Si-Mohammed, Samir; Bouaziz, Maha; Hellaoui, Hamed; Bekkouche, Oussama; Ksentini, Adlen; university, oulu; Tomaszewski, Lechoslaw; Lutz, Thomas; Srinivasan, Gokul; Jarvet, Tanel; Montowtt, Orange

Supporting Unmanned Aerial Vehicle Services in 5G Networks: New High-Level Architecture Integrating 5G With U-Space

Published in:
IEEE Vehicular Technology Magazine

DOI:
10.1109/MVT.2020.3036374

Published: 01/03/2021

Document Version
Peer reviewed version

Supporting UAV Services in 5G Networks: New High-Level Architecture integrating 5G with U-space

Samir Si-Mohammed[1], Maha Bouaziz[1], Hamed Hellaoui[2], Oussama Bekkouche[2], Adlen Ksentini[1], Tarik Taleb[2,8], Lechosław Tomaszewski[3], Thomas Lutz[4], Gokul Srinivasan[5], Tanel Järvet[6], and Pawel Montowtt[7]

[1]EURECOM, Sophia Antipolis, France, {firstname.surname}@eurecom.fr
[2]Aalto University, Espoo, Finland, {firstname.surname}@aalto.fi
[3]Orange Polska, Poland, lechoslaw.tomaszewski@orange.com
[4]Frequentis, Vienna, Austria, thomas.lutz@frequentis.com
[5]Robots Expert, Vantaa, Finland, gokul.srinivasan@robots.expert
[6]CAFA Tech, Tallinn, Estonia, tanel.jarvet@cafatech.com
[7]Involi, Lausanne, Switzerland, pawel.montowtt@involi.com
[8]Sejong University, Seoul, Korea; Oulu University, Oulu, Finland

***Abstract*—To provide efficient, safe, and secure access to the airspace, the European Union has launched a set of new services called U-space, allowing supporting Unmanned Aerial Vehicles (UAVs) management and conflict preventing of flights in the airspace. These services are based on communication technology, where it is foreseen that it will be the key enabler to unlock the underlying potentials of UAVs' operations. In this regard, the upcoming generation of mobile networks "5G" is envisioned to be the communication standard to support diverse UAV operations and applications. In this paper, we propose a novel architecture that integrates 5G systems with U-space. The main aim of this architecture consists in providing a reference design that demonstrates how 5G can support U-space services and shows the interactions between different stakeholders. Furthermore, we introduce the 5G!Drones project that relies on the proposed architecture to trial UAV use-cases scenarios on top of 5G infrastructure.**

***Keywords*—5G, UAV, U-space, Architecture, Flying Drones, UTM.**

I. Introduction

Application of Unmanned Aerial Vehicles (UAVs), including flying drones, has been initiated in a wide range of civilian and commercial activities/areas, such as cargo delivery, precise agriculture, remote inspection, photogrammetry, video streaming, rescue and search, and data collection for the Internet of Things. There is a wide consensus whose areas of activity will significantly expand in the years to come. For Europe in particular, the Single European Sky ATM Research (SESAR) [1] Joint Undertaking reports that there is the potential for a European market exceeding EUR 10 billion annually by 2035 and EUR 15 billion by 2050, identifying value-added services using UAVs "Drone-as-a-Service" as the largest market opportunity.

UAVs are aircraft flying without human pilots on board. They can be operated either manually using a remote controller or autonomously using an embedded autopilot. Nevertheless, in both cases, UAVs are a part of an Unmanned Aircraft System (UAS) that consists of a Ground Control Station (GCS), drones themselves, and communication technology between them for exchanging Command & Control (C2) messages. Besides, operations of UAVs are regulated and controlled by Aviation Safety Agencies (ASAs) such as the Federal Aviation Administration (FAA) in the USA and the European Aviation Safety Agency (EASA), who are conducting extensive research and development projects to innovate new systems that allow the integration of UAVs in the low-altitude airspace. The European initiative of this system is called "U-space". The main aim of this system is to prevent flight conflict and provide efficient and safe UAVs traffic management, as it consists of a set of services that allows the automation of procedures related to the safety of the airspace. Indeed, UAVs missions require a very low latency communication for the remote C2 traffic and a high capacity data transmission for bandwidth-demanding applications, such as video surveillance streaming.

In this vein, 5G technology is assumed to guarantee wider bandwidth and very low-latency connectivity, which definitely place it as a key enabler of UAV-based services and applications. Indeed, 5G brings into light several new concepts that can be beneficial for UAV. On one hand, 5G New Radio (NR) provides larger bandwidth (up to 100 MHz in $<$ 6 GHz frequency band, and up to 400 MHz in $>$ 6 GHz frequency band) to accommodate high data-rate demanding applications, such as VR/AR, 4K video streaming, which may be used by UAVs for high-quality video streaming or remote steering of the UAVs. Moreover, 5G NR uses new physical layer numerology that drastically reduces Radio Access Network (RAN) latency; and when it is combined with the edge computing capabilities at the vicinity of the radio network, very low latency will be achieved for UAVs remote C2 applications. On the other hand, Network Slicing (NS) is a novel concept introduced in 5G aiming at partitioning of a general-purpose mobile network into virtual network instances that are individually tuned to accommodate different services characterized by different requirements in terms of communication Quality of Service (QoS), within a common physical infrastructure. The introduction of NS allows the mobile operators to support efficiently three classes of services using the same physical infrastructure: (i) Enhanced Mobile Broadband (eMBB) for applications requiring high data rates, (ii) massive Machine-Type Communications (mMTC) intended to cover IoT applications that require support for a massive number devices, and (iii) ultra-Reliable and Low Latency Communication (uRLLC) for applications with strict requirements on the communication latency and reliability. However, UAVs services cannot fall into only one class of service. Indeed, the remote command and control applications of UAVs are considered as uRLLC applications, while the services offered by the UAV (e.g., live video streaming) may also require an eMBB or mMTC network slice instance. Hence, UAVs may need a combination of a uRLLC slice instance and either an eMBB or an mMTC slice feature.

In this paper, we first propose a novel reference architecture aiming at integrating the 5G system with the U-space ecosystem. The proposed architecture intends to show a reference design that demonstrates the way 5G can support U-space services and details the interaction between the different elements allowing to run several UAV services using the 5G system as the communication infrastructure. Second, we introduce the European project "5G!Drones"[1], its objectives, and how it relies on the introduced U-space and 5G integration reference architecture to build trials of UAV use-cases and scenarios using 5G ready facilities.

The remainder of this paper is organized as follows. Section II discusses some of the relevant works related to the previous efforts done for UAVs traffic management and the underlying communication technologies. Section III presents the proposed reference architecture integrating 5G systems with U-space, as well as the different actors and interfaces. Thereafter, section IV introduces 5G!Drones project and how the latter allows the trial of UAV applications on top of 5G infrastructure building on the proposed reference architecture. Finally, Section V concludes the paper.

II. Related works

Different projects have been initiated to develop and deploy solutions aiming to enhance drones' traffic management. In this context, series of SESAR projects have been launched. For instance, the Concept of Operation for EuRopean UTM Systems (CORUS) project [2] has been established within the SESAR program with the aim to develop and write a concept of operations for U-space. The project also addresses the integration of drones into a Very Low Level (VLL) airspace. Furthermore, in order to demonstrate the U-space concept, different demonstrator projects have been started. One of the important projects is GOF (Gulf of Finland) [3], which aims to demonstrate advanced drone operations, including both manned and unmanned aircraft in shared airspace, with a view to accelerating the uptake of U-space in Europe (starting with low-level airspace).

Moreover, since wireless communication technologies represent a key enabler to unlock UAVs' potentials, the use of mobile networks for UAVs has a significant attraction for both academic and industrial research. Several real evaluations and trials have been elaborated based on the 3GPP standardization, as some 3GPP research works provided different challenges to apply 4G and 5G for the UAV domain. In [4] the LTE enhancements for interference's mitigation, mobility performance, and aerial UE identification have been proposed. For 5G network, the UAS support requirements related to remote identification of UAS and aerial traffic management, as well as functional and performance requirements for specific UAV use cases (network exposure, positioning, C2/payload communication, etc.) have been defined [5]. Recently, 3GPP has started the study on supporting UAS connectivity, identification and tracking [6], where an initial view of reference architecture composed of UAV, its controller, UTM, authorized 3rd party and 5G System (5GS), which acts not only as a relay, but it exposes interfaces for interactions with other actors, has been shown. In parallel, the study on application layer support for UAS is also carried on [7]. The outcomes of these studies will contribute to future amendments of 5G network architecture and mechanisms.

Knowing the potential of 5G to overcome 4G limitations in accommodating a diversified range of new applications such as autonomous driving, virtual reality, and all sorts of mission-critical applications, we propose in this paper a reference architecture that integrates 5GS within U-space. Such integration would boost U-space services by providing the required information on the communication networks accommodating the UAVs applications. A complementary vision of the current work has been recently published in [8], where the 3GPP 5GS architectural framework (cf. [9], [10]) has been analyzed in terms of its ability to be integrated with U-space in order to accommodate the technical requirements and to support business processes of the U-space framework and UAS environment. In addition, [8] investigates the U-space integration-compliant 5GS implementation architecture with necessary functional amendments to fill in the identified gaps has been proposed. On the other hand, the multi-operator platform (both in terms of network and drone operators) built around the UTM system has been proposed in [11] where the UAV services brokerage is used for finding the best flight offer for the drone services customer, based on an available fleet of drone operators, flight area coverage by different 5G networks and air space availability for the requested timeframe. The concept also presents the feature of dynamic and variable instantiation of elements of the overall architecture during the flight life cycle.

III. Proposed architecture of integration of 5G systems with U-space

A representative view of the proposed reference architecture, integrating 5GS as a communication platform within U-space, is illustrated in Fig. 1. This architecture aims at accommodating the end-to-end business processes of the aviation domain, namely the U-space, by considering the drone flight plan's life cycle perspective, including all the concerned stakeholders and the interactions between them. The proposed architecture is divided into three blocks: Customer, consisting of End User and the Business Provider, U-space with its different components, and the 5G infrastructure. It is worth noting that U-space includes several actors (UAVs Operator, 5G Network Owner, 5G infrastructure, U-space Service Provider, UTM, and Authorities) that interact to ensure that UAVs management, as illustrated in Fig. 1. U-space represents the set of federated services and associated functions within a complete framework [12]. The main goal of this entity consists of enabling

[1] https://5gdrones.eu/

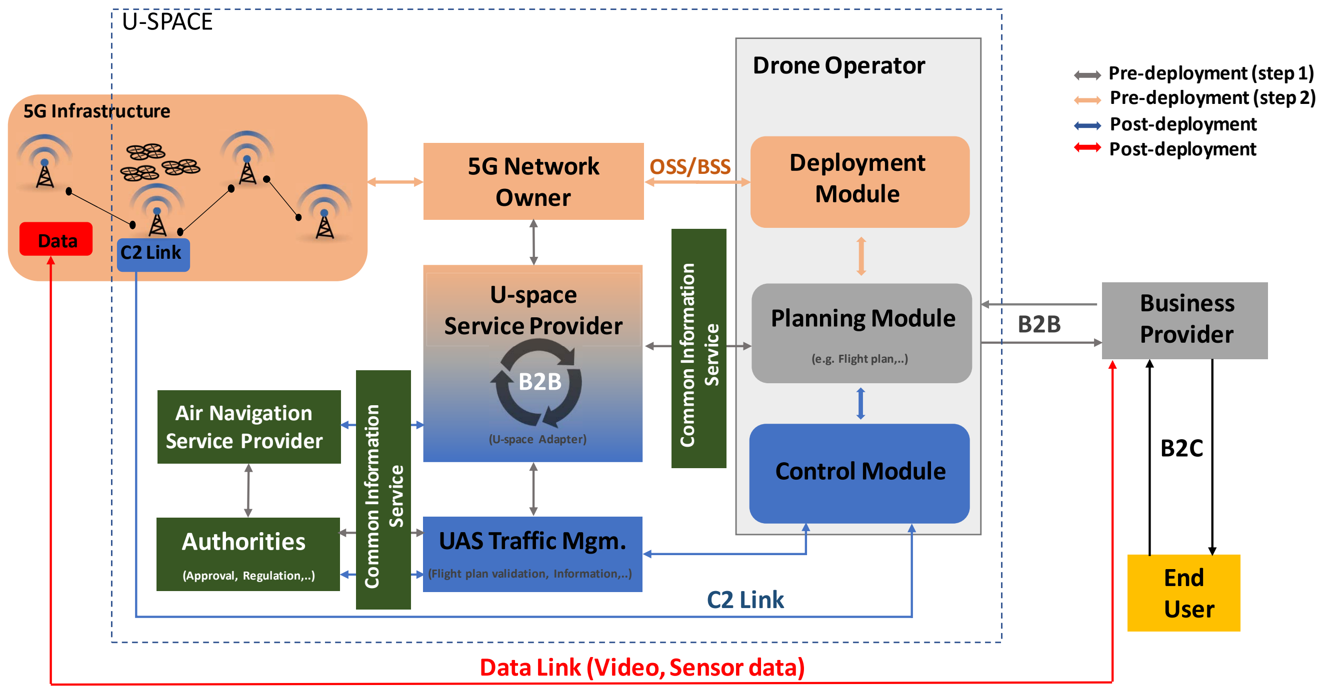

Fig. 1. The proposed architecture integrating 5G infrastructure with U-space

and supporting safe and efficient multiple and simultaneous operations of UAVs. In our proposed architecture, the Business Provider must contact U-space for Drones deployment, safety, and coverage reasons. The figure also indicates the different steps of the deployment of a mission: (i) pre-deployment phase that corresponds to all the steps needed to prepare the flight plan and validate it, with UTM and 5G Network Owner; (ii) post-deployment phase that corresponds to the procedures to safely fly drones. The next section describes the different components and interfaces of the architecture.

1) Actors: We introduce in the following the role of each actor in the architecture.

- End User: is a person, or an entity, that wants to benefit from a UAV-based service. It can be, for instance, a customer who orders a package and wants it to be delivered by a UAV; or a security company that wants to monitor a building using UAVs equipped with a camera.
- Business Provider: This actor is considered as the entry point to the system, as it offers to End Users the possibility to use UAV-based services. The End Users have to pass through the Business Provider to be granted any service by communicating the most relevant information about their needs.
- UAS Traffic Management (UTM): is an existing service used for the management of the multiple UAS operations, as it refers to the set of federated services with an all-encompassing framework [13]. Indeed, UTM is responsible for the management of drone flights since it is supposed to hold information (presence, trajectory, etc.) of all drones flying in the areas that it is responsible for. Thus, it can validate a flight plan or reject it for safety reasons. For instance, the flight can be rejected if the region is already occupied by already approved flight plans that may cause a collision. In addition, UTM shall provide interfaces to relevant stakeholders (e.g. Air Navigation Service Providers) and aviation authorities.
- Authorities: Designated by a state or an international organization. Authorities are entities providing regulation, supervision, and guidance for the UAV ecosystem, for instance, : Civil Aviation Agency, Radio Communication Agency and other authorities competent to decide on restrictions or authorizations for UAV flights, areas (permanent or temporary No-Fly-Zones – NFZs) and usage of radio communication equipment. Among others, one of their most important tasks is ensuring safe and secure operations in the aviation domain.
- Air Navigation Service Provider: An entity providing services to aviation (e.g., commercial airliners, general aviation, Helicopter Emergency Medical Service (HEMS) helicopters, etc.). This typically sub summarizes air traffic control, managing air traffic in controlled airspace (e.g., around airports, en-route, , etc.).
- Common Information Service: Entity that ensures that all the information can be exchanged between the various organizations to fulfill their obligations and enables the exchange of essential information between the U-space service providers, the Drone operators, the air navigation service providers, and all other participants in the U-space airspace [14].
- 5G Network Owner: is the operator of the 5G Network and holds information about the available coverage and communication QoS offered by the mobile network. Thus, it is responsible for providing to the UAV Operator, via specific interfaces, information about the available 5G connectivity on a selected area in a given timeframe.

- 5G Infrastructure: is the infrastructure operated by the 5G Network Owner. It consists of 5G radio base stations (i.e., geNB), 5G Core Network (CN), Edge, and central Data Center. All services and applications required for communicating and operating UAVs will be deployed on top of this infrastructure. The part of 5G Infrastructure supporting the UAS domain should be considered as one of the U-space resources, hence being subject to U-space resources management processes. In particular, these processes will cooperate with the internal processes of resource management, planning, and reconfiguration of the Network Owner's network. Therefore, the need for prior flight plan validation is advantageous for the Network Owner and allows the preparation of the necessary configuration to ensure flight safety and quality of payload transmission.
- Drone Operator: is the entity that pilots the UAVs and can offer UAV-based services. It is responsible for creating the flight plan of UAVs, which is a document containing relevant information about the scenario, like starting and ending times of the UAV's mission, the flight path, and needed requirements in terms of communication QoS (i.e. latency, reliability, bandwidth, etc.). It is composed of three major modules:
    - Planning module: is responsible for preparing the flight plan to be executed by the UAVs to fulfill the requested mission, considering coverage conditions provided by 5G Networks and airspace safety provided by UTM. This module has to communicate with the 5G Network Owner and the UTM through the Service Provider in order to validate the flight plan.
    - Deployment module: once the flight plan is defined and validated by the three parts (i.e., 5G Network Owner, UTM, and Authorities), this module communicates to the 5G Network Owner the communications requirements of the service provided by the UAV. The 5G Network Owner then enforces the deployment of the associated network slices and applications to serve the UAV during its mission.
    - Control module: once the flight has started, real-time information concerning the flight progress (e.g., location, energy level, etc.) is sent by the UAV to the Control Module, using the C2 link. Then, this module, in its turn, communicates them to the UTM, which sends an alert to the UAV operator if required, it may ask for trajectory change if deemed appropriate to avoid possible collisions.
- U-space Service Provider (USSP): is the part of U-space that is responsible for ensuring the communication between the Planning Module of the Drone Operator, the 5G Network Owner, and UTM, through a Business to Business (B2B) Interface (described below).

2) Interfaces: After presenting the different actors of the proposed architecture, we describe here the different communications and interactions between them. As discussed before, since actors belong to different domains, different kinds of interfaces take place, like Business to Customer (B2C) and B2B communications. Of course, all these communications follow a certain order that we divided, in the figure, into Pre & Post deployment as follows:

- End User – Business Provider interface (B2C): The End User communicates to the Business Provider some information about the requested flight, for instance, the route endpoints, and the the flight timeframe. Similarly, the Business Provider communicates to the End User some real-time control information like the UAV location, allowing it to monitor the flight progress. Moreover, it can communicate to the End User another type of data like video streaming from the camera on-board the UAV.
- Business Provider – Drone Operator interface (B2B): The Business Provider uses this interface to transmit the information received from the End User. Other information may be added, such as the location of a package in the case of a delivery service. On the other side, the Drone Operator reports to the Business Provider information about the flight progress.
- Planning Module – 5G Network Owner – UTM interface (B2B): This interface is considered as the most important since these three actors are involved in the validation/rejection of the flight plan proposed by the Drone Operator. Indeed, the Drone Operator, via the Planning Module, knows the starting and ending times as well as the starting location and the destination of the UAV's mission. Hence it can propose a flight plan that consists of a sequence of Global Positioning System (GPS) coordinates (a.k.a waypoints) to be followed by the UAV. This flight plan will be transmitted to U-space Service Provider through the Common Information Service (CIS) and to the 5G Network Owner in order to get information about the coverage area for the specified time period. Once this information is obtained, the flight plan is transmitted to UTM for validation. This latter ensures that the proposed flight plan does not engender conflicts with other planned flights and verifies whether the flight plan is compliant with the airspace restrictions (e.g., NFZs). Furthermore, UTM can request additional information from the authorities to ensure the safety of the flight. In case the flight plan is rejected, an update is required, and hence a new one is proposed by the Drone Operator. This process is repeated until the validation of one of the proposed flight plans or the cancellation of the UAV mission from the Drone Operator or the Business Provider.
- Deployment Module – 5G Network Owner interface: The Deployment Module is used to transmit the validated flight plan to the 5G Network Owner, requesting the allocation of required resources for serving the UAV during its mission; this mainly includes the allocation of Network Slice Instances (NSIs). For this purpose, the Deployment Module communicates with the 5G Network Owner using the Operation Support

System/Business Support System (OSS/BSS) portal based on a blueprint that includes the necessary information for the deployment and execution of the services required by the UAV during its flight. Afterward, 5G Network Owner requests the physical deployment on the 5G Infrastructure through a Network Slice for each service.

- Control Module – C2 Link: This link is used during the execution of the UAV's flight. It allows the Control Module to control and monitor the UAV flight in real-time. It is worth mentioning that the C2 link should be associated with a uRLLC NSI.
- Control Module – UTM link: This link is used by the control module to forward the telemetry data received during the flight monitoring process to UTM. This data will be used by UTM to verify that all the UAVs flights are compliant with the restriction negotiated during the flight validation phase. UTM can request a trajectory update to the control module, which in turn, via the C2 link, forwards the requested changes to the UAVs.
- Payload data – Business Provider link: This link is only used in some use-cases, for instance, if the deployed UAVs are responsible for recording videos or collecting some measurements. This data is gathered by drones and directly sent to the Business Provider, which in its turn transmits them to the End User through the B2C interface.
- UTM – Authorities interface: UTM holds a permanent communication link with the authorities through the CIS, allowing it to have real-time information about the ongoing flights. This information is crucial in order to avoid conflicts and ensure a safe environment for the UAVs flights.
- Authorities – ANSP link: The authorities hold permanent links with the Air Navigation Service Provider to get real-time information about air traffic control for safety purposes.
- ANSP – USSP link: The link between the Air Navigation Service Provider and the U-space Service Provider goes through the CIS and aims at exchanging essential information like airspace restrictions, a status of the airspace, and available traffic information, to make the USSP able to provide services to the Drone Operator.

IV. 5G!DRONES UAV TRIAL SYSTEM

A. *5G!Drones project*

The 5G!Drones project aims at trialing UAV use-cases on top of 5G facilities[2]. It is funded by the European Union in the context of 5G Public Private Program (5GPPP) phase 3 call that aims to trial vertical scenarios using 5G facilities. The project consortium is composed of 20 partners, including 5G network operators, UAVs verticals, industrial groups, small and medium size enterprises (SME), research centers and universities. The 5G!Drones project aims at running several trials of UAVs, such as public safety, disaster recovery, site surveillance, connectivity extension, indoor localization, etc. Indeed, trailing UAVs scenarios and use-cases before the commercial deployment is very critical, since these scenarios involve flying aircrafts, which may collapse if their traffic is not well controlled via a reliable and stable C2 connectivity. On the other hand, the 5G!Drones project will allow UAV verticals to test their tools and applications, such as remote C2 applications, UTM integration, and video streaming service, while validating both UAVs and 5G Key Performance Indicators (KPIs). Finally, the 5G!Drones project will feed the standardization bodies, such as 3GPP, with the needed improvements to fully and safely support UAVs scenarios in 5G and beyond.

[2]5G facilities are experimental small scale 5G networks deployed in multiple sites across the Europe, to allow different verticals to test their applications that require 5G connectivity

B. *The UAV trial architecture*

In order to run UAVs trials, the 5G!Drones project relies on the proposed reference architecture with few adaptations to consider: (i) the trial system should abstract the low-level details to allow the UAV verticals to describe the trial scenario, in terms of mission planning and the needed network and computing resources, by providing an intuitive and user-friendly interfaces; (ii) each trial consists of running one or two Network Slices (one uRLLC and eMBB or mMTC); (iii) each 5G facility uses a different template to deploy and run a network slice. Fig. 2 represents the 5G!Drones trial architecture. Some components are the same as those included in Fig. 1, while others are new compared to the earlier stated adaptations. The objective is to reproduce closely the steps described in the reference architecture to mimic a real UAV scenario deployment.

The key element of the 5G!Drones architecture is the 5G Trial Engine, which includes several functions of the Drone Operator, such as Preparation and Validation of the flight plan, deployment of the UAV use-case scenario on top of one of the available 5G facilities. A web portal is defined, which corresponds to the B2B interface between a Drone Operator and Business Provider. The 5G Trial Engine will have an additional component that allows the Trial Owner to visualize the results of the trial, i.e., a selected list of KPIs. In the following, we describe the components that differ from those introduced in the reference architecture.

1) Trial Owner (or the UAV vertical): It represents the Business Provider that aims to run and trial a UAV use-case scenario. It interacts with the 5G Trial Engine through a web portal.

2) Web Portal: The Web Portal represents the interface interacting between the UAV verticals and the Trial Engine, which is in charge of enforcing the trial scenario. The Web Portal consists of two sub-modules. The first one is used to prepare the planning of trials, and the second one to monitor the trial status during its execution. In the trial planning, the Trial Owner provides the required information for their scenarios' description, including the execution period, flight path, and facility choice. This information will be handled by the Trial Engine for validation. Once the trial is validated, the Trial Owner indicates, via the Web Portal, the network and

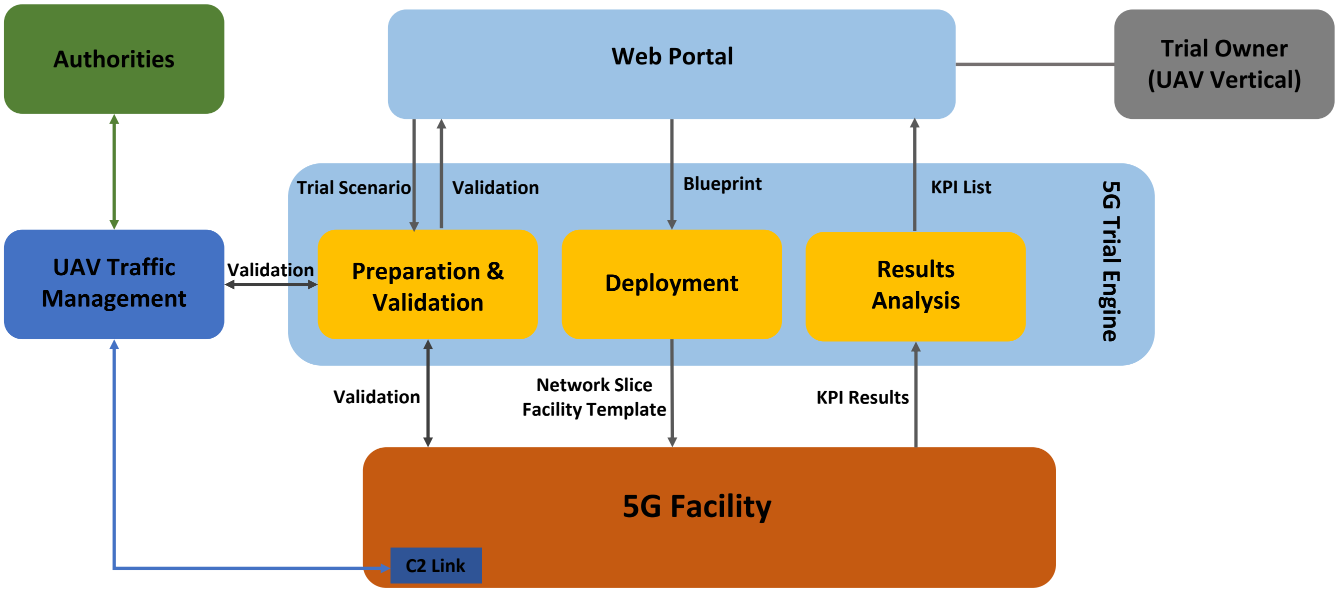

Fig. 2. 5G!Drones UAV trial architecture

computing resources needed to run the trial, such as type of network slice to run (i.e., uRLLC and eMBB or mMTC), the list of Virtual Network Functions (VNF) to deploy (e.g., C2 applications, video streaming services), and the KPIs to be monitored among others. Then, during the execution, the Web Portal allows the Trial Owner to monitor the trial evolution by presenting the mission status updated using the received telemetry data, the KPIs measurements, and the collected data by the UAVs.

3) Trial Engine functions: As stated earlier, most of the Drone Operator functions are included in the Trial Engine. As illustrated in Fig. 2, the Trial Engine is composed of three functional blocks:

- Preparation & Validation: This function is triggered upon the reception of a request from the Trial Owner through the Web Portal, describing the trial scenario. First, this phase prepares the flight plan, then proceeds to its validation. To validate the trial and ensure safe access to the airspace by the UAVs, the Trial Engine interacts with the UTM and the facility through a dedicated interface in order to avoid collision with other flight, check authorization, and availability of 5G resources. In case of a rejection, the Trial Owner is requested to update the flight plan following the encountered limits. This process is repeated until the flight is validated and approved, or the Trial Owner decides to cancel the request.
- Deployment: After the flight plan validation and the reception of the network as well as computing resources requirement, in the form of a Blueprint, the deployment module translates the latter to a Network Slice Template (NST), which will be used to request the creation of a network slice on top of the selected 5G facility to run the trial. As no standard exists but only recommendation for the NST, each facility has its own NST model. Therefore, the Trial Engine has to translate the Blueprint to a NST according to the selected facility model or template.

4) Results Analysis: As the main objective of the system is to run trials and validate the usage of 5G, it is important to collect KPIs on the run scenario and display them to the Trial Owner through the Web Portal. This allows the Trial Owner to observe and analyze the results on run time. A specific module in the Trial Engine is dedicated to KPI monitoring and visualization. Indeed, after the deployment of the required services, the result analysis module uses the API provided by the 5G facility to collect and monitor the KPIs as per the Trial Owner request. The result analysis module also performs statistics collection before displaying the results to the Trial Owner through a dedicated web interface.

5) 5G Facility: As stated earlier, the 5G facilities of the project provide a 5G infrastructure to trial UAV use-cases, including computation capabilities, in the form of Edge Cloud or centralized cloud resources, and 5G connectivity in Standalone mode and Non-standalone mode. All the facilities: (i) include 5G NR base stations; (ii) support Network Slicing; (iii) manage the Life Cycle Management (LCM) of VNFs. The 5G facilities play the role of the 5G Infrastructure in the reference architecture.

V. Conclusion

In this paper, we proposed a novel reference architecture integrating 5GS with U-space, where the objective is to use 5G networks to support operations and services of UAV applications and safe drone flights. Then, we introduced the 5G!Drones project that aims to trial UAV use-cases on top of 5G facilities. We also showed how the 5G!Drones project implements the reference architecture components to build a system allowing to integrate UAV components and 5G aiming to trial several UAV use-cases. Ultimately, the 5G!Drones project will validate the usage of 5G as a connectivity system for UAVs and UAS, and hence in U-space.

Acknowledgment

This work was partially supported by the European Union's Horizon 2020 Research and Innovation Program under the 5G!Drones project (Grant No. 857031).

References

[1] SESAR Joint Undertaking. (2020) Single European Sky ATM Research. [Online]. Available: https://www.sesarju.eu/

[2] CORUS Project. (2020) Concept of Operation for EuRopean UTM Systems. [Online]. Available: https://www.sesarju.eu/projects/corus

[3] GOF Project. (2020) Gulf of Finland project. [Online]. Available: https://www.sesarju.eu/node/3387

[4] 3GPP, "Study on enhanced lte support for aerial vehicles," *3GPP Technical Report TR 36.777*, ver. 15.0.0, January 2018.

[5] 3GPP , "Unmanned Aerial System (UAS) support in 3GPP," *3GPP Technical Specification TS 22.125*, ver. 17.1.0, December 2019.

[6] 3GPP, "Study on supporting Unmanned Aerial Systems (UAS) connectivity, Identification and tracking," *3GPP Technical Report TR 23.754*, ver. 0.1.0, January 2020.

[7] 3GPP , "Study on application layer support for Unmanned Aerial Systems (UAS)," *3GPP Technical Report TR 23.754*, ver. 0.7.0, April 2020.

[8] L. Tomaszewski, R. Kołakowski, and S. Kukliński, "Integration of U-space and 5GS for UAV services," in *IFIP Networking 2020 Conference, Second International Workshop on Network Slicing*, 2020, p. TBU).

[9] 3GPP, "System architecture for the 5G System (5GS)," *3GPP Technical Specification TS 23.501*, ver. 16.4.0, March 2020.

[10] 3GPP , "5G System (5GS) Location Services (LCS); Stage 2," *3GPP Technical Specification TS 23.273*, ver. 16.3.0, March 2020.

[11] S. Kukliński, L. Tomaszewski, P. Korzec, and R. Kołakowski, "5G-UASP: 5G-based multi-provider UAV platform architecture," in *6th IEEE International Conference on Network Softwarization (NetSoft 2020)*, 2020, p. TBU).

[12] SESAR Joint Undertaking. (2019) Initial view on Principles for the U-space architecture.

[13] Federal Aviation Administration. (2018) Unmanned Aircraft System (UAS) Traffic Management (UTM), Concept of Operations.

[14] European Union Aviation Safety Agency. (2020) High-level regulatory framework for the U-space.