Integration of U-space and 5GS for UAV services

Lechosław Tomaszewski*, Robert Kołakowski*, Sławomir Kukliński*◇ *Orange Polska, ◇Warsaw University of Technology

Abstract

This paper concerns the integration of slicing-enabled 5G System (5GS) with the U-space Service Provider domain for supporting Unmanned Aerial Vehicles (UAV) services. Based on the analysis of recent 3GPP standardization together with current regulations and research in aviation sector, the architecture integrating 5GS and U-space architectural frameworks has been proposed. Deep integration of both ecosystems is a fundamental task in terms of massive realization of commercial UAV services in a common airspace. Therefore, the special focus has been laid on support of UAV traffic management, considering necessary 5G enhancements due to UAV domain requirements. The implementation within the network slicing framework and impact on telco business model have also been discussed.

Index Terms

UAV, UAS, drone, U-space, UTM, 5G, network slicing, business model, business architecture

I. Introduction

Expansion of Unmanned Aerial Vehicles (UAV) services' market is widely expected and tightly connected with a huge variety of UAV use cases recognized in multiple economic sectors [1]. So far, the "Visual Line of Sight" (VLOS) flights with manual control are dominant due to utilization of direct transmission in ISM bands (2.4 GHz and 5.8 GHz, with maximum distance of 5-8 km with no obstruction or interference in case of high-end drones). The most significant barrier for the expansion is a lack of reliable and widespread communication technology supporting flights in "Beyond VLOS" (BVLOS) scenarios, optionally aided with "First Person View" (FPV) – real time 360° UHD video for pilot.

LTE, despite its usually good coverage, is unable to support very low latency and high data rate scenarios. The 5G mobile network is commonly recognized as a candidate for a high-coverage communication platform for Unmanned Aerial Systems (UAS), satisfying even the most challenging requirements. The standardization efforts of 3GPP, concerning support of UAV control and traffic management as well as payload transmission (use case-specific, e.g. real-time video, sensoric data, periodic still photos etc.), have already been started. However, it is only the involvement of telco operator in a role of active participant of UAS processes (e.g. admission control, resources and data exchange risk management, early warning, trusted third party for UAS localization, identification and data integrity etc.) instead of being just a transparent data pipeline, which will bring an added value to the U-space environment and finally will be beneficial for both parties. Therefore, deep integration of both aviation and 5G ecosystems, including business processes, is advisable to enable efficient support of massive UAV traffic.

Usage of 5G and beyond for UAV use cases is the subject of a number of individual studies (see [2] for comprehensive review) focused on specific communication features or mechanisms. The 5G!Drones project [3] is dedicated to trials of 12 UAV scenarios, development of UAS-related enablers and validation of relevant 5G KPIs – precisely in the integrated ecosystem of 5G network and aviation domain systems.

This paper presents the analysis of the current status and dependencies of both U-space and 5G ecosystems as well as outlines a concept of their mutual integration with its multi-faceted discussion. Finally, the impact of the presented approach on business model has been described.

II. Aviation-domain context

To ensure safety and efficiency of UAV operations, several organizations and initiatives such as ICAO, FAA, EASA or JARUS have started their work on development and unification of UAV regulations within corresponding regions, the European Union (EU) or USA. The EU efforts are carried out in accordance with the paradigm of "Single European Sky", i.e. free circulation of UAV services. One of the heavily influenced sectors that is currently under intense research, is flight and airspace management. Building of UAS ecosystem around the UAV Traffic Management (UTM) system [4] is commonly accepted. There are projects devoted to UTM development [5], [6] or air traffic management efficiency [7].

The U-space is a framework of services and procedures for supporting large numbers of drones in a common EU airspace. Its implementation is composed of 4 phases (U1-U4) [8], each introducing new obligatory services to be incorporated in the UAV ecosystem. The U1 phase will come into force on the 1st of January 2021, together with the first common EU regulation on the rules and procedures for the UAVs' operation [9], [10].
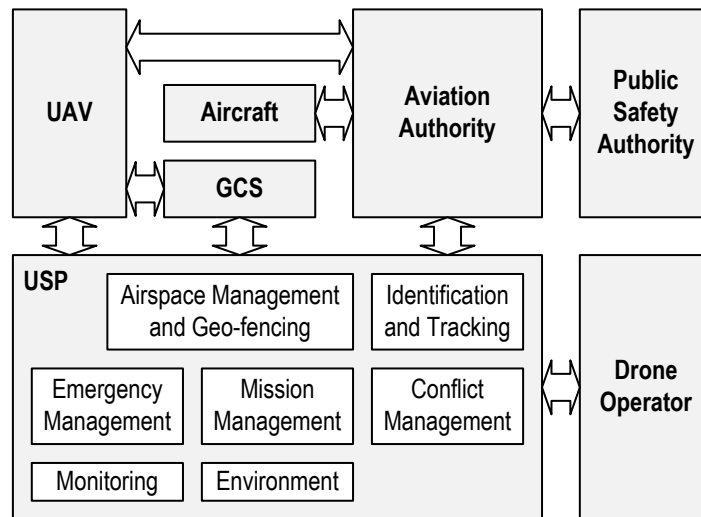
Fig. 1: The U-space ecosystem (based on [11])

The U-space ecosystem [11] (cf. Fig. 1) is comprised of the following: (i) *Aviation Authority*, responsible for flight information management services and manned aircrafts traffic management; (ii) *Public Safety Authority*, e.g. police, fire brigade or search and rescue organizations; (iii) *Ground Control Station* (GCS); (iv) *Aerial vehicles* – UAVs and manned Aircrafts; (v) *Drone Operator* (DOP) – commercial or recreational; (vi) *U-space Service Provider* (USP), i.e. an operator of a UTM system – according to the EU policy, there may exist more than one USP operating in a specific area.

The last of the aforementioned entities is concerned to play a vital role in drone-based services facilitation. The USP's main goal is to provide services and information essential for coordinated flight planning, execution and control. Specifically, USP services can be divided into the following categories [5]: (i) *Identification and Tracking:* registration, e-identification, position report submission and surveillance data exchange; (ii) *Airspace Management and Geofencing (automated control of access to airspace areas):* geo-awareness, aeronautical and geofence information management; (iii) *Mission Management:* operation plan preparation, optimisation and processing, risk analysis assistance [12] and dynamic management of airspace capacity; (iv) *Conflict Management:* strategic (pre-flight) and tactical (in-flight) conflict resolution; (v) *Emergency Management:* incident and accident reporting as well as citizen reporting of observed accidents or violations; (vi) *Monitoring:* navigation and communication infrastructure monitoring, traffic control and legal recording of all user inputs to U-space; (vii) *Environment:* information about weather, geo-spatial positioning, electromagnetic interference, navigation and communication coverage, and population density.

Some of the listed services are strongly related to 5G functionalities. Therefore, the 5G mobile network can be considered as part of U-space services and actively contribute to other U-space services, e.g. radio signal coverage prediction and provision for UAV traffic planning, capacity management, resources allocation planning or incident reporting.

III. RELATED WORKS BY 3GPP

A. 3GPP UAS requirements

The requirements for UAS support by the 5G System (5GS) – especially interactions of the Network Operator (NOP) with UTM – are described in [13]. The 3GPP defines UAS as UAV and its controller (UAC), i.e. GCS according to the U-space nomenclature. The 3GPP recognizes UAS utilizing 3GPP Command and Control (C2) connectivity between UAV and UAC(m) – mobile UAC as well as UAC(nn) – non-networked UAC, e.g. located at fixed flight operations centre, connected with non-3GPP link.

The specific requirements apply to the following areas:

1) Remote identification of UAS: In addition to support of communication between UAS components and UTM, 5GS should be able to augment the exchanged data with network-based positioning information and UAS components' identities. UAS components do not need to be in the same PLMN.

2) Network admission control and UAS equipment validation: UTM may be involved in admission of UAS components to 5GS, which shall support detection, identification and reporting of problematic UAS components to UTM as well as identification of UAS components with UAS-capable and non-UAS-capable User Equipment (UE).

3) Credible location information: 5GS should be able to provide supplementary location information of UAS components to UTM in a real time.

4) UAV-UAS interactions: The overall latency of interactions between UTM and UAS components (e.g. route modification, notifications) has to be less than 500 ms. 5GS should enable UTM to take over the communication for UAV control.

5) Direct UAV-UAV interactions: 5GS shall enable broadcasting and receiving the information exchanged directly between UAVs with UEs attached to any PLMN, with a maximum latency of 100 ms, at a distance up to 600 m, flying at relative speeds up to 320 km/h.

6) Security and trust: 5GS shall protect the transport of data between UAS and UTM as well as preserve from spoofing attacks of UAS identities. It shall also ensure non-repudiation of data sent between UAS and UTM in the Application Plane (AP) and support integrity and privacy protection of UAS-UTM connections and data as well as regulatory requirements as Lawful Intercept for UAS traffic.

7) Service status monitoring: 5GS has to provide to UTM a real-time monitoring of UAS links status and performance as well as the information regarding the service status for UAVs in a certain geographical area and/or at a certain time. This refers especially to C2 communication.

8) Early warning about risk of communication loss: UAS operator or UTM should be warned before leaving 5G UAS services' authorization space (altitude, coverage area etc.).

9) Support of different QoS: 5GS shall provide support of multiple simultaneous communication links (for C2, UAS-UTM, optional FPV, and payload transmissions) with different QoS limits, which are defined for specific use cases (cf. [13]). The most demanding use case is the manual remote control of UAV, when the end to end latency of 20/40 ms (for C2 signaling frequency of 50/25 Hz respectively) is specified.
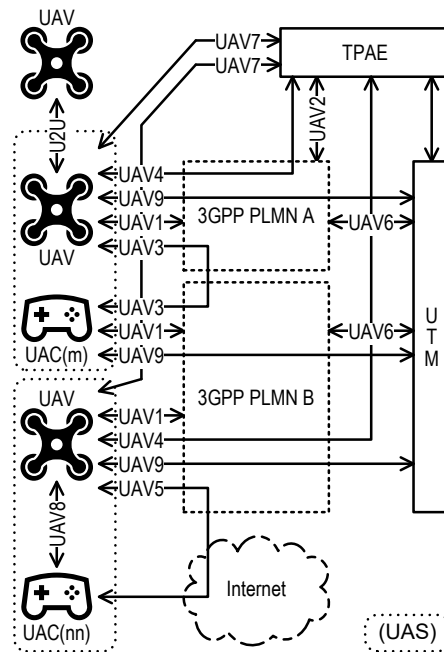

Fig. 2: 3GPP reference architecture of U-Space ecosystem.

B. 3GPP UAS and U-space reference architecture

The 3GPP view on the architecture of UAS and UTM ecosystem has been provided in [14] (cf. Fig. 2). It defines interfaces needed for support of the requirements (cf. [13]):

- Interface for direct inter-UAV communication – U2U, directly via Proximity-based Services (ProSe);
- Interfaces for intra-UAS C2 communication – UAV3, UAV5 and UAV8, respectively for UAC(m), UAC(nn) through 5GS (partially) and directly connected UAC(nn);
- Interfaces for the Third Party Authorized Entity (TPAE – a privileged UAC(m) or UAC(nn), or another entity which gets information on sets of UACs/UAVs, e.g. police, etc.) access – UAV2, UAV4 and UAV7, respectively to PLMN, UAV via 5GS and UAV directly via ProSe;
- Interfaces exposed by 5GS – UAV1 and UAV6, respectively for UAV/UAC and UTM;
- Interface for UAV/UAC-UTM communication – UAV9.

The interfaces UAV1, UAV2 and UAV6 exposed by PLMNs support requirements associated with deep 5GS integration.

C. 3GPP 5GS architectural framework

The 5GS architecture by the 3GPP [15] and its extensions (e.g. Location Services – LCS [16]) define Network Functions (NFs) and mechanisms important for UAS support. 5GS Control Plane (CP) is based on service-oriented architecture and

includes Network Slice Selection Function (NSSF), Session Management Function (SMF) – a User Plane (UP) control agent specific to its design, Application Function (AF) – embedding service-augmenting functions within 5G CP, Network Exposure Function (NEF) – a gateway to CP functions for external business (e.g. vertical) environment, and Network Data Analytics Function (NWDAF) – network monitoring and analytic engine.

Due to inclusion of network slicing (NS), separate virtual networks optimized for different classes of services can be provided for specific use cases and/or tenants. The support of NS includes per-IMSI Network Slice Instance (NSI) selection and admission control. The 3GPP slice service types include: eMBB, URLLC, mMTC and additional V2X class (since the Release 16), but future extensions are possible. In addition to its hitherto role of UP tunnel with mobility anchor, UP Function (UPF) in 5GS is an NSI-specific chain of functions processing the user traffic (e.g. firewall, deep packet inspection – DPI, classification, redirection and alteration, formerly supported within the 4G SGi LAN).

D. 5G Proximity-based Services

Such solution has been defined for LTE-Advanced and LTE-Advanced Pro [17], but it does not exist for 5G, yet. Only the study on enhancements of 5GS for accommodation of ProSe has already been started [18], as a part of the Release 17.

IV. OUTLINE OF U-SPACE AND 5GS INTEGRATION PROPOSAL

The architecture of 5G CP supporting U-space services is presented in Fig. 3. It is designed in accordance with basic 5GS architecture [15] enhanced with LCS [16]. Some of the native 3GPP 5GS functionalities or mechanisms need enhancements (depicted further in the text) to enable UAS support and the proposed deep integration with UTM. Additionally, the special gateway function is included to serve as the North-Bound Interface (NBI) to UTM and TPAE.

A. Description of architectural entities

The architecture shown in Fig. 3 is based on the non-roaming 5GS reference architecture with addition of functional instances supporting LCS. Roles of individual CP functions in the context of UTM integration and UAS support as well as their modifications (if necessary) are described below.
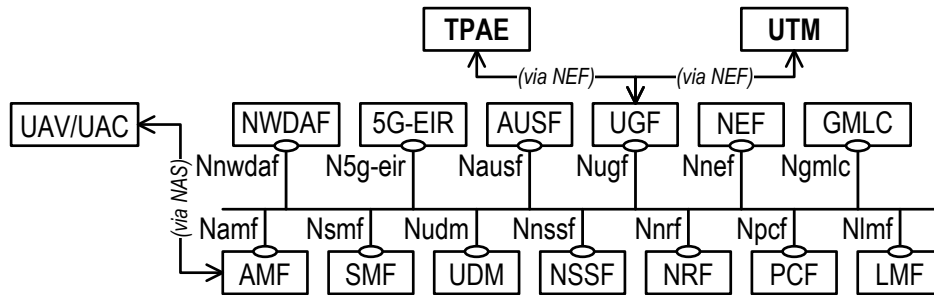

Fig. 3: Integration of U-space and 5GS – CP view

1) Authentication Server Function (AUSF): It supports NSI-specific authentication and authorization (cf. [19]). For admission to the UTM NSI and its Data Network (DN) the procedures, normally using the customer's subscription data stored in the Unified Data Management (UDM), should be enhanced to enable interactions with UTM. Therefore, a modification of AUSF functionality is needed.

2) 5G-Equipment Identity Register (5G-EIR): Based on the UE Permanent Equipment Identifier (PEI) check, it identifies the on-board UE as UAV-capable. The results of identification may be used at the UTM slice admission stage and at the 5G network registration stage.

3) Network Data Analytics Function (NWDAF): This function, which combines data collection from all 5GS NFs, further data processing, analytics and exposure, provides real-time monitoring of UAS links, detection of communication loss risk and identification of problematic behavior of connected UAV/UAC UEs. It can also provide individual statistics at IMSI level. Here, the special monitoring of UAV UE-specific threshold crossing events can be subscribed.

4) Gateway Mobile Location Centre (GMLC): It exposes 5G LCS, serves as a gateway point to these services and stores charging information for their usage. If UTM requires alternative positioning for validation of location data provided by UAV/UAC, then the Network-Assisted Positioning Procedure will be used (gNBs upgraded to its support are needed).

5) Location Management Function (LMF): It acts as a coordinator of all procedures and resources required for locating a UE (either registered with or accessing Core Network – CN). LCS can be requested as single, periodic or triggered service. LMF also performs calculation or verification of final location and estimated UE velocity, and may assess the accuracy.

6) Access and Mobility Management Function (AMF): It is a CP proxy for interactions with UEs (NAS protocols, cf. the UAV1 interface in Fig. 2) and NG-RAN (especially for requests of positioning based on RAN measurements, cf. [20]).

7) UTM Gateway Function (UGF): Hereby proposed, it is a special case of a generic AF of the 5GS architecture, which is a mediator and coordinator of all interactions of UTM and TPAE with 5G CP – it subscribes to the NWDAF services, sends Immediate Location Requests to GMLC or requests periodic or triggered location reporting jobs, interacts with management of security measures for the UAS-UTM traffic and participates in UTM DN admission procedures with cooperation of CP network functions. The UGF is exposed to UTM and TPAE via NEF, which acts as a termination point of UAV6 and UAV2 interfaces, respectively (cf. Fig. 2). UGF should be also used to respective extent for interactions of DOP systems (context of C2, FPV and payload links) with 5GS to avoid duplication of similar functions and signaling traffic.

8) Session Management Function (SMF): This function represents multiple instances of SMFs dedicated to dealing with NSI-specific UPFs individually.

9) Policy and Charging Function (PCF): It is related to support of various possible charging models associated with different business models of 5G UAS support implementation.

10) Network Slice Selection Function (NSSF): It is responsible, in cooperation with the Network Repository Function (NRF), for validating, determining and selecting the NSIs and AMFs to serve the requesting UAV/UAC UE.
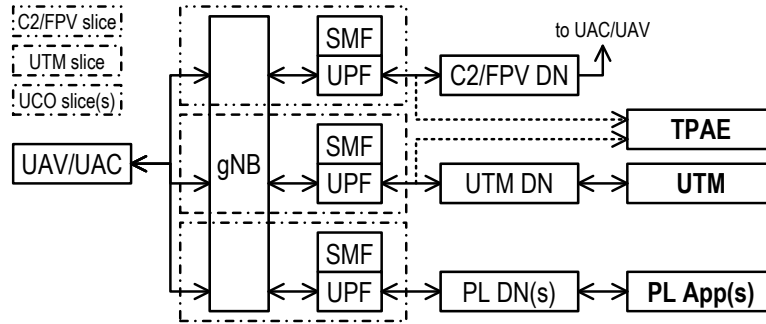

Fig. 4: Integration of U-space and 5GS – UP view (PL – payload)

B. UP issues

1) Network slicing: Specific UAS communication links will be provided through separate NSIs (cf. Fig. 4). UAV/UAC UE has to be NS-aware and the on-board application needs to have both Single Network Slice Selection Assistance Information (S-NSSAI) and Data Network Name (DNN) provided in its settings. The UP design should be adapted to requirements of each communication link. In case of very low latency target or when the UAV data-consuming party is located near to UAV, the MEC-based [21] integration of AP with 5GS can be used.

2) UAS-UTM communication integrity assurance: In addition to anti-spoof mechanisms in CP, PLMN can ensure the integrity of UP data flow through connecting the UTM interface to a separate DN with enhanced admission measures. Furthermore, implementation of DPI in the UPF chain is hereby proposed to provide "stamping" of traffic by PLMN as a Trusted Third Party (TTP) through amendment of packets with additional UAS identity information to certify the exchange.

3) Payload channels: Their characteristics depends on specific use case, the AP-level solution architecture and required QoS class according to [13]. The detailed design of these channels is outside of scope of this work, but it will be subject to similar considerations as those aforementioned above in the context of flight control and management channels.

4) TPAE-UAV channel (UAV2 interface): 5GS procedures definitions [19] currently do not include any mechanisms for CN-requested PDU session establishment, which would additionally need to be answered at the UE side. It is possible, however, to provide a secure TPAE access to any UP DN upon request of TPAE, e.g. to UAS-UTM DN or C2 DN. Mechanisms of lawful interaction between TPAE and UAS applications have to be further defined and standardized, then their additional support by 5GS may be studied.

C. Exposure of 3D information about 5G network coverage

Sharing of 3D information about network coverage and performance is a significant feature for USP flight plan validation and environmental awareness, especially real-time UAV traffic management. 5G RAN physical layer measurements at UE are defined in [22], but no mechanisms similar to 3G/4G measurements collection (Minimization of Drive Tests – MDT, cf. [23]) have been specified in 5G, yet. Therefore, the only way for an NOP to provide such information is interfacing its RAN planning system (outside of 5GS) with the USP domain. Once the appropriate mechanisms are defined for 5G, exposure of 3D network coverage data through UGF and NEF, based on measurements collected by UAVs, will be possible.

Considering elevated safety requirements for aerial communication, associated NSIs should be of high priority. It should be noted that involvement of NOP in the flight planning process is an important advantage from the network engineering point of view. Hence, the non-UAV customers' traffic does not need to be perturbed by abrupt requests of augmentation of resources for aerial communication traffic. Freeing of base station resources by moving non-UAV users in advance and change of gNBs users' serving policy can be performed in a coordinated manner, taking into account flights trajectories.

D. Common admission control

Non-payload channels (i.e. UTM, C2 and FPV ones) are of particular importance for flight safety. Their smooth operation requires protection against unauthorized access or attempted abuse. It is advisable to implement common admission control mechanisms in the network slice access request procedure where both parties – NOP and USP decide to grant access (or not) to a special-purpose part of the 5GS. In case of refusal, UAV will be unable to take off.
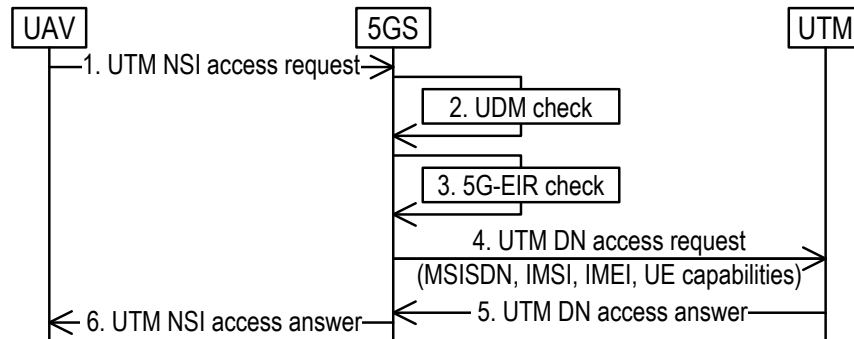

Fig. 5: Common UTM NSI admission control

Fig. 5 presents a simplified message flow for UE request of access to the UTM slice. After the request from an on-board UE of UAV, 5GS performs UDM check for subscription information and 5G-EIR check for UE validation in terms of UAV capabilities and being blacklisted. Then the complete information is transferred to UTM via UGF for validation against UAS register and final decision, which is sent back to 5GS and then forwarded to UE (UPF connection will be provisioned or not, according to the decision). To support the common admission control, AUSF procedures have to be accordingly adapted. The decision for UTM NSI access may be reused for handling of access requests to public C2 or FPV NSIs. Additionally, in case of big DOPs being tenants of private C2/FPV NSIs, a similar mechanism of common admission control may be used, involving DOP systems.

E. Implementation of the architecture within network slicing frameworks

Architectural frameworks supporting mechanisms of common/dedicated slice, lightweight CP and per-plane slicing [24] are particularly suitable for implementing the proposed architecture. Handling of specific payload and non-payload communication channels with specific QoS will be provided by dedicated UP slices having their own separate SMFs in CP. Implementation of CP functions related to UAS support will be realized by means of vertical CP slice stitching, i.e. concatenation of lightweight common CP and dedicated CP via slice API.

The point is not only in mechanisms of mutual isolation between dedicated CPs but also in protection of common CP against excessive signaling traffic caused by multiplication of the same requests. Common CP API should consolidate requests related to handling of the same UE by different dedicated slices (e.g. for UAV location check, early warning about possible coverage loss etc.) or coming from different entities (e.g. UTM, UAC/GCS or TPAE).

In case of distributed approach to UTM/GCS integration, instead of centralized one, the MEC-enabled 5G NS framework [25] can be used, where UGF will be implemented as MEC App interfaced with 5G CP via MEC Platform APIs.

F. Roaming issues

In general, 5GS supports two scenarios for roaming: Home Routed (HR) and Local Breakout (LBO). In terms of UAV communication, LBO is especially important due to low latency requirement typical in drone services (C2, FPV or payload transmission) but also for connection with a local (visited) UTM. However, implementation of LBO roaming architecture is problematic, as the transparent mechanisms for control of charging errors/frauds are currently nonexistent in this scenario. For LBO, to be implementable from the point of view of home MNO, it is essential to provide means for augmenting mutual trust between HPLMN and VPLMN operators. Additionally, roaming-related UGF enhancements have to be implemented to facilitate multilateral interactions between UTMs and PLMNs, both visited and home ones (e.g. for common admission control).

Another fundamental issue related to roaming scenarios is meeting the requirement for latency of 500 ms of UAS-UTM communication during PLMN change in cross-border flights. As the interruption during de-registration and re-registration procedures lasts much longer, dual-SIM terminals on-board UAV and successive re-registration are a work-around, but a redesign of these procedures for zero interruption time is needed. Also, the specific service NSI architecture (UPF chain) designed by HPLMN has to be replicated at VPLMNs.

More details concerning the issues of cross-border UAV operations and necessary 5G network enhancements for the proposed hereby 5GS-UTM integration can be found in [26].

V. Impact on the business model

Wide range implementation of 5G networks, to be built according to NS concept – based on the network softwarization and virtualization technologies leveraged by open market of shared infrastructure resources, will be a disruptive change of the current telco business ecosystem. The future business model [27] can be applied with some modifications, in case of 5G services for UAVs.

NOP can create payload NSIs, which can be partly or fully managed by verticals (DOPs), acting as Slice Tenants. It is worth mentioning that NSIs are not "external" to 5GS, but they are a part of it. For providing UAV services, a single UAV has to be attached to several different NSIs to cope with the UTM, C2 or FPV link as well as payload communication. Big DOP can order a development of their own specific Slice Templates or Slice Functions at respective Providers for further implementation within NOP's 5G network. As it has been also shown, 5G CP may provide some services (offered by NOP to DOPs) to support UAV services. Therefore, DOP has to interact with NOP as a consumer of 5G CP services. The alternative approach is that DOPs can be Slice Customers of payload UAV communication services supported by generic UAS NSIs provided and managed by NOP using common UAS NSI templates.

The UAS-UTM communication has to be provided between DOPs and their UTM. The UTM slice can be created individually for DOP (as a Slice Tenant) or as a common one for all DOPs attaching to specific PLMN. The common UTM NSI may be managed by NOP, in such case the DOPs will obtain UTM services via their NOP and will be charged for their UTM traffic by NOP. However, USP may also act as UTM Slice Tenant (i.e. a vertical for its NOP), then DOPs may be charged e.g. based on a per-UAV monthly fee. The UTM Slice Template will be rather UTM-specific, especially the interface for deep integration of UTM with 5GS (to use 5G CP services, LCS, common authentication, UAS links monitoring etc.). NOP can also act as TTP for the UTM transmission.

It has to be noted that due to sharing of 3D coverage and communication service performance maps by NOPs with USP, DOPs will be able to find and choose the best PLMN for their needs, which will stimulate the competition. On the other hand, active involvement of NOPs in flight planning process is beneficial for them, because it gives an opportunity to prepare relevant network configuration in advance, with proper distribution of global network load and resources allocation.

Business model not only specifies different actors but also business interfaces between them and mutual responsibilities. These interfaces should be also used for SLA negotiation, verification and accounting. It has to be emphasized that NOP offers not only the connectivity for UAV services, but also NSI (probably with dynamically changing coverage) and advanced CP services. Therefore, the billing should include costs of all services delivered to DOP.

VI. Summary and conclusions

In the paper, after the analysis of UAS domain specifics and the 3GPP vision of UAS support, the proposal of 5GS-based architecture with necessary functional enhancements enabling integration with the UTM ecosystem, facilitating commercial UAV services, has been presented. Introduction of the special UTM Gateway Function to coordinate U-space interactions with the 5GS has been proposed. The discussion of UP issues, exposure of 5G network coverage, common NS admission control, application within the NS framework, roaming issues and considerations on implications to the telco ecosystem business model have also been provided.

The 5G network features and mechanisms can significantly contribute to diverse U-space services; however, some enablers are still missing, i.a. 5G device-to-device communications, proactive radio coverage adaptation (e.g. by beamforming), full NS support and UAS NSI templates, MEC support, customized and programmable CP, joint UTM NSI/DN admission or 5G MDT. But above all, the potential of cooperation between 5GS and aviation ecosystem will be fully exploited only as a result of their deep integration and close cooperation of telecommunications and aviation standard developing organizations. Otherwise, 5GS may not respond accordingly to aviation processes needs and dynamics, whilst the aviation domain may not benefit of all available technical features, which can be potentially embedded in its environment.

In conclusion, the close cooperation between standardization bodies of both domains is hereby strongly advocated. Establishment of a harmonized and commonly accepted architecture and interfaces is essential in terms of deployment of large-scale UAV services, which can be a killer application for the 5G network.

References

[1] H. Shakhatreh et al., "Unmanned Aerial Vehicles (UAVs): A Survey on Civil Applications and Key Research Challenges.", IEEE Access 7, Digital Object Identifier 10.1109/ACCESS.2019.2909530, Apr. 2019.
[2] B. Li, Z. Fei, Y. Zhang, "UAV Communications for 5G and Beyond: Recent Advances and Future Trends", in IEEE Internet of Things Journal, vol. 6, no. 2, pp. 2241-2263, Apr. 2019.
[3] 5G!Drones Project, https://5gdrones.eu/ [Online]
[4] Global UTM Association, "UAS Traffic Management Architecture", ver. 1.0, Apr. 2017.
[5] CORUS Project, https://www.sesarju.eu/projects/corus [Online].
[6] PODIUM Project, https://www.sesarju.eu/projects/podium [Online].
[7] EURODRONE Project, https://www.sesarju.eu/node/3202 [Online].
[8] SESAR JU, "U-space Blueprint", Oct. 2017.
[9] European Commission, "Commission Implementing Regulation (EU) 2019/947 of 24 May 2019 on the rules and procedures for the operation of unmanned aircraft (Text with EEA relevance)", Official Journal of the European Union, L 152, 11.6.2019, pp. 45–71.

[10] European Commission, "Commission Implementing Regulation (EU) 2020/639 of 12 May 2020 amending Implementing Regulation (EU) 2019/947 as regards standard scenarios for operations executed in or beyond the visual line of sight (Text with EEA relevance)", Official Journal of the European Union, L 150, 13.5.2020, p. 1–31.

[11] EANS, "SESAR 2020 GOF USPACE Summary, FIMS, Design and Architecture" [Online]. Available: https://www.sesarju.eu/node/3203 [Accessed: Jan. 2nd, 2020].

[12] JARUS, "JARUS guidelines on Specific Operations Risk Assessment (SORA)", Joint Authorities for Rulemaking of Unmanned Systems Guideline JAR-DEL-WG6-D.04, ed. 2.0, Jan. 2019.

[13] 3GPP, "Unmanned Aerial System support in 3GPP; Stage 1", TS 22.125, ver. 17.1.0, Dec. 2019.

[14] 3GPP, "Study on supporting Unmanned Aerial Systems (UAS) connectivity, identification and tracking", 3GPP TR 23.754, ver. 0.1.0, Jan. 2020.

[15] 3GPP, "System Architecture for the 5G System", 3GPP TS 23.501, ver. 16.4.0, Mar. 2020.

[16] 3GPP, "5G System (5GS) Location Services (LCS); Stage 2", 3GPP TS 23.273, ver. 16.3.0, Mar. 2020.

[17] 3GPP, "Proximity-based services (ProSe); Stage 2", 3GPP TS 23.303, ver. 15.1.0, Jun. 2018.

[18] 3GPP, "Study on system enhancement for Proximity based Services (ProSe) in the 5G System (5GS)", 3GPP TR 23.752, ver. 0.3.0, Jan. 2020.

[19] 3GPP, "Procedures for the 5G System", 3GPP TS 23.502, ver. 16.4.0, Mar. 2020.

[20] 3GPP, "NG Radio Access Network (NG-RAN); Stage 2 functional specification of User Equipment (UE) positioning in NG-RAN", 3GPP TS 38.305, ver. 16.0.0, Apr. 2020.

[21] ETSI, "Multi-access Edge Computing (MEC); Framework and Reference Architecture", ETSI GS MEC 003, V2.1.1, Jan. 2019.

[22] 3GPP, "NR; Physical layer measurements", 3GPP TS 38.215, ver. 16.1.0, Apr. 2020.

[23] 3GPP, "Universal Terrestrial Radio Access (UTRA) and Evolved Universal Terrestrial Radio Access (E-UTRA); Radio measurement collection for Minimization of Drive Tests (MDT); Overall description; Stage 2", 3GPP TS 37.320, ver. 16.0.0, Apr. 2020.

[24] S. Kukliński, L. Tomaszewski, A. Ksentini, P. Frangoudis, E. Cau et al., "A reference architecture for network slicing", 2018 4th IEEE Conference on Network Softwarization and Workshops (NetSoft), Montreal, pp. 217-221, 2018.

[25] L. Tomaszewski, S. Kukliński, R. Kołakowski, "A new approach to 5G and MEC integration", 16th International Conference on Artifical Intelligence Applications and Innovations (AIAI 2020) – 5th Workshop on 5G — Putting Intelligence to the Network Edge (5G-PINE 2020), Porto Carras, 2020 (in press).

[26] L. Tomaszewski, R. Kołakowski, P. Korzec, "On 5G support of cross-border UAV operations", IEEE ICC 2020 – Workshop on Integrating UAVs into 5G and Beyond, Dublin, Ireland, 2020 (in press).

[27] S. Kukliński, L. Tomaszewski, K. Kozłowski, S. Pietrzyk, "Business models of network slicing", 2018 9th International Conference on the Network of the Future (NOF), Poznań, pp. 39-43, 2018.