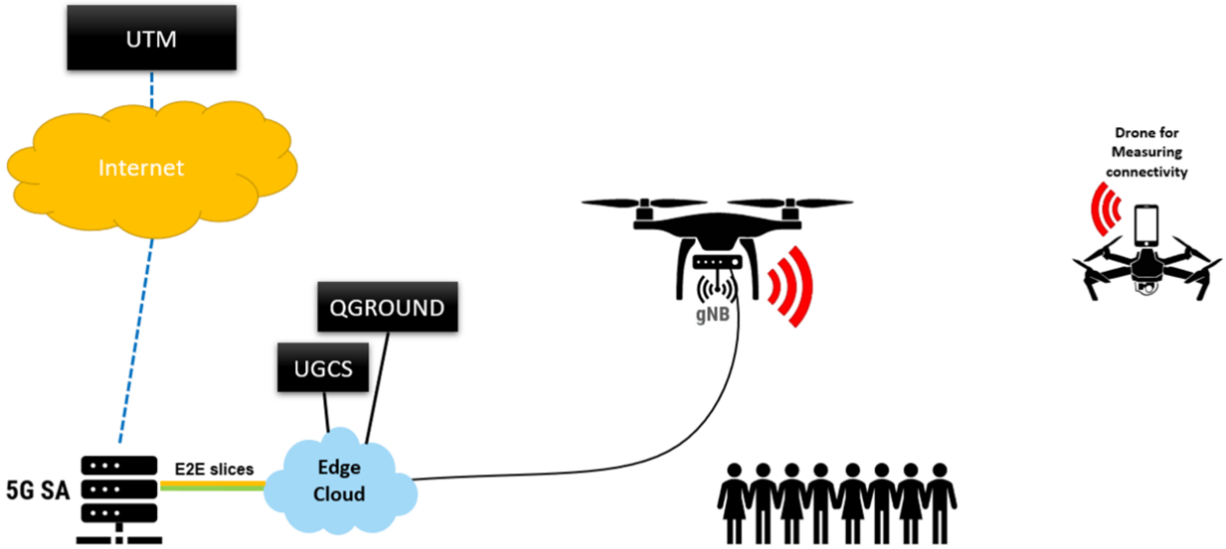


Figure 82. High-level illustration of the UC4:SC1 Connectivity extension and offloading

Infrastructure drone (Hepta)

The infrastructure drone will be carrying a 5G base station (gNodeB) and will have a backhaul link to the ground 5G Core via cables. To implement this approach the drone will be tethered also to avoid C2 link radio interferences and will offer unlimited power supply and secured data transfer for safer operations.

Patrolling drone (CAFA Tech)

Initially the base station will be located in a specific point in the stadium in order to provide 5G coverage. Afterwards, a patrolling drone flies over the stadium, taking photos that are sent to a private cloud, where 3D Mapping software processes a 3D map of them. The patrolling drone uses 5G Android phone or 5G module and a computing device onboard the drone, which runs 5G network QoS measurement application – nPerf or similar. nPerf measurement results will be sent with x,y,z coordinates to MEC/Edge-based CAFA Tech 3D 5G QoS Map and the results of the network quality will be shown. Simultaneously, the patrolling drone 5G device sends video feed to the Video Streamer server application, but which runs in the Private cloud (COSMOTE server). Video Streamer server provides video feed for the Event Command Centre.

Surveillance drone (UMS)

Surveillance Drone (DJI M600): The drone will be installed with a companion computer, which contains the Unmanned Life Autonomous Control Endpoint (UL-ACE) software to enable autonomous command & control. Orchestration and management of the drones will be taken care of our Central Control Platform (UL-CCP) that will be deployed as a container on MEC. Search drone will be equipped with a video camera that is going to be used to survey the flight areas and stream HD footage of back to our Video Analytics (UL-VA) module, which is also hosted on MEC. UL-VA consists of AI-based object detection algorithms that will analyse the video to detect humans in real time and relay the information back to the UL-CCP.

Trials' architecture

The demonstration of the scenario is envisioned to be performed in two phases. During the first phase the base station will be located at a specific position in the stadium with a focus on the 5G propagation, which is related to the direction and pitch of the 5G antenna. The patrolling drone will perform 5G network QoS measurements, and the surveillance drone will stream HD video. Based on the network quality situation and given the analysis of UL-VA (e.g. number of people on the stadium), the Event Command Centre can decide to deploy additional temporary Infrastructure drone with 5G base station as shown in the Figure 83 below.

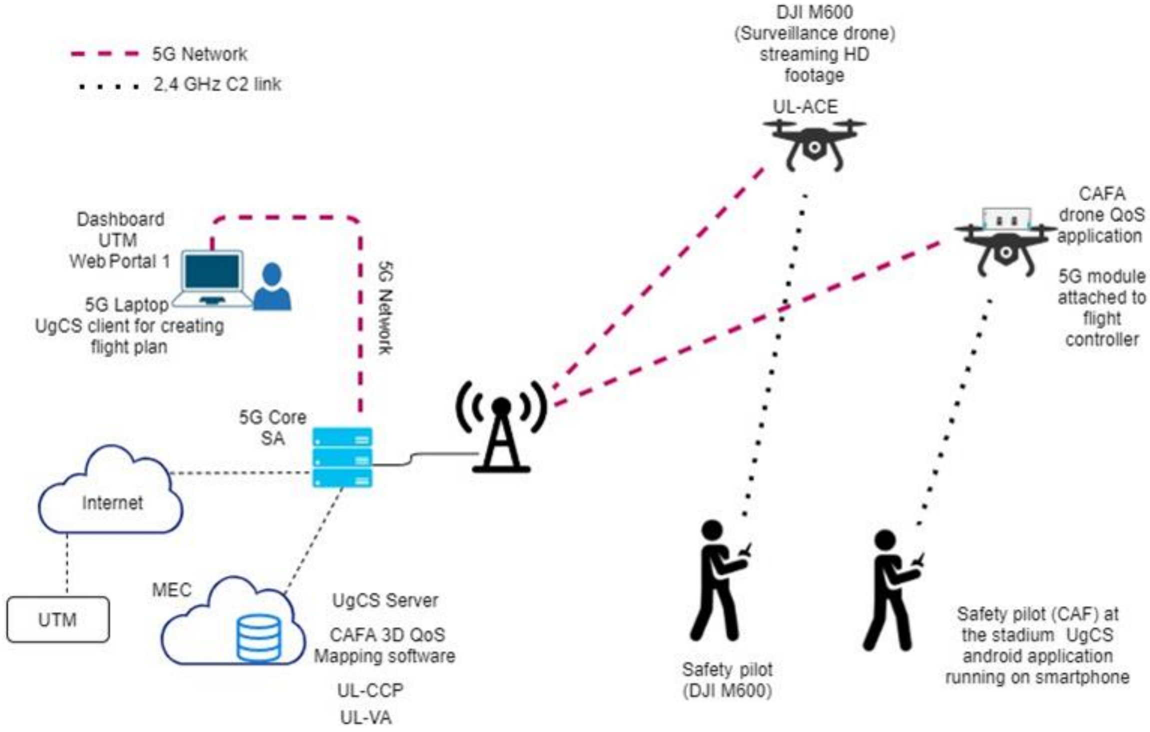


Figure 83. Description of UC4:SC1 trials' architecture (phase 1 of the trial at the Egaleo stadium)

The second phase describes the flight that will be performed by the infrastructure drone, to expand the 5G coverage to the stadium and as a consequence the connectivity for any additional services that require enhanced capabilities. Likewise, to the flight of the first phase, the patrolling drone will also perform 5G network QoS measurements, and the surveillance drone will stream HD video. The relative architecture is illustrated in the Figure 84 below.

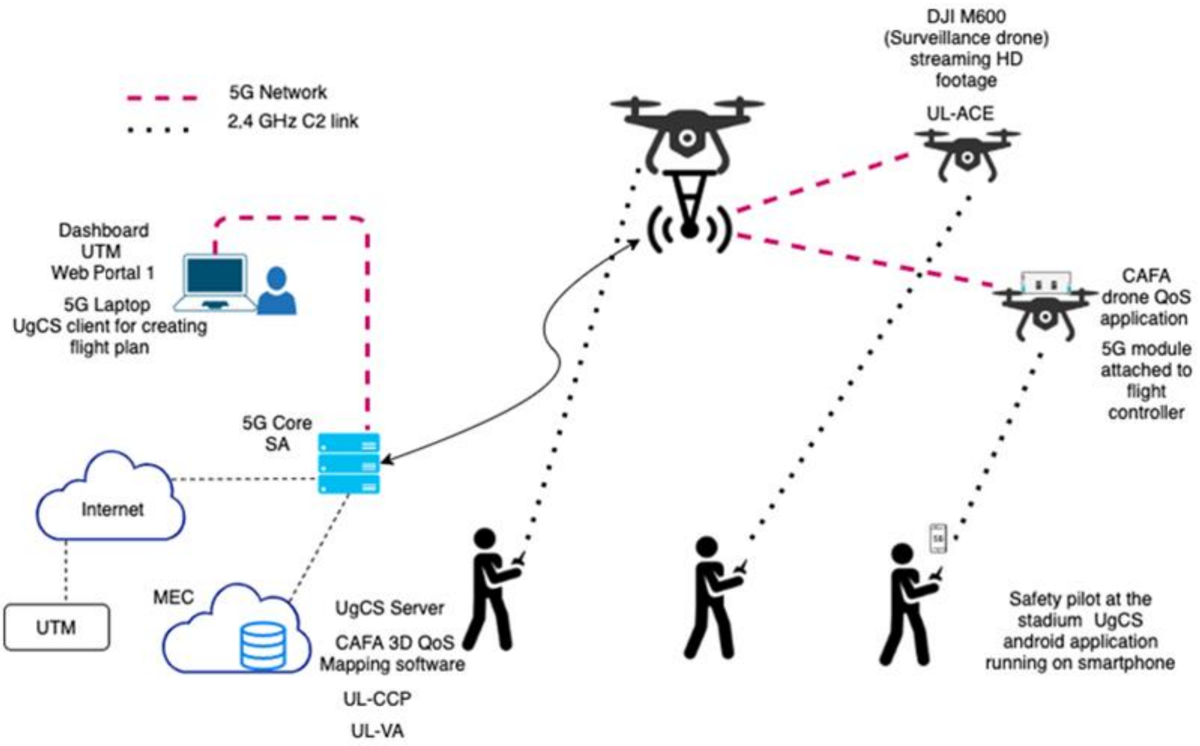


Figure 84. Description of UC4:SC1 trials' architecture (phase 2 of the trial at the Egaleo stadium)

As already mentioned above, both the UL-CCP and UL-VA modules will be hosted in MEC.

For the aforementioned trial scenario, risk management and contingency planning is important to ensure trial's proper operations and outcomes. To that end, having in mind potential barriers that would not allow the involved partners to conduct the trials in a proper way, an identification of all the alternative activities required to overcome these barriers has been performed.

Regarding the second phase of the trial, one of the key points for a successful outcome, is that the infrastructure carrying a 5G base station (gNB), has a backhaul link to the ground 5G Core via cables. In the case that it will not be feasible for the infrastructure drone to lift the gNB, the alternative option is to onload another lighter component that can provide 5G coverage and convert the network to 5G concurrent connections.

4.5 Tallinn showcasing event and trial

The aim of the showcasing trial is to involve a wider range of stakeholders and to introduce the possibilities of using 5G cellular drones.

The tests will be performed in Estonia, Tallinn. A more detailed location will be agreed at the end of the 1st quarter of 2022, depending on whether a 5G commercial network can be used on the territory of the Estonian Academy of Security Sciences or a 5G test network on the territory of Tallinn University of Technology. The use of Edge server solutions (incl. Trial controller) will be specified with the respective infrastructure owners.

During the showcasing trial, it is planned to test the following scenarios as they described in previous subchapters:

- UC1:SC3 Logistics (CAF);
- UC2:SC3 Police (CAF);
- UC3:SC1:sub-SC2 Long range powerline inspection (HEP).

Preliminary information from the showcasing trial will be sent to both stakeholders and the media to introduce 5G!Drones technical solutions more widely. The Table 31 below describes stakeholders and their interests.

Table 31. Stakeholders and their interests

Stakeholder	Interest of the stakeholder
Estonian Air Navigation Service Provider	To understand the needs of businesses using cellular drones.
Civil Aviation Authority	To understand the needs of businesses using cellular drones.
Estonian Radio Frequency Authority	To understand the needs of businesses using cellular drones and the impact of interference on mobile networks.
Mobile network operator	To understand the needs of businesses using cellular drones and the impact of interference on mobile networks.
U-space service provider	To demonstrate how U-space services supports drone operations in the urban airspace.
Professional drone operators	To understand regulation and possibilities to use cellular (4G, 5G) drone for commercial drone services.
Hobbyist drone users	To understand regulation and possibilities to use cellular (4G, 5G) drone for hobby flights.
Drone manufacturers	To understand regulation to manufacture cellular drone models.
Estonian Police and Border Guard Board	To understand regulation and possibilities to use cellular (4G, 5G) drone for Police operations.
Estonian Academy of Security Sciences	To understand regulation and possibilities to use cellular (4G, 5G) drone for law enforcement services.
Tallinn Technical University	To understand and teach to students the values of 5G for UAV businesses.
Infrastructure (electricity network, gas pipelines, railways, etc.) provider	To understand possibilities to use cellular (4G, 5G) drone for BVLOS infrastructure inspections.
Logistics companies	To understand possibilities to use cellular (4G, 5G) drones for BVLOS logistics flights.

5 Conclusion

The objective of this document is to describe the experience gained from the feasibility tests and pretrials carried out in 2020 and 2021 and provide general principles and detailed plans to conduct trials in 2021-2022. The Trials plan provides project partners with a harmonized approach to conducting trials to achieve project objectives. The results collected during the trials, are analysed by Task 4.3 and the results will be presented in the deliverable D4.4, which will be submitted on M42.

The target of the feasibility tests and pretrials has been to conduct physically or remotely tests in Finland, Greece and France in 2020-2021, to map deficiencies and to collect inputs for 5G!Drones next developments and actions.

Specifically, in 2020-2021, feasibility tests were performed physically using Aalto University, University of Oulu and NCSRD 5G networks. Remote feasibility tests were performed in EURECOM in December 2020 due to COVID-19 restrictions. In January 2021, the simulated tests were conducted by NCSRD and UMS, which provided a collaborative experience on how to further simulate the use of a larger number of drones at the same time and in the same room.

ORA team conducted tests in November and December 2020 to identify interferences generated by cellular UAV on terrestrial UE in neighbour cells in Lannion (France). Commercial cellular networks would leverage promising use cases on long distance drone flights, but there are some issues with interference as mentioned in CEPT/ECC Report 309 [5]. However, there are two major threats that should be more characterized for influencing regulators and mobile network operators to revisit their position. The first is about the impact of cellular UAV traffic on normal cellular traffic on ground due to interferences. The second is about coverage in altitude (e.g. between 30 m high and up to 120 m) due to antenna patterns (primary and side lobs). Based on results over 96 measurements, it can be concluded that UAV communicating on cellular bands have no major impact on the normal mobile communication traffic on ground.

5G!Drones partners remotely conducted pretrials in June 2021 using EURECOM infrastructure. The mission was to test Integration Release 1 components, incl. Web Portal 1 and Web Portal 2 existing enablers, WP2 and WP3 enablers and UC1:SC1 and UC2:SC1, UC2:SC2 scenarios as much as possible for collecting feedback for next physical tests. The tests were successful and the connection between Web Portal 1 and Web Portal 2 worked smoothly.

The purpose of the executed feasibility tests and pretrials was primarily to validate the integration activities and evaluate the feasibility to execute the target demonstrations. A phased approach, with early, 1st year feasibility trials, and pretrials in 2021, ensures that all aspects that need tuning and optimisations are identified timely and acted upon as part of the on-going development and integration work-packages. While in the first year the focus has been to ensure that the basic infrastructure components are properly in place, the interest in subsequent trials is shifting towards successful integration and measurable objectives.

According to the project schedule, the developments of WP2 and WP3 enablers are planned to be completed by M36 at the latest. WP2 focuses on the development of a Trial controller that allows the vertical to describe the scenario to be trialled on the top of the 5G facilities. The trial controller is also responsible for enforcing the trials and managing their lifecycles. WP2 covers a number of enablers, which are related to the Trial controller. The aim of WP3 is to design and implement the missing components that will allow 5G facilities and vertical services to support the target use cases. The development plan for WP3 enablers predicts that developments will be finalised by M36 (May 2022).

There are in total 4 integration releases planned, which will assure that Trial Controller system is ready to fulfil 5G!Drones requirements:

- Release 1: Integration validation release;
- Release 2: Trial Controller release;

- Release 3: KPI release;
- Release 4: Use case release.

The trials are planned to be conducted in two rounds in 2021 and 2022. Based on Integration Releases, it is planned to test Release 1, 2 in 2021 and Release 2, 3 in 2022:

- 1st Round from June to October 2021 to test Integration Release 1 and Release 2 components in all four 5G!Drones facilities: 5G-EVE, 5GENESIS, 5G-TN, X-Network;
- 2nd Round from June to September 2022 to test the complete solutions of the 5G! Drones project in all four 5G!Drones facilities: 5G-EVE, 5GENESIS, 5G-TN, X-Network.

During the project, a total of 11 scenario tests will be performed, which are mentioned below with scenario leader:

- UC1:SC1 UTM Command & Control application (INV);
- UC1:SC2 3D map and supporting visualization/analysis software for UTM (UO);
- UC1:SC3 UAV logistics (CAF);
- UC2:SC1 Monitoring a wildfire (AIR);
- UC2:SC2 Disaster recovery (UMS);
- UC2:SC3 Police including counter-UAS (CAF);
- UC3:SC1:sub-SC1 3D mapping of 5G QoS (CAF);
- UC3:SC1:sub-SC2 Long range powerline inspection (HEP);
- UC3:SC1:sub-SC3 SAR operations on the lake (ALE);
- UC3:SC2 UAV-enhanced IoT data collection (AU);
- UC3:SC3 Location of UE in non-GPS environments (NOK);
- UC4:SC1 Connectivity extension and offloading during crowded events (NCSRD).

Since 31-Dec-2020, the European Commission Implementing Regulation (EU) 2019/947 [3] has replaced each EU state's existing laws with respect to drone's operations. Most trials take place as Open category flights, but at the same time it is necessary for drones heavier than 2 kg (HEP, ALE, NOK drones) to apply for permits to fly in the Specific category. It is important to note that transition period is until 31-Dec-2022 in connection with the implementing the Regulation 2019/947.

In April 2021, the European Commission published Implementing Regulation (EU) 2021/664 on a regulatory framework for the U-space [4]. Its entry into force is planned for January 2023. Testing of U-space services is planned in the project trials, which will provide valuable experience to share with stakeholders who adapt their systems to comply with the U-space regulations, which will enter into force in January 2023.

In the EU level there are no restrictions for using cellular communication (mobile networks) for drones. CEPT Electronic Communications Committee (ECC) Report 309 "Analysis of the usage of aerial UE for communication in current MFCN harmonised bands" [5] deals with the use of mobile frequencies in unmanned aircraft systems. The ECC reports are not binding and do not impose specific conditions on Member States of the Conference of European Postal and Telecommunications Administrations (CEPT). On the basis of the report, an ECC decision will be drawn up and will be sent to member states and stakeholders to get feedback (expected on second half of 2022).

The general principles of conducting trials, such as – Safety requirements, Schedule for preparations, technical tests, execution and conclusions – give all partners the same principles for conducting trials under different scenarios and in different locations. The information, photos and videos collected during the Trials are planned to support the communication and dissemination activities of the 5G! Drones project.

In May 2022, the project partners will conduct 5G!Drones showcasing event and trials in Tallinn, Estonia. The aim of the showcasing trial is to involve a wider range of stakeholders and to introduce the possibilities of using 5G cellular drones. During the showcasing trial, it is planned to test the three scenarios: Drone logistics; Police; Long range powerline inspection.

In summary, the trials of the 5G! Drones project are very relevant to work within the framework of the new EU UAV flights and U-space regulation and to use cellular devices on board drones and also considering the roll-out of 5G in Europe.

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