HORVÁTH

Feasibility Study 2021

”Feasibility Study about the possibility of using mobile telecommunication technologies for making manned aircraft electronically conspicuous in U-space”

EASA

European Union Aviation Safety Agency

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Glossary

Term	Explanation
Accuracy	'Accuracy' of an estimated or measured position of an aircraft at a given time means the degree of conformance of that position with the true position, velocity and/ or time of the aircraft. Since accuracy is a statistical measure of performance, a statement of navigation system accuracy is meaningless unless it includes a statement of the uncertainty in position that applies.
Aircraft	'Aircraft' means a machine that can derive support in the atmosphere from the reactions of the air other than the reactions of the air against the earth's surface.[1]
ADS-B Light	A draft standard built by EASA and Eurocontrol experts based on already existing standards for 1090 MHz Mode-S Extended Squitter ADS-B Out.
Integrity	The measure of the trust that can be placed in the correctness of the information supplied by a navigation system. Integrity includes the ability of the system to provide timely warnings to users when the system should not be used for navigation.
U-space	U-space consists of a set of new services, rules and processes designed to support safe, efficient and secure integration of drones in the uncontrolled airspace. The U-space framework supports routine drone operations as well as clear and effective interfaces to manned aviation, ATM/ ANS service providers and authorities. The U-space airspace is a UAS geographical zone designated by the Member States where UAS operations are only allowed to take place with the support of USSP. However, the U-space is not only considered as a defined airspace segregated and designated for the use of drones. It is designed to ensure safe, efficient, and secure operations of drones in all operation environments in all types of airspaces (in particular but not limited to the very low level of airspace).

[1] (EASA, 2007)

Abbreviations

Abbreviation	Explanation
3D	Three-dimensional space
3GPP	3rd Generation Partnership Project
ACJA	Aerial Connectivity Joint Activity
ADS-B	Automatic Dependent Surveillance–Broadcast
AES	Advanced Encryption Standard
AGL	Above Ground Level
AMC	Acceptable Means of Compliance
AMPS	Advanced Mobile Phone Service
ANS	Air Navigation Services
ASTM	American Society for Testing and Materials
ATM	Air Traffic Management
BT	Bluetooth
CA	Collision Avoidance
CE	Conformité Européenne
CEPT	The European Conference of Postal and Telecommunications Administrations
CSV	Comma-Separated Values
EAN	European Aviation Network
ECA	European Common Allocation (Table)
ECC	Electronic Communications Committee
EMC	Electromagnetic Compatibility
EU	European Union
EUR	Euro
FLARM	Flight Alarm
FM59	Working Group Frequency Management for UAS within ECC
Gbps	Gigabit per second
GHz	Gigahertz
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSM	Global System for Mobile Communications
GSMA	Global System for Mobile Communications Association
GUTMA	Global UTM Association
HAP	High-Altitude Platform
HD	High Definition
HTTPS	Hypertext Transfer Protocol Secure
ICAO	International Civil Aviation Organization
ICD	Interface Control Document
ID	Identity
IEEE	Institute of Electrical and Electronics Engineers
ISM	Industrial, Scientific and Medical Band
ITS	Intelligent Transport Systems
ITU	International Telecommunication Union
JRC	Joint Research Centre

kbps	Kilobit per Second
kHz	Kilohertz
km/h	Kilometre per hour
LTE	Long Term Evolution
m	Metre
Mbps	Megabit per Second
MEC	Mobile Edge Computing
MEMS	Micro-Electro-Mechanical Systems
MHz	Megahertz
MIMO	Multiple Input Multiple Output
ms	Millisecond
mW	Milliwatt
nm	Nanometre
NMT	Nordisk MobilTelefoni
NRA	National Regulatory Authority
OGN	Open Glider Network
PMSE	Programme Making and Special Events
PT1	Project Team 1 - Lead group on mobile in ECC
RED	Radio Equipment Directive
RLAN	Radio Local Area Network
RSA	Rivest–Shamir–Adleman
SERA	Easy Rules for Standardised European Rules of the Air
SIM	Subscriber Identity Module
SLA	Service Level Agreement
SMS	Short Message Service
SSR	Special Service Request
TACS	Total Access Communication System
Telco	Telephone Company
TLS	Transport Layer Security
UAS	Unmanned Aircraft System
UE	User Equipment
UK	United Kingdom
UMTS	Universal Mobile Telecommunications System
US	United States
USSP	U-Space Service Provider
UTM	UAS Traffic Management
V2V2X	Vehicle to Vehicle to Others
WCDMA	Wideband Code Division Multiple Access
Wi-Fi	Wireless Fidelity

1. Management summary

Objective of the present study is to evaluate the suitability of mobile telecommunication technologies for making manned aircraft electronically conspicuous in U-space under the consideration of the Commission Implementing Regulations (EU) 2021/664, 2021/665 and 2021/666 of April 22, 2021. The study refers only to aircraft such as small aircraft, helicopters, and paragliders that are not provided with an air traffic control service, to continuously make themselves electronically conspicuous to U-space service providers in urban and low-level airspace.

Result of the study is that from a technological point of view, mobile telecommunication technology could generally be used as solution to make manned aircraft electronically conspicuous in U-space, especially, if not considered to be a "safety of life" application.

However, there are complications that need to be considered and addressed:

1. Interferences through unpredictable data upload: When considering an application-based tracking with a mobile phone, it needs to be taken into account, that an app cannot easily eliminate other apps or functions that might run in the background of a mobile phone. This might lead to an unpredictably higher consumption of bandwidth than needed for the tracking service and thus, can seriously affect the ground network with interferences.
2. Lagging roaming agreements: National and international roaming agreements rely on a basic understanding of the roamed services (SMS, Voice Streaming etc.) which cannot be presumed for aerial services. These aerial services are currently concluded in international and European standardization bodies. Once these aerial services are concluded, these concerns could be dropped (probably finished 2022/23).
3. Frequency restrictions: There are country specific restrictions in the use of certain frequencies below 1 GHz for aeronautical services. However, mobile phones are made to cover the widest range of frequency bands possible and do not allow to exclude frequency bands from usage. The Electronic Communication Committee (ECC) aims for a European decision until November 2022. Afterwards, the national authorities are supposed to implement this decision.

Considering the technological and legal perspectives, the use of mobile telecommunication technology cannot be recommended at this stage, unless further measures are taken: It needs to be ensured, that the EASA policy does not convey that mobile phones can generally be used for aerial services. EASA needs to make explicitly clear, that the mobile phone should only be used for this specific purpose (electronic conspicuity in U-space). This includes recommendations such as shutting down all background apps. Thus, EASA emphasizes that they focus on a narrowband service to avoid interferences (1) and issues between Telco providers in case of roaming (2).

Furthermore, it needs to be ensured that ECC decisions as well as the implementation of these decisions in national legislation are considered in a EASA's policy. To accelerate this time critical process, a way should be found to approach officially ECC board directly. In parallel, EASA should make use of the gradually planned U-space implementations across Europe to prepare an early consensus of all Member States to follow the ECC decision (3).

If these measures are brought to success, the use of mobile telecommunication technologies to make aircraft electronically conspicuous in U-space is considered to be feasible.

An already available fallback solution is to recommend the use of affordable, dedicated narrowband tracking devices with the capability to switch off the critical frequencies.

2. Overview of study

The following chapter describes the initial situation, which raised the demand for this feasibility study to be conducted. Furthermore, the key objectives for developing the feasibility study, the scope and the applied methods of the study are described.

2.1 Initial situation

The new Commission Implementing Regulation (EU) 2021/666 was published on 22 April 2021 as an amendment to Regulation EU No 923/201, and to provide new requirements for manned aviation operating in U-space airspace. Thereby, point (c) in SERA.6005 Requirements for communication, SSR transponder and electronic conspicuity in U-space airspace discusses the requirement for manned aircraft operators to make themselves conspicuous to the USSP to prevent collisions:

> (c) U-space airspace
>
> Manned aircraft operating in airspace designated by the competent authority as a U-space airspace, and not provided with an air traffic control service by the ANSP, shall continuously make themselves electronically conspicuous to the U-space service providers.

EASA needs to develop an Acceptable Means of Compliance (AMC) to meet the new requirements, aligned with Air Traffic Management and Air Navigation Rules. Moreover, EASA envisages to go beyond traditional certified surveillance means in aviation (transponder) and to consider simpler, lighter, and more affordable ways to report the aircraft position and status by taking into consideration the possible use of mobile telephony to gather the information, and to provide data to the USSP.

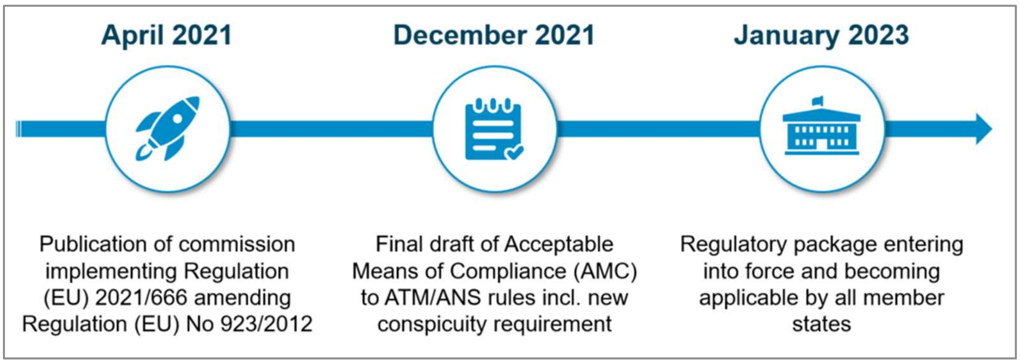

Figure 1 Overview timeline of the initial situation

2.2 Objectives and scope of the study

The main objective of this study is to evaluate the feasibility to utilize mobile telecommunication technologies for making manned aircraft electronically conspicuous in U-space under the consideration of the Commission Implementing Regulations (EU) 2021/664, 2021/665 and 2021/666 of 22 April 2021. Thereby, the aim is to clarify whether mobile telephony is suitable as the solution for making manned aircraft electronically conspicuous in U-space, with consideration to urban and low-level airspace.

This study is a supporting document for EASA to draft the AMC to ATM/ANS rules including this new conspicuity requirement to facilitate a timely implementation of U-space regulations with a maximum of compliant U-space users from 2023 onwards. Notwithstanding, this entails a sufficient level of safety and a minimum level of harmonization across all possible solutions.

Scope of the study

The scope of the study comprises manned aircraft operators such as small aircrafts, helicopters, paragliders, balloon operators, hang gliders and gliders etc. passing through the U-space airspace and which are managed by a USSP. Even if the U-space airspace is a geographical zone designated by the responsible authorities to enable safe, efficient, and secure operations of drones in the uncontrolled airspace, the scope of the study does not consider any (increasing numbers of) drone operations and/ or drone technologies which might influence and affect manned aircrafts flying through the U-space. Therefore, the study does not consider the interoperability of drones with manned aircrafts using mobile telecommunications technology in the U-space. The isolated operability of manned aircrafts making themselves electronically conspicuous to the U-space service providers is the focus of the study.

Moreover, the scope of the study is limited to assess if mobile telecommunications technology is suitable to be used as solution to gather the necessary information by manned aircrafts and to provide the respective data to the USSP. This is described as the Message Exchange Function (incl. the transmission of data to the airborne segment as well as to the ground segment) – please refer to figure 2.

The scope of the study is within the 'ADS-B Light' system; however, it regards mobile technology as solution for the Message Exchange Function. Although the 'ADS-B Light' standard is essentially technology-agnostic, the scope of the study focusses on the possibilities that mobile telecommunication infrastructure may offer. The present study does not assess other technological solutions.

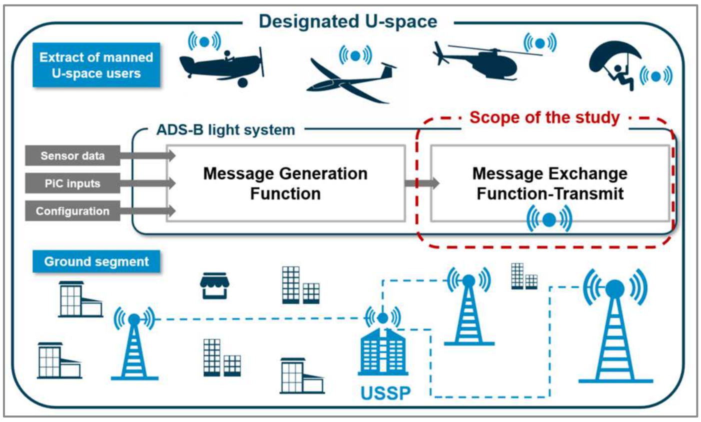

Figure 2 Scope of the feasibility study

2.3 Applied methods

The present study focusses on seven pre-defined Areas by EASA: (1) Network coverage and altitude restrictions, (2) Security, (3) Mobile telephony and network performance, (4) Roaming and network access, (5) Telemetry in mobile phones, (6) Future air-to-air communication, and (7) Legal. For each Area, EASA defined specific questions that need to be answered.

To answer the questions of each Area, applicable sources were collected, categorized, and analysed. The sources include scientific journal articles, institutional publications (e.g., governmental), consultancy publications, industry groups and others (see Figure 3). A total of 74 sources were considered as relevant. More than 50% of the evaluated sources come from institutional publications and scientific journal articles and can therefore be classified as objective sources. The industry sources must be evaluated under consideration of the respective company interests. However, these sources represent significant know-how due to the technology focus of the study.

It is important to highlight the limitations in existing literature, as the field of research is not in depth explored at this stage. Therefore, knowledge was built on any applicable sources with focus on the use of mobile telephony in airspace, may it be on drones or manned aircraft, as it does not make difference regarding the mobile network performance.

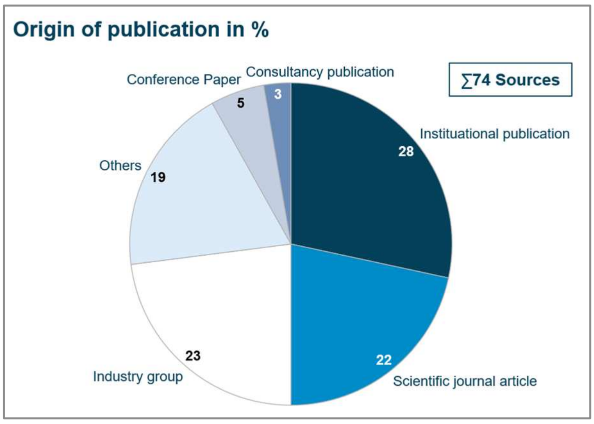

Figure 3 Origin of publication

As seen in figure 4, the sources were chosen with consideration to their topicality to ensure a state-of-the art discussion, and most of the sources were published recently within the years 2019 and 2021.

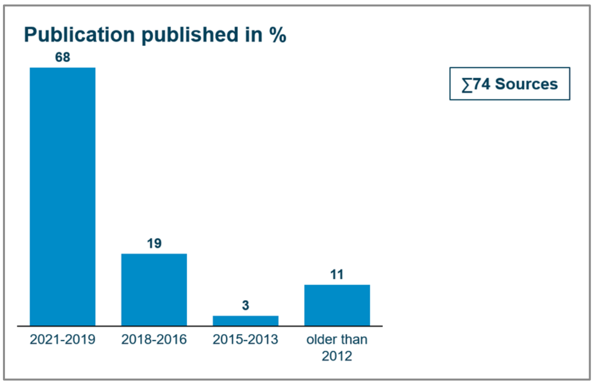

Figure 4 Overview of publishing year

As existing studies show limitations with regards to the research topic, some conclusions were drawn from expert evaluations, e.g., for experience-based estimation of technical limitations through testing or legal expertise. Also, specific qualitative expert interviews have been facilitated to support evidence from secondary sources. Moreover, the insights of the workshop “What are USSP’s needs for aircraft to be electronically conspicuous in U-space” held by EASA on 22 July 2021 have been considered. No primary data in form of field tests was collected.

3. Underlying assumptions

Several underlying assumptions must be taken into consideration, which directly influence the feasibility of utilizing mobile telecommunication technologies for making manned aircraft electronically conspicuous in U-space. These include the choice of mobile network, performance levels, handover, and interference, as well as the characteristics of mobile phones in contrast to dedicated tracking devices.

3.1 Mobile network generations and performance levels

Mobile networks started in 1979 with 1G standard, which stands for 1st generation. Roughly every ten years a new generation comes into deployment, leading typically to more speed and capacity for the sake of the ever-growing data demand of mobile customers. Where 1G was only able to offer 2.4 kbps, 2G was already able to make 64 kbps with the GSM standard, including basic security and reliability features. 3G (so called UMTS) offers 144 kbps and 2 Mbps, whereas 4G provides up to 100 Mbps and 1 Gbps based on LTE technology.[2]

1G is not available anymore, as it was substituted by 2G. 3G is the next network to be eliminated, or more precisely, it is transferred into 4G. 5G is the latest mobile telephony standard, which again relies mainly on additional available frequencies used and better transmission technologies. Whereas 1G relied on the small 30 kHz band, 5G uses min. 6 bands with several hundred MHz bandwidth (700 MHz, 800 MHz, 900 MHz, 1800 MHz, 2.1 Ghz, 2.6 GHz, 3.5-3.8 GHz are most common bands in Europe). The today remaining GSM (2G) runs on parts of 900 MHz, UMTS (3G) on 2.1 GHz. All other bands are standardized for LTE. 5G is currently deployed mainly in 700 MHz and 3 GHz.[3]

Regarding quality measures for aerial use, latency within the mobile network might be a critical factor. While nominal latency of 2G is up to 1000 ms, 3G reaches 200 ms. 4G achieves typically between 40 and 70 ms in aerial use, whereas its latency is officially considered as up to 100 ms. 5G aims to achieve <20 ms, however this is physically hard to achieve and depends on many factors that need to be highly optimized, like fibre backhauling or mobile edge computing (MEC).[4] With every change of network generation new handsets become available to the market, covering the new standard. Devices are typically network agnostic, meaning they choose the best network generation available. Current Android devices offer the possibility to choose between the networks (2G, 3G, 4G, 5G).[5] Apple iPhones only allow the 2 latest generations to choose (e.g., with iPhone 12 only 4G and 5G are available).[6] Figure 5 shows a comparison of the different mobile communications generations and the respective technical specifications.

Generation	1G	2G	3G (UMTS)	4G (LTE)	5G
Commercial start	1979	1991	2001	2009	2019
Bandwidth	2.4 kbps	64 kbps	144 kbps - 2 Mbps	100 Mbps - 1 Gbps	>1 Gbps
Technology	AMP, NMT, TACS	GSM	WCDMA	LTE	MIMO, nm Waves
Frequency[7]	30 kHz	900 MHz	2.1 GHz	2-8 GHz	700 MHz, 800 MHz, 900 MHz, 1800 MHz, 2.1 GHz, 2.6 GHz, 3.5 - 3.8 GHz
Latency	No data available	Up to 1000 ms	200 ms	40-70 ms	<20 ms

Figure 5 Comparison of mobile network generations[8]

[2] (Sapna, 2013), (net-informations.com, 2021),
[3] (International Telecommunication Union (ITU), 2020), (Sapna, 2013), (Electronic Communications Committee, 2020)
[4] (Boyland, 2019)
[5] (Tweakker, 2021)
[6] (Apple Inc., 2021)
[7] Most common bands in Europe
[8] (net-informations.com, 2021), Expert experience

The assumption on e-conspicuousness should consider a future proof technology with a minimum throughput of 20 kbps for position transfer including a timestamp in a format with medium overhead (csv-format).[9] This can be achieved throughout all remaining network generations. Moreover, a nominal latency below 150 ms should be aimed.[10] Considering the use of a mobile phone, it should provide an option to select the respective standard. As 2G has a much higher latency and is no longer an option for iPhone users to actively choose a 2G, it cannot be recommended for this purpose. 3G is still highly available across Europe in terms of aera-coverage, partly even better than 4G, and its latency is only a little higher than recommended. Technically it could be used for tracking. However, 3G networks are gradually being turned-off across many countries[11], and it cannot be chosen anymore with the current iPhone12 generation.[12] As mobile phones typically make use of the best mobile technology available it can be seen as an "automatic" backup in case 4G network is not available.

This leads to 4G and 5G as the common standard, because the two networks fulfil all requirements mentioned, such as bandwidth, latency, throughput and can be considered as future proof for the next 10 years. Therefore, in this study, the underlying standard considered is LTE (Long Term Evolution). While LTE is considered faster than former 2G and 3G standards, it also serves as the foundation upon which the upcoming 5G mobile network is built. One main consideration for LTE is the fact that the predecessor 3G is expected to be gradually taken-off the network, as the 2100 MHz band will be distributed towards LTE. Moreover, state -of-the-art modems are specialized for LTE technology, which performance is expected to constantly improve within the next years. Despite focussing on LTE as the primary solution, it must not be neglected that the possibility of using 3G as an additional source remains feasible, as long as provided by the Telcos.

3.2 Handover and interference

Mobile networks are optimized for ground usage[13], as the antennas are typically tilted slightly down. Airspace coverage comes from reflections or in most cases side-radiations. Due to free line-of sight, which typically comes with aerial usage, the aerial coverage can be expected even better than on the ground. Thereby, the aircraft does not typically connect to the cells directly underneath, as the best serving cells are usually several km away (up to 40 km).[14] Whereas normal mobile user equipment on the ground typically detects to 3-5 base stations, a flying device can reach up to 40 base stations. This leads to a massive increase in illogical handovers between the cells, as they necessarily have not a "ground-like" neighbourhood relationship.[15] While this can cause serious problems to the network management in older network technologies (2G and 3G), modern LTE and 5G networks most likely can manage these handovers fast enough. Some limitations may arise with the number of users over a certain area, but at a level which is by far not expectable in the coming years (est. >50 concurrent UEs over 5 km^2).[16]

Another limiting factor is the interference of flying user equipment caused when uploading data down to the ground. Whereas few kbps (for mentioned tracking service) even by a higher number of aircraft do not harm the network (in terms of interference) significantly, a broadband upload (pls. see 3.3) from a few aircraft over a certain area can interfere severely with the ground network.[17] The effect causes an up to 7 times heavier traffic load compared to the same usage on the ground, so the serving base station might overload and automatically deny further terrestrial usage.[18] Directional externally mounted antennas on the aircraft could help to mitigate these problems, but it is hardly possible to check conformity of every used antenna and their position. A mobile phone is not even designed to direct its antenna in any way.[19]

[9] Experience based expert knowledge
[10] For the sake of safety latency should be as low as possible, with 150 ms aircraft in lower airspace would cause ~19 m in latency considering a max. speed of 125 m/s. This seems an acceptable range for collision avoidance with drones and other manned aircraft.
[11] e.g. Deutsche Telekom Group in Germany, the Netherlands, Hungary, Poland, Czech Republic, Greece, Austria
[12] (GSM Association, 2021)
[13] (Zhang, Zeng, & Zhang, 2018), (Vodafone, 2018)
[14] (Neubauer, 2020)
[15] (Muruganathan, Lin, Määttänen, & et. al, 2018)
[16] (Lin, Yajnanarayana, Muruganathan, & et. al, 2018), (Zhang, Zeng, & Zhang, 2018), (Fotouhi, Qiang, Ding, & et al., 2019)
[17] (Muruganathan, Lin, Määttänen, & et. al, 2018), (Marojevic & Abdalla, 2021), (Vodafone, 2018)
[18] (Hahn, 2017), see also chapter 3.3.
[19] (Lin, Yajnanarayana, Muruganathan, & et. al, 2018)

3.3 Considerations on the use of smartphone apps

A wide range of smartphones is available on the market, mostly either based on iOS or Android. Depending on their product generation they come with a high variant of heterogeneous hardware specifications and operating systems.

The following considerations refer to state of the art smartphones (mainly iPhone 12 on iOS 14, and Android based devices using Android 11). With the given network limitations there are basically two main reasons why conspicuousness via a smartphone app may be problematic:

1. Uncontrollable payload upload: An app cannot easily eliminate other apps/ functions that might run in background of a smartphone.[20] This might lead to unpredictable higher consumption of bandwidth than needed for the tracking service and with that, can negatively influence latency and capacity. Moreover, it can seriously harm the ground network with interferences, which might lead to actions by network service providers (e.g., exclusion of aerial services in terms and conditions). A suppressing mechanism is not possible through the network service providers. Example: An LTE transmission tower is designed for a bandwidth of e.g., 300 Mbps. Once the tower capacity is exceeded by appr. 50% (Germany), it is considered to be fully utilized and the Telcos take actions, e.g., by adding further sectors. Three aircraft in the same cell would already exceed this bandwidth with an HD video transfer[21], without taking into account the base load from users on the ground. Antennas and GPS receivers within a smartphone are not ideal for aerial usage but might be sufficient in terms of accuracy. The best way to mitigate interferences with the ground network are directed, externally mounted antennas on the aircraft but smartphones have omni-directional antennas.[22]
2. No options to deselect/ prioritize frequencies: CEPT is currently discussing possible complications with other frequency holders due to aerial uploads. Foreseeable, there will be a need to switch off 700 MHz in special aeras near radio astronomy stations. To safeguard meteorological satellite services, it will be necessary to strictly guard the lowest end of the 1800 MHz band. In 3.4GHz complications might arise with radio altimeters. In case European countries, like Finland stick to the “except aeronautical mobile” passus in the European ECA-table 700 MHz, 800 MHz and 900 MHz are not allowed for the use in airspace at all.[23] In its “European version” the iPhone12 currently serves 44 international bands in LTE and 5G. In Europe, it utilizes the full 10 bands available for optimal ground coverage. Both mobile handsets (iOS 14/ Android 11) offer no option to select frequencies in the ranges of their mobile.[24]

[20] (Apple Inc., 2021), (Google LLC, 2021)
[21] Exemplary: HD video transfer would be added with (10 Mbps), 3 aircraft with the same serving cell would cause minimum 7 times the traffic load of a ground-based device or minimum 210 Mbps.
[22] (Parchin, 2020)
[23] (Finnish Transport and Communications Agency Traficom, 2021), (Electronic Communications Committee, 2020)
[24] (Apple Inc., 2021)

4. Analysis of message exchange function transmit

The following chapter provides an analysis of different aspects regarding the feasibility of utilizing mobile telecommunication technologies for making manned aircraft electronically conspicuous in U-space. EASA pre-defined 7 focus Areas, including specific questions. Furthermore, a question on dedicated networks has been raised in EASA's USSP-workshop on July 22nd, 2021 and a question regarding future developments of networks has been asked.

4.1 Area 1: Network coverage and altitude restrictions

The use of mobile telephony for the purpose of improving the electronic conspicuity of airspace users undeniably relies on the coverage provided by the mobile telephony ground infrastructure, both laterally and at altitude.

Several studies conclude that Long Term Evolution (LTE) mobile radio technology is essentially able to make aircraft electronically conspicuous and share its position in U-space (with 150 m above ground level) with regards to altitude, coverage, security, and latency. Even though scientific studies are the main source for the study, additional experts have been contacted to discuss the study results. These experts confirmed, based on experience, that mobile technology is generally capable to make aircraft electronically conspicuous up to 150 m.

While with rising altitude the likeliness of getting a connection increases, the link quality decreases and the latency grows as mobile networks are optimized for ground usage.[25] With licensed spectrum, a sufficient level of air interface security and service management can be achieved. Different interdepending factors influence the capability of the mobile network to serve aircraft:

- number/ density of potential serving cells
- used spectrum
- mobile phone model and/ or modem/ antenna capabilities (on the pilots' device)
- number of aircraft using the service
- required bandwidth
- ground speed of the aircraft (LTE networks support speed up to 350 km/h)
- power of the emitting device (to be considered as fixed, as this is regulated in the frequency regime)
- weather conditions and topography/ ground surface patterns.

To ensure the intended safety level and to identity "white spots" in the network coverage, a one-time upfront measurement/ testing and/ or network modelling could be conducted over the dedicated U-space:

- Provision of 3D-coverage maps: 3D-coverage maps are a new field for network operators. Some operators are working on own solutions, others use specialized start-ups who are providing these maps initially based on the network configuration data of the underlying network provider. By collecting network quality data and machine learning these players claim to continuously learn and optimize these maps. The effort to calculate an initial coverage map for an aera, with the dimension of a U-space (with roughly 10-20 km in diameter) is relatively low but provides a high level of confidence for the U-space users.
- Initial airspace/ U-space LTE/ 5G measurements: Various tools are used to measure network performance, e.g., for network tests on the ground. These tools can also be applied in airspace and can help USSPs to set SLAs on mobile network performance in terms of coverage and available altitude, link quality and integrity in the respective U-space.[26]

[25] (Mishra & Natalizio , 2020), (Xu & Zeng, 2019), (Muruganathan, Lin, Määttänen, & et. al, 2018), (Ivancic, 2019), (Qualcomm Technologies, 2017), (Zulkifley, Behjati, Nordin , & et. al, 2021), (Lin , Wiren , Euler, & et. al, 2019), (Lin, Yajnanarayana, Muruganathan, & et. al, 2018), (Umlaut Consulting , 2020), (Vodafone, 2018)
[26] (Rhode&Schwarz, 2021), (GSM Association, 2021)

Question 1: What is the maximum altitude or height above ground at which the mobile telephony infrastructure still supports nominal operations?

Most of the studies refer to unmanned aircraft flying at altitudes of up to 150 m above ground level (AGL)[27], while one single study simulated extensively up to an altitude of 300 m AGL.[28] Above this altitude, no scientific sources have been identified. However, some trials in European average quality networks indicate a permanent tracking link loss can be expected between 600 and 1200 m AGL.[29]

One of the main findings is that available altitude is highly depended on the topography of the respective country. Furthermore, it depends on the number and speed of the aircraft, relative speed to ground in one area, as well as the number of achievable base stations. Another common opinion shared is that the higher the aircraft, the higher the probability of connection to a base station. In contrast, latency and link quality suffer due to more handovers. As U-spaces are not expected to exceed 150 m AGL it can be assumed that sufficient mobile connectivity and appropriate link quality is given.[30]

Question 2: Where are the areas in the 27 European Member States where there is insufficient coverage to allow an airspace user to transmit aircraft identification and flight parameters (as detailed in Annex 2 to the request for service) to a mobile telephony provider on the ground. Is the information provided by the Joint Research Centre (JRC) netBravo website representative of the coverage in Europe?

The analysis of the coverage maps of 31 countries (27 European Member States and selected non-EU states, namely Norway, Switzerland, Lichtenstein, and Iceland) reveals that overall, the 4G/ LTE coverage within the EASA Member States can be overall evaluated as well developed (Figure 5). However, especially rural areas still show local inconsistencies in network coverage, e.g. in Scandinavia or Transylvania. In addition to a country level analysis, an exemplary coverage analysis of urban areas was conducted for Hamburg, Frankfurt, Cologne, Munich, Budapest, Helsinki, Port of Antwerp, Bratislava, and Bucharest, which discloses that especially urban areas show consistent coverage. For this question, 4G/ LTE was considered as the primary network with 3G as a backup. 5G coverage is not yet well developed throughout the countries considered (see chapter 3.1).

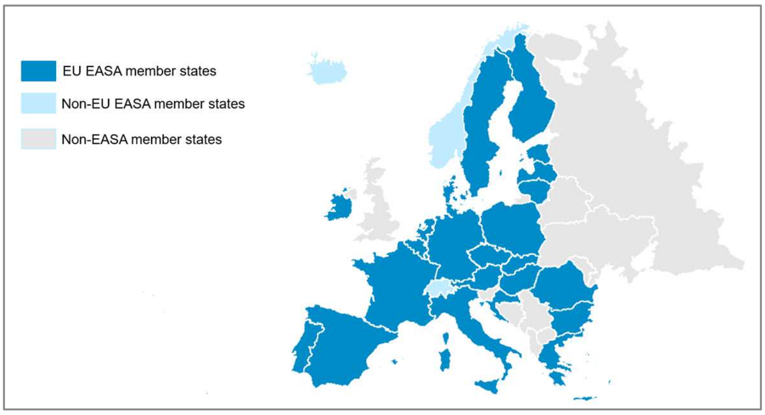

Figure 6 EASA Member States (EU and non-EU)

Various sources outline national network coverage of different technologies such as 3G, 4G/ LTE and 5G, e.g., local telecommunication providers. For this study, it was found that the Global System for Mobile Communications Association (GSMA) provides the most consistent and applicable data base to compare 4G/ LTE and 3G networks along the various states considered.[31] The GSMA has developed visual coverage maps, which enable to detect white spots on the respective country map. Moreover, the maps show the different networks for the main telecommunication providers, indicating superior provider positions or the need for roaming within certain areas. Another reason for using GSMA as the primary data source is that coverage maps published by telecommunication providers may be biased in terms of showcasing an optimal coverage,

[27] (Zulkifley, Behjati, Nordin , & et. al, 2021), (MoNIfly, 2020), (Umlaut Consulting , 2020), (Vodafone, 2018)
[28] (Xu & Zeng, 2019)
[29] (Neubauer, 2020), (Aviaze, 2021), (Safesky, 2021), (Lilly, Cetinkaya, & Durak, 2021)
[30] (Zhang, Zeng, & Zhang, 2018)
[31] (GSM Association, 2021)

while disabling to compare among the EASA Member States in a consistent manner. NetBravo[32] was not considered because the source only shows measurements of certain locations which does not give information of the overall achievable coverage. Thus, a more comprehensive map-view was preferred in consideration for the research question. It must be taken into consideration that any LTE coverage map is limited in reliability due to various uncertainties, as reflection a side radiation remains depending on factors such as weather conditions.

Mobile networks are built for ground usage only.[33] Thus, the present study distinguishes between ground and air coverage, whereby it is important to highlight that sources available on network coverage focus on ground coverage. Despite partially bad coverage on the ground in some rural regions, airspace usage is expected to be significantly better, as line-of-sight operations allow connect to more base stations even up to 40 km away.

In general, the geographic area considered provides a solid 4G/ LTE network coverage with the exclusion of certain rural coverage gaps. On a country-level, certain Member States such as the Netherlands and Norway are proven to be among the global top countries for 4G/ LTE availability, with 92.8 % and 95.5 % 4G availability respectively, while Ireland shows the lowest 4G/ LTE availability of 63.3 %.[34] Especially in dense areas with a comparably high ground risk/ air-to-air risk the coverage is sufficient. This finding derives from the analysis of the exemplary urban regions such as Port of Antwerp and Hamburg, which show a comprehensive coverage within a 40 km radius. However, to secure a stable connection in urban U-spaces, it is suggested to conduct exact measurements of mobile coverage in the respective areas. Besides an overall good coverage, gaps and white spots depicted in the coverage maps indicate that especially rural areas network coverage is not always a given. Even though many initiatives have been developed to close gaps within Europe, e.g., site sharing of mobile operators, the areas in question are often deployed with <1 GHz spectrum covering wide areas at low throughput.[35] One main reason for this is that networks are built based on population coverage and not area coverage, which aggravates the closure of white spots. Consequently, a loss of link can partially happen in rural areas, which might raise the need for redundant systems and fallback solutions at high cost and latency.

One central aspect of consideration is that coverage is highly dependent on the national providers and their local network coverage. This in turn raises the need for roaming capabilities if mobile telecommunication technology should make manned aircraft conspicuous in U-space (see Area 4, question 4), as the mobile device must be able to switch across providers in case of a lost connection.[36]

For the future development, network coverage is expected to constantly improve due to high political pressure on operators to close coverage gaps in the network. In Western European countries, the objective is to close gaps by 2025 (e.g., in Germany by 2024[37]). To achieve this, there are different approaches such as additional, publicly funded towers and coverage obligations that come with new spectrum licenses.

[32] (European Comission, 2021)
[33] (Mishra & Natalizio , 2020)
[34] (Boyland, 2019), (Vodafone, 2018)
[35] (GSM Association, 2021)
[36] (Qualcomm Technologies, 2017)
[37] (German Government, 2019)

4.2 Area 2: Security

Security represents an important area of concern for the use of mobile telephony for airspace users, as it needs to be examined how the transmission of data may be manipulated or spoofed, and what measurements e.g., encryptions, may mitigate these risks.

> **Question 1:** Would it be possible for a malicious person or entity to manipulate data transmitted from an airspace user to the ground or to insert spoof-aircraft into the system using the 'signal in space' other than to use separate mobile phones?

In opposite to free available spectrum (e.g., Wi-Fi, BT, ADS-B, FLARM), Telcom's mobile spectrum is exclusively licensed.[38] Together with randomly established security mechanisms, this comes with a higher degree of application security. However, constantly increasing cyber criminality rates and recent related events have proven that the manipulation of data is a significant threat. It was found that external data sources can spoof GPS locations with expert knowledge. This does not concern the mobile signal in the air.[39]

Regarding the mobile signal in airspace, one approach would be to imitate the existence of a ground base station controlled by a third party, where the tracking device/ mobile phone is connected to. Nonetheless, this is not a common approach and rather applicable on state-level. For a second approach, the malicious party would need to have a valid SIM and access to the data structure to spoof this, as well as access to the system (e.g., USSP). Sending out "signal in space" can be done but requires a lot of effort. This rather applies for state-sponsored hacker-professionals. It could be prevented with additional security measures like Cell-ID verification (please also refer to Question 3).[40]

> **Question 2**: What would be the implications of introducing end-to-end encryption on the data that is being transmitted by the airspace user?

End-to-end encryption represents the encryption of transmitted data across all transmission stations. Encryption has become a proven standard and is increasingly implemented in various public communication and tracking services. Only the communication partners can decrypt the message and have access to the data, and thus, it prevents the transmitted data to be read by everyone else using the service. Yet, only the transportation of data is encrypted, and not the actual content itself as it would have to be encrypted separately by using a key. Some examples for end-to-end encryption are Hypertext Transfer Protocol Secure (HTTPS) or in general Transport Layer Security (TLS), which can be intercepted, but not decrypted.[41]

End-to-end encryptions would have no implications on the data sent. Data transmitted via LTE have always a "basic encryption", but additional encryption may be helpful.[42] For this purpose, either symmetric encryptions or asymmetric encryptions can be used. The difference between both methods is that when using symmetric encryption, the key used to ensure end-to-end encryption must be known only by the end communication partners. On the other side, when using asymmetric encryption, it must be ensured that the (private) key is exclusively in the possession of the recipient. Introducing additional encryptions to ensure safe data transmissions can introduce negligible latencies. Another aspect is that control data can be additionally encrypted by encryption algorithms (AES/ RSA), while tracking data cannot necessarily be encrypted due to its "fire and forget" logic.[43]

> **Question 3:** To what extent would a 'reasonability' check, using the time stamp provided with the data that is transmitted by the airspace user, mitigate the concern of spoofing?

A time stamp is a specific form of a digital signature containing reliable information and therefore confirming the exact time of data transmitted by the airspace user. Therefore, it helps to identify the reliability of the data transmitted. However, time stamps will not help to guarantee the full reasonability check, as they only consider the up-to-dateness of data. Thus, time stamps can easily be spoofed. However, there are ways to identify spoofed messages and sort them out like with ADS-B or in Multilateration procedures. One good alternative without significant impact on latency is to prevent the concern of spoofing in cooperation with the

[38] (Mishra & Natalizio , 2020)
[39] (Marojevic & Abdalla, 2021)
[40] (Marojevic & Abdalla, 2021)
[41] (Mynttinen, 2000)
[42] (Forsberg, Horn, Moeller, & et. al, 2013)
[43] (Knezevic, Nikov, & Rombouts, 2012)

mobile network provider via a cell-ID.[44] Therefore, the reasonability check must proof if the position data is dialled/ connected to a close base station where the time stamp is claiming it. These data provided by the mobile network provider cannot be changed. Further reasonability checks can be made via databases with serial numbers or registration IDs.

4.3 Area 3: Mobile telephony and network performance

Latency of transmission is likely to severely impact the ability of a UAS operator based on traffic information provided by USSP to timely respond to a potential encounter between a drone and a manned aircraft. Therefore, the availability and performance of traffic information service by USSP and a very low probability of corruption of the data are of importance.

Question 1: What is the nominal performance of EU based telecommunication networks with regards to the following aspects:

a) Nominal latency

Nominal latency describes the delay (in milliseconds) of the transmission from the moment of that the mobile phone of the airspace user would start transmitting and the moment that the transmission reaches the first server of the telecommunications provider. Thus, it is determined by the physical distance between device and corresponding server measured on the ground as a combination of system latency for signal processing and radio link latency.[45]

Mobile networks are widely standardized and deployed in a similar manner across EU. Modern LTE networks have an average latency between 20 and 60 ms[46] while technology used in air traffic control has a latency up to 3 sec. This delay is mainly due to retransmission. The 3GPP release-15 standard claims that the required data rate for command and control and payload communications in uplink is 100 kbps and 4 Mbps, with a latency of less than 50 ms.[47] Overall, the impact is highly dependent on the network, because the higher the altitude, the higher the latency, meaning that there is a linear correlation.[48]

In 2021, an open signal network performance test tool has been established and carried out by telecommunication experts to test the nominal performance of EU based telecommunication networks. For future dense traffic scenarios, 5G will lead to further enhanced latency, shortest ranges possible offer Mobile Edge Computing solutions.[49]

b) Availability of service (‘continuity’)

In order to assess the nominal performance of EU based telecommunications networks with regards to the above, there is a need to distinguish between the “availability of service” and the “continuity” of service. The availability of service indicates where enough signal is available, how good the connectivity is and where interferences might arise.[50] Continuity can be described as “best effort”, meaning that the network provider does not ensure a faultless connection, yet follows the objective to provide the most superior connection possible. The continuity of a signal indicates a performance parameter of the network considering in relation the number and duration of unplanned interruptions in a given timeframe (“how often was the network interrupted in one week and how long did the interruption take?”). The availability of the network service and the level of continuity present key performance indicators to quantify the quality of a network service. In order to guarantee continuity of the mobile network, telecommunication network provider aim to build and provide a resilient network and developing robust continuity plans in case of unplanned interruptions. ACJA working group is currently defining indicators that can be made available to USSPs in a standardized manner.[51]

c) Integrity or probability of corruption of the data provided

The integrity or probability of corruption of data provided explains the likelihood of packet losses to be expected.[52] Therefore, it describes the number of packages and the certainty of the losses, which will not reach their planned destination after being transmitted. Performance indicators simply

[44] (Neubauer, 2020)
[45] (Neubauer, 2020)
[46] (GSM Association, 2020)
[47] (Ng, Islam, Alevy, & et. al, 2019)
[48] (Neubauer, 2020)
[49] (Boyland, 2019)
[50] (Zhang, Zeng, & Zhang, 2018), (Lohan, Talvitie, Wang, & et. al, 2018)
[51] (GSM Association, 2021)
[52] (Neubauer, 2020)

measure the error rate for a given time frame which must not be over a predefined rate. Even though the Radio Technical Commission for Aeronautics proposes a standardized definition and threshold values, these do not apply for telecommunication, as they are no safety networks. This limitation must be acknowledged.

Question 2: What is a reasonable assumption for the average latency of transmission of a package of data as described in the 'ADS-B Light' standard between two servers connected through the internet and located in the European Member States?

Physical network transmission is difficult to predict between two endpoints since one cannot predict the speed of the internet in a meaningful way. Moreover, various factors of the location influence the transmission, such as peering or physical distance. Very often dedicated private networks are used by mobile operators with special SLAs.[53] Thus, the general assumptions do not apply, resulting in a rather short latency, which is limited above the speed of light.[54]

Question 3: Is there much variety in the network performance between Member States that could negatively affect latency?

LTE can be described as an established and yet recent technology, which has been deployed since more than 10 years and is constantly being expanded. As already explained in area 1 question 2, network coverage was found to be rather well developed across Europe. However, with consideration to the effect on latency, countries with less developed network structures may have an advantage, as they do not build on historic coverage architecture and thus, are able to implement network structures faster.

The network performance can be expected to be similar across the Member States. It is dependent on mobile backhauling (via fibre, wireless or copper), which is defined as the connection of cell sites to data centres, which accommodate the applications/ content of mobile users.[55] If backhauling is realized via copper, a negative impact on latency can be expected. These deviations can mainly be expected in rural areas and they do not affect the latency significantly (estimated: up to 150 ms instead of 20-60 ms).

Question 4: Are there any (remaining) technical difficulties related to the use of mobile telephony in an aircraft at altitude? If so, can these be mitigated through technical means or by operational procedures (e.g., speed restrictions) and how?

In addition to the already mentioned difficulties in Chapter 3.2 (interference and handover), no further technical difficulties are expected form the use of smartphones in aircraft.

4.4 Area 4: Roaming and network access

Transmission of data from the aircraft to the USSP is dependent on availability and performance of the mobile telephony networks. Roaming agreements can help to achieve best network coverage, inside a country (national roaming) or with cross-border flights (international roaming). Besides the existing Roaming Regulation (EU) 531/2012, which ensures seamless roaming across EU Member States, it must not be neglected that some EASA Member States (such as Switzerland) are not considered within the regulation. In addition to the answers on EASA's questions, a legal excursus on the aerial usage patterns with regards to roaming agreements is provided.

Question 1: What are the benefits and drawbacks of each of the two architectures described below, in terms of latency, availability, integrity and security?

a) I) An architecture whereby the airspace user has a contract with a third party that receives the aircraft identification and flight parameters, assesses the area in which the airspace user is operating and redirects the data to the responsible USSP or

II) An architecture whereby the mobile telephone application detects that the airspace user operates in U-space airspace based on the aircraft's position and a database of all dedicated U-space airspace and connects to the responsible USSP directly.

[53] (Sutherland, 2007)
[54] (Kareem, Zeebaree, Dino, & et al., 2021)
[55] (Ciena, 2021)

The first architecture of contracting with a third party represents a consolidated and centralized approach. Data distribution occurs based on the geographical position. This architecture can be seen as a “single point of truth” which is explicit and provides USSPs with the accurate data at the right time. Also, a single point of truth is securable, but may also be subject to hacker attacks, due to its superiority.

In contrast, the second architecture represents a more decentralized approach, as data transmitted from point to point. If there is a direct connection of airspace users and USSPs, latency, availability and security of this architecture can be evaluated as more superior as those parameters are highly depended on network quality and after all, a direct transmission of data mitigates risks such as delays.

Mobile telephony applications (as well as dedicated tracking modules) must be “certified” or at least aligned via Interface Control Document (ICD)[56] with the USSPs in order to make the app (or device) “talking” to the respective UTM for the operating aircraft in the respective U-space.

b) In both cases, can we envisage a situation whereby a manned pilot registers with one app that allows operations in all MS or the EU?

The situation in which a manned pilot registers with one app that allows operations in all EU Member States is primarily related to roaming agreements[57], and not to the technical prerequisites of mobile telecommunication. Moreover, it raises the need for international inter-USSP communication standards to allow the usage of one app in all Member States. Nonetheless, as explained in Area 7, the use of mobile telephony in airspace is not allowed across all EU Member States, such as Finland, which complicates a comprehensive international approach.[58]

Question 2: Is it possible to define a single standard using the IP to share information between third party service providers and the various USSPs?

It is possible to use the internet protocol to share information between service providers and USSPs, as various already existing standards can be used. Established standards are e.g., ASTM (American Society for Testing and Materials) on Inter-USSP (UTM Service Providers)[59], or the ASD STAN[60], which is being developed.

Question 3: Would it be possible to provide a feedback loop indicating to the pilot whether the information has been received by the USSP, in order to provide a pilot with an alert if the pilot is not conspicuous to the USSP.

Providing a feedback loop between the pilot and the USSP indicating conspicuousness is technically feasible, as e.g., apps are able to demand, receive and send feedback. However, this also depends on the already discussed factors such as altitude and network coverage. The app could also indicate if no connection and with this no tracking service is available.

Question 4: Every user of a mobile telephone has a contract with a provider. In the Member State where the contract has been agreed, the user is automatically connected to this provider. When the provider’s network goes down, connection is not guaranteed. In other EU Member States however, roaming arrangements apply, and the non-availability of a single network may be mitigated by switching to a different provider. Often, this is done without the user even noticing. Is there any possibility that roaming arrangements could apply in the Member State where the contract between user and provider was agreed?

Roaming basically aims at extending the network coverage of a mobile network operator for its customers and is dealt directly between the Telco-Providers.[61] International roaming agreements exist between all mobile network operators. They ensure customers can use their mobile services even when abroad. Since 2017 roaming is enforced by the European Commission to be free of extra-charge in all Member States. That

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56 Apps and tracking devices should be accepted by respective local USSP in terms of data quality in the UTM system, so they need at least to comply with the communication patterns (ICD) that are accepted by UTM. Data quality in UTM systems are harmonized by the certification process which is needed to become a USSP. Between USSPs (national or pan-European) air traffic data is shared via CIS (Common information service providers) or inter USSP agreements (analogue to roaming agreements).

57 (Schwenk, 2020)

58 (Finnish Transport and Communications Agency Traficom, 2021)

59 (ASTM, 2021)

60 (ASD-STAN, 2021)

61 (Schwenk, 2020), (Latvian Mobile Telephone (LMT), 2020)

means customers can use their services across Europe for the rates of their home countries at least within the first 90 days being abroad.[62]

National roaming comes into place when a mobile network provider does not provide a nation-wide network or has big coverage white spots, which can be filled by an agreement with another network provider. Roaming contracts are mainly commercial agreements which include net volumes and referring payments when service provider A generates more traffic in the network of service provider B than vice versa. For that they refer to widely standardized services, like voice, SMS, and data streaming.[63]

Streaming from the air should not be considered as "normal" data streaming, as it may create a much higher traffic load to the network due to interferences. In consequence this would need to be dealt directly between the operators, but this would require experience-based knowledge on the technical patterns of such a service of all providers involved into such an agreement. Institutional bodies like 3GPP, CEPT or GSMA are currently working on standardizing these aerial services, aiming to conclude on this service until 2022/23.[64] If successful, roaming agreements will adapt these standards in the commercial roaming agreements. One service, E112 – the European emergency call- implementation has been enforced by European regulation, some others are on a national basis. However, these services are terrestrial use and need, by the required bandwidth (in kbps) no significant extra investment into the network infrastructure.[65]

Legal excursus: Choice of network operator for roaming

The legal assessment is to conclude if there is a legal possibility to assign a specific network operator abroad to the sending device for security reasons in the case of cross-border flights. The underlying consideration was to prevent the tracking from suddenly leaving because the user must manually confirm a network selection, or the device is not allowed to dial into individual networks in the foreign country.

From a legal point of view (applying German law), there are initially no compelling reasons why a national telecommunications provider may not appoint a specific operator abroad to the user of the network. The EU Roaming Regulation makes provisions on the prohibition of increased roaming charges when used abroad, but not on a general right to free choice of network. From this point of view of commercial law, a fixation on a network provider would certainly restrict the user to a certain extent. This restriction should not constitute an unreasonable disadvantage since it can easily be justified for security reasons.

From a legal point of view network access and billing of the costs incurs usually in bilateral or multilateral roaming agreements. The roaming agreements with the network providers of other countries must normally allow the use of network access for the position tracking. As of today, however, there is no information available on the roaming agreements of relevant network operators between such as German and further European providers abroad.

Normally, roaming agreements contain clear categories of usage. However, these contracts do not include and did not foresee such usage for electronical position tracking in U-space. As there are no contractual agreements in place considering the transmission of position data of manned aircraft users, network providers would consequently be allowed to block the login of such devices until a contractual arrangement will be found.

4.5 Area 5: Telemetry in mobile phones

Some mobile telephone manufacturers (e.g. Apple) augment the position data received by the GNSS with other telemetry data, for example by triangulation of antenna towers, use of MEMS and accelerometers, etc. This may affect the accuracy and integrity of the position.

> **Question 1:** What is the impact of the augmentation through triangulation, use of MEMS and accelerometers, Wi-Fi or other means on the accuracy and integrity of the horizontal and vertical position computed by the mobile phone?

[62] (European Union, 2017)
[63] (Sutherland, 2007)
[64] We expect CEPT to be ready in 2023, because U-space regulation comes into force in January 2023.
[65] (European Emergency Number Association, 2021)

Augmentation through additional sensors can decrease the time until a device gets a fix. Additional sensors can also improve the accuracy, e.g., an accelerometer can enhance the measured speed (not just GPS based speed). Triangulation and Wi-Fi Sensing is used by Apple and Google to help get a fix faster, but this requires access to the databases or to build up your own. Usually, triangulation is not very precise, while other functions provide a more accurate data and a more precise location. Devices and drones which use dedicated antennas (PX4 based drones, DJI drones) for positioning often get a fix in a similar timeframe and often have a superior accuracy compared to mobile phones.[66]

Question 2: If triangulation is being used, could the slant range have an effect?

Triangulation based on the mobile network takes the position of serving cells in the vicinity and the time the signal needs to travel from the device to the station. This can be done from the device itself or by the network provider. The slant range effect can have an effect if triangulation is used. This can be mostly negated when more than two base stations are used for the triangulation, since the overlap of the possible position is used.[67] This does not mean the position is accurate, e.g., the US requires an accuracy of 50 m, the EU does not have a similar requirement.

Question 3: To what extent may multipath affect the accuracy and integrity of the position?

Multipath describes the effect when a signal of a base station or satellite is not only directly received by a device but also through reflections off the ground or buildings. Multipath can have an impact on the accuracy of triangulation and even GNSS precision. Especially if triangulation over the mobile network in urban and dense areas is used, the accuracy can decrease further. The signal is bounced of a surface and therefore, increasing the travel time. For flying objects this can have an effect since a lot of coverage comes from reflections but also side coils. The GNSS precision is not affected as much since there is most likely a clear view of the sky without any reflections but might be an issue in an urban environment at low height.[68]

4.6 Area 6: Future air-to air communications

Mobile telephony may represent an affordable means for airspace users to comply with SERA-6005 (c) and for USSPs to safely manage the U-space airspace. It is however assumed that the use of a ground infrastructure may not be adequate to support an airborne Collision Avoidance (CA) function. Offering pilots with an affordable CA function through an application on their mobile phone could potentially help reduce the risk of Mid-Air Collisions in general aviation.

Question 1: Would it be possible to share the parameters established in the ADS-B Light standard over an open link that is accessible to airspace users in the area, e.g., over Wi-Fi or Bluetooth, without action by the pilot?

Broadcast remote ID based on Wi-Fi or Bluetooth 5 has been created to identify an ID of a UAS using a mobile handset on the ground.[69] In principle, this would also allow sharing the position with other concurrent airspace users. Instead of one sending and one receiving device, mobile phones would need to cover both, sending and receiving at the same time. Because mobile handsets are not optimized for these usage patterns (especially no external antennas) the link range is expected to be shorter than e.g., with drone-based broadcast solutions.

For Bluetooth 5, with maximum reach of 1 km[70] (see Question 2), it seems not to be sufficient to serve airborne collision avoidance. In case of an unoptimized 500 m distance, two aircraft allowed at 125 m/s speed in lower airspace would have only two seconds to identify the other aircraft and react. Wi-Fi 802.11 y running on the 3,6 GHz and 802.11 ah running on ISM-band around 900 MHz seem to be the best available Wi-Fi-standards to achieve distances, however both are not used in state-of the-art mobile handsets.[71]

Airborne ISM-users (e.g. FLARM, OGN, etc.) also utilize the 900 MHz frequency. In opposite to Wi-Fi, they achieve greater distances by using optimized and certified external antennas on aircraft. A Wi-Fi option yet

[66] (Marojevic & Abdalla, 2021)
[67] (Osa, Matamales, Monserrat, & et. al)
[68] (Lohan, Talvitie, Wang, & et. al, 2018)
[69] (Cenelec, 2021)
[70] (Bluetooth SIG, Inc., 2021)
[71] (Sensible Radio, 2008)

to be optimized for usage could be the ITS band in 5,9 GHz, which is explicitly allocated to "Intelligent Transport Systems" for the sake of road safety. ITS band is widely tested in "vehicle to vehicle to others" (V2V2X) use cases, meaning connecting cars with cars in the vicinity or to dedicated road infrastructures.[72] It has not been used as aerial service so far, but could be considered as dedicated ITS-based collision avoidance system, as this also concerns somehow traffic safety and should not interfere with other services if used as an air-to-air channel.

IEEE defines the complementing communication standards for this band and services: 802.11 p is a Wi-Fi amendment that can establish connection much faster, because it uses only a small ad-hoc "authentication" header between the pre-defined users with one time stamp. Especially for fast moving vehicles this should add valuable time in safety context. Neither standard nor band will be utilized by common mobile phones. However, as the automotive industry might need millions of these devices (routers) in future, they could come as an extra device for aviation grade collision avoidance, but at an affordable pricing level.

Question 2: If so, what is the unobstructed range of the Wi-Fi or Bluetooth signal in space?

The communication protocol standards Bluetooth and IEEE 802.11 (Wi-Fi) define a physical layer and a medium access control layer for wireless communication within a short range and with low power consumption (from less than 1 mW up to 100 mW).[73] Bluetooth is used with portable products of short ranges and limited battery power, as it offers very low power consumption, while Wi-Fi is designed for longer-range connections and supports devices with a substantial power supply.

The relevant factor to determine the maximum range of Wi-Fi is the 802.11 standard and access point is based on. Various sources provide different maximum Wi-Fi signal ranges one access point can reach under the current 802.11 n standard, with an official maximum of 4 km.[74] Thereby, the maximum range may be even further away, as 4 km represents the "secured" signal. There are different factors influencing the Wi-Fi signal, with the most significant being:

- the number of wireless access points (antenna)
- the performance and type of access points (antenna)
- the strength of the device transmitter
- the specific 802.11 protocol it runs
- the nature of physical obstructions and/or radio interference in the surrounding area

Bluetooth technology has evolved throughout the years, with Bluetooth 5.2 being the most recent standard in 2021. Bluetooth uses the 2.4 GHz ISM spectrum band (2400 to 2483.5 MHz), enabling a decent balance between range and throughput and a maximum range of up to 1 km.[75] There are different factors influencing the Bluetooth signal, with the most significant being:

- Receiver sensitivity (minimum power level required)
- Path loss and environmental impact
- Transmitter power
- Transmitter antenna gain
- Receiver antenna gain

Having discussed general Wi-Fi and Bluetooth signals, it must not be neglected that in the matter of context that mobile devices may not realize the maximum range, and that the signal in space vs. on the ground may differ (see Question 1).

Question 3: Can this range be expanded by tuning the power output of the mobile phone or by the use of affordable other means?

In general, the maximum range may not be exceeded by tuning the mobile device due to several reasons. Firstly, the power output of mobile phones is standardized and follows an electromagnetic compatibility and

[72] (ACEA, 2018), (US Department of Transportation, 2009), (ETSI, 2021)
[73] (Ferro & Potorti, 2004)
[74] (SZ DJI Technology Co., Ltd., 2021)
[75] (Wolley, M, 2021), (Bluetooth SIG, Inc., 2021)

the Radio Equipment Directive (RED) certification, which are both necessary for European approval procedures for CE certificates of any mobile devices. Secondly, neither unlicensed nor licensed frequency bands are allowed to be exceeded.[76] Also, Wi-Fi may be limited to the 2.4 GHz band to achieve a broader reach, but for mobile phones this is irrelevant, as they choose the best band available. Therefore, the tuning can only be conducted within regulatory limits, and higher outputs can lead to higher interferences in the vicinity.

4.7 Area 7: Legal

There are uncertainties regarding the use of mobile telephony for aviation, i.e., in aircraft when airborne.

> **Question 1:** Within the context of operations in a U-space environment, are there any legal restrictions stemming from either international aviation law or international and national telecommunications regulations, to the use of mobile telephony by airspace users that would otherwise be non-conspicuous to the USSP to provide the USSP with essential data on location, altitude, speed and direction (as detailed in Annex 2 of this request of service), and to the use of such information by the USSP to manage drone-traffic in the U-space airspace in such a manner that the risk of an encounter between a manned aircraft and a drone is reduced to an acceptable level?

Two approaches have been chosen to investigate this question. Both approaches lead to the result that the use of apps for making manned aircraft conspicuous in airspace is legally doubtful. The first approach ("Approach A") focuses on the definition of the European frequency regime and states that airspace conspicuousness could be an aeronautical mobile service which must not be used in telco frequency bands below 1 GHz. The second approach ("Approach B") does not come from the definition of mobile aeronautical services by ITU but from the necessity to safeguard aeronautical services.

The result is that no matter how the bands below 1 GHz are used on a terrestrial level, the use for aircraft conspicuousness needs to be cleared. This may happen either now by each NRAs on Member States level or needs to wait for a European decision by Radio Spectrum Regulation, e.g., in CEPT/ ECC.

Approach A: Based on European frequency band plan (Telco expert perspective)

In 2018, the usage of mobile networks for drones was discussed in European Telco Regulation body CEPT intensively for the 1st time. In particular, the usage of mobile network frequencies below 1 GHz was elaborated, because these telco bands (700, 800, 900 MHz) are allowed for terrestrial mobile services and come with a passus "except aeronautical mobile" in the frequency allocation table provided by ECC.[77] Aeronautical mobile is defined by ITU with 3 definitions:

- **1.32 aeronautical mobile service:** A mobile service between aeronautical stations and aircraft stations, or between aircraft stations, in which survival craft stations may participate; emergency position-indicating radio beacon stations may also participate in this service on designated distress and emergency frequencies.
- **1.33 aeronautical mobile service:** An aeronautical mobile service reserved for communications relating to safety and regularity of flight, primarily along national or international civil air routes.
- **1.34 aeronautical mobile service:** An aeronautical mobile service intended for communications, including those relating to flight coordination, primarily outside national or international civil air routes.

In principle, this would also count for a tracking service of an aircraft, however some mobile radio frequencies come with the obligation of terrestrial use only, e.g., in Europe all bands below 1 GHz, and even more specific "except aeronautical mobile". In 2018, the CEPT Workshop "on Spectrum for Drones" could not conclude on withdrawing this passus. However, in the minutes, it was agreed on giving the national regulation authorities the right to allow the aeronautical use if no other users were affected. In Germany, Deutsche Telekom AG applied for allowance of the of 800 MHz band for aerial use at the Bundesnetzagentur in 2018. After a study delivered by Technical University of Braunschweig and some field tests, the Bundesnetzagentur approved 800 MHz for aeronautical use in Germany.

[76] (Neubauer, 2020)
[77] (Electronic Communications Committee, 2020)., (CEPT, 2018), https://efis.cept.org/view/search-general.do

Other Member States are more reluctant and intend to wait until a final CEPT decision will be taken. In Finland, any use of radio equipment, including mobile cellular phones on aircraft when flying, is not allowed unless specifically allowed. Approvals are mainly granted for governmental and related use (police, rescue service, medical services, border-control). These rules are in force until 31 March 2024. After this, the Finnish Transport and Communications Agency Traficom will consider whether mobile use will be acceptable for all aerial users in the future. However, this may only happen if it is secured that there is no harm to existing users and if mobile operators have no objection to that.[78]

Standardization efforts for aerial use of the mobile networks in CEPT/ ECC are still ongoing with the ambition to harmonize spectrum usage across Europe. Except the mentioned diverging examples, it is currently not transparent how all national radio agencies in Europe handle the aerial usage of mobile radio, especially below 1 GHz.

In addition, CEPT working groups more deeply investigate possible co-existence issues and so far, three potential conflict zones have been identified. These will lead to a more differentiated regulation for aerial mobile usage probably in 2022/ 2023. While using frequencies from the air, the following co-existing issues were identified:

- 700 MHz band in defined geographical areas against radioastronomy stations
- Lower part of the 1800 MHz band against meteorologic weather satellites and ground systems
- 3.4 GHz against radio altimeters (this concern was raised by EASA)

In opposite to the terrestrial use, where a co-existence in this fields can be assured, these issues arise because the receivers of these services are tilted directly upwards, so an upload of these frequencies from the air can interfere with their antennas.

Approach B: Based on necessity to protect aeronautical mobile services (legal expert perspective)

The first part of the section examines how the addition “except for aeronautical mobile services” in most frequency allocations of the supervisory authorities of the European Member States is to be understood, i.e. how a useful separation of the EASA project from the aeronautical mobile service or an integration into the aeronautical mobile service can be shaped from a legal point of view.

Part two of the chapter includes a brief statement on whether it is possible to prescribe switching to a certain network provider abroad in cross-border roaming for security reasons.

[78] (Finnish Transport and Communications Agency Traficom, 2021)

1. Legal situation on aeronautical mobile services

The first part of the legal assessment includes whether the use of frequency bands of less than 1 GHz that are officially excluded from use for aeronautical mobile services, may be used to make manned aircraft flying in the U-space conspicuous.[79]

Referring to international legal requirements, there is no generally binding definition of aeronautical mobile services to decide in which frequency range the service should be classified. Regarding to Article 1.33 of the International Telecommunication Union's Radio Regulations, an aeronautical mobile service is reserved for communications relating to safety and regularity of flight, primarily along national or international civil air routes. However, holding on to such definitions is unlikely to answer the core of the question. To answer the question, it is required to differentiate aeronautical mobile services from other radio communications or in other terms: Are manned aircraft operating in the U-space (scope of the project) assigned to the protected area of aeronautical mobile services or should they be assigned to other frequency range for mobile data?

National authorities have created secured frequency ranges that are to be reserved explicitly for the aeronautical mobile service to serve safety, so that that radio traffic is not affected by network overload in the frequency bands or interference. Because of the safety relevance of radio links for the movement of manned aircraft in airspace, only special frequency ranges have been designated for this purpose. From a technical point of view, it is required to assess and decide whether the data which is transmitted by manned aircraft in the U-space must be protected in a special frequency range or whether it is dangerous if the data transmission takes place in a frequency range already protected for the aeronautical mobile service.

The final minutes of the 92nd Working Group FM Meeting of 6 October 2018, provide examples of how the frequency bands are being organized in Germany's neighbouring countries within the EU.[80]

France had provided some information on the differences of aeronautical use of the bands 960 - 1164 MHz and 2700 - 2900 MHz in that meeting: one of the key challenges is the pilot environment impact of interference which only affects the 960 - 1164 MHz band.81 Switzerland and Italy stated that they support the proposal from France.[82]

ICAO expressed a concern about an apparent disconnect in the studies of the 960 - 1164 MHz band for PMSE. Aeronautical radionavigation systems within the band operate in accordance with very stringent international performance provisions, requiring availabilities of those systems to be measured with numbers like 99.9999 %.[83]

Eurocontrol (an intergovernmental organization with 41 Members and 2 Comprehensive Agreement States) captured that aeronautical systems being in use in the 960 - 1215 MHz band are safety critical. They underline that it is nowadays possible to purchase illegal PMSE equipment using the 960 - 1215 MHz band on the internet. They invited administrations to take precautions to avoid repeating the same problem as the meteorological radars are currently facing from RLAN. They highlighted the importance of precise communication on the subject in order not to mislead administrations. For instance, in the UK, the current PMSE trials make use of the 960 - 1164 MHz band; the PMSE safety case is not approved and by no means it can be used at national level.[84]

The examination of the German Federal Network Agency on drone control via mobile radio has resulted in the assessment that the use of mobile radio for drone control can be understood both as an aeronautical mobile radio service and as general wireless network access. According to a communication our legal experts were given by the Federal Network Agency on 15 October 2019, an allocation of the mobile radio service for drone control was possible, insofar as special areas of the aeronautical radio service are not affected. This was the case for the 800 MHz frequency range applied for. The Federal Network Agency had, therefore,

[79] (Waldeck Rechtsanwälte, 2021). Brief statement prepared by Waldeck Rechtsanwälte does not constitute a detailed and comprehensive legal opinion that examines in detail which legal restrictions are opposed to the EASA's project, both from international aviation law and from international or national telecommunications law. This opinion also does not constitute a comprehensive expert opinion on the legal situation in other Member States.
[80] (CEPT, 2018)
[81] (CEPT, 2018)
[82] (CEPT, 2018)
[83] (CEPT, 2018)
[84] (CEPT, 2018)

approved the use of mobile radio for drone control outside the special frequency ranges for "aeronautical mobile services".

This strengthens the judgement that there is a legitimate interest of the state regulatory authorities not to use the frequency bands of the "aeronautical mobile services" additionally for contents of the U-space.

Therefore, it is highly important that the respective regulatory bodies decide within which frequency ranges manned aircraft operating in the U-space should take place and should ultimately be assessed from a technical perspective. Based on the legal assessment, the final decision will probably depend on how the service is designed, which and how many terminal devices are planned and allowed to be used for position transmission (e.g., app vs. transponder).

1.1 Usage via smartphone

If the service making manned aircraft conspicuous in the U-space is designed as a smartphone app, the classification can be done as a "wireless network access". A smartphone usually transmits on several frequency bands that cannot be controlled individually. If additional apps or functionalities are used by the smartphone user (e.g., a livestream of one's own flight) during the flight, there is a risk of overloading the radio cells. From a technical point of view, it needs to be examined whether simultaneous position information via mobile communication (in addition to the use of other mobile communication services) would not impair flight safety in general. The legal assessment concludes that is not possible to instruct an app on a smartphone to use only a certain frequency band. Rather, it can be assumed that an app for position reporting uses the same frequency band in which the user is currently performing other mobile radio services (in particular, the wireless network access and general data traffic of his smartphone in all apps).

The conclusion indicates that the use of an app can hardly be allowed within the protected frequency range of the aeronautical mobile service. At the same time, however, it would also have to be technically examined whether a combined use of a frequency range outside both for position data and for further network access of the smartphone could be considered. All in all, and according to the legal assessment, there are serious concerns that the use of an app by the state regulatory authorities can be brought into line with aviation safety at all, since position data would also be mixed with general data traffic in the free frequency range.

1.2 Usage as positioning device or transponder

A dedicated transponder which does not send any other mobile data besides the manned aircrafts position data in the U-space represents a solution to qualify this type of communication as a pure aeronautical mobile service.

A prerequisite for the dedicated transponder would be a technical examination of whether the specially protected frequency range can also be opened for this service for security reasons. The feasibility of a dedicated transponder would be confirmed if less position data of only a few transponders would be transmitted without leading to overload or interferences. A dedicated device hinders the transponder to move in frequency ranges where there is a risk that radio cells are fully occupied or that tracking is not always guaranteed for other reasons.

The legal assessment concludes that the ideal scenario includes a possibility to agree on a dedicated protected frequency range within the European countries enables by the relevant regulatory bodies that is neither used by wireless network access nor by other airspace users.

4.8 Dedicated public mobile network for U-space

During an EASA-workshop with USSPs on July 22nd 2021, the question has been raised, whether dedicated public mobile networks should be set-up for U-space. For a sufficient and non-interfering service, mobile base station antennas would need to be tilted upwards.

Until today, mobile radio network planning is optimized to configure an ideal network (locations, antenna tilt, frequency used, topology, others) in a mainly two-dimensional space. Exceptions are dense urban environments with very high buildings/ skyscrapers. Building networks actively covering airspace would request a totally new network infrastructure or probably more efficient to install another coverage layer on top of the ground network to strictly separate these layers and avoid interferences between the layers. This could be technically realized in a much easier way by using different spectrum than in the ground network, but so far, such a kind of dedicated spectrum is not allocated by ITU, CEPT or others.[85]

In case it will be considered to reallocate existing mobile spectrum to an own airspace layer one simple example is that if 2x10 MHz (paired spectrum) is re-used, this spectrum needs to be freed up of every concurrent use. In 2019 spectrum auction in Germany, 2.100 MHz spectrum was granted at approximately 430 Mio. EUR per 2x10 MHz block for a national license (which is an average European pricing level).[86] For this price, such spectrum will probably be used where it can get most payback, which is on the ground. Accordingly, this is not considered to be a scenario for the future.

[85] (Zulkifley, Behjati, Nordin , & et. al, 2021), (Lin, Yajnanarayana, Muruganathan, & et. al, 2018)
[86] (Nett, 2019)

4.9 Potential future networks

Looking into the future, two alternative network architectures could help to solve some issues of the aerial use of the mobile ground networks. However, assuming the current market developments, it must be taken into consideration that these solutions will need further development and will not be available on the markets until 2025.

Mid-term outlook: *Combined Satellite Ground-to-Air networks*

The European Aviation Network (EAN) is built, owned and run by Inmarsat and Deutsche Telekom. EAN is a combined network of satellite and dedicated ground infrastructure operating on Inmarsat's S-Band spectrum and explicitly targeting Airspace from 3 km altitude upwards. According to experts, technically this infrastructure could be down tilted to even serve everything down to 1000 m. In the mid-term, such hybrid-networks could be one solution to complement LTE/ 5G ground infrastructure to serve the whole airspace[87]. However, as of today, there are some technical hurdles to overcome, such as the size and weight of the on-board units (which are made for big aircraft) and the changeover from one network to the other.[88]

Long-term outlook: Stratospheric platforms or High-altitude platforms (HAPs)

Mobile Comms Radio spectrum is basically able to make great distances. UK based stratospheric platforms has proven that 2.1 GHz and 3.5 GHz spectrum is able to serve ground users from 20 km altitude. However, the spectrum used for these "flying networks" must be allocated to high-altitude platforms (HAP), which holds true for 2,1 GHz and 48 GHz. HAPs could be an ideal future complement to terrestrial networks to fill coverage gaps from the air. As one flying "stratospheric base station" enables up to 140 km diameter coverage it would only require around 400-500 stratospheric base stations to cover whole Europe on the ground.[89] To cover not only the ground, but a U-space Airspace up to 300 m AGL the "flying network" must only be a little denser (estimated 600 HAPs). The complexity of a flying fleet of base station and the unclear spectrum allocation makes it only a long-term consideration.[90]

[87] (Inmarsat & Telecom , 2020)
[88] (Plantaz, 2020)
[89] (Stratospheric Platforms Limited, 2021)
[90] (Stratospheric Platforms Limited, 2021), (Zhang, Zeng, & Zhang, 2018), (Marojevic & Abdalla, 2021)

5. Conclusion

The analysis of the 7 Areas in Chapter 4 regarding the underlying assumptions explained in Chapter 3 shows that although utilizing mobile telecommunication technologies for making manned aircraft electronically conspicuous in U-space is technically feasible, it comes with several limitations. Therefore, an in-depth conclusion is drawn in the following, including recommended measures that should be taken to overcome these limitations.

Mobile networks are typically served as “best effort” available service, as this brings highest economic value to providers and customers. A technical dedicated network for airspace users would need a separated network infrastructure, dedicated exclusive spectrum, would probably last 20 years to concept and create very high cost. Providing aircraft with existing LTE/ 5G networks and the used equipment (smartphones or dedicated devices) causes an impact on the terrestrial network. Enabling connectivity to the aircraft while minimizing the impact on ground network requires a rethinking of many models, assumptions and configurations used to date for cellular networks.

In opposite to pure safety systems, Telco networks have no static structures, but are reworked and optimized every day to deliver on the growing demand and customer needs. Therefore, USSPs relying their services on the cellular network should align with their respective mobile network service providers. Also, planned outtimes and network enhancements should be exchanged to come to a reliable Service Level Agreement (SLA) all parties can work with.

Referring to the existing network monetization the potential additional aircraft users would probably not be a business case for Telcos to heavily invest into the third dimension of their network now. With growing aerial demand and the current developments in network technologies, a toolbox can be expected to fulfil different kinds of specific needs of aircraft users more and more (e.g. MIMO for aerial antenna optimizations, 5G network slicing for airspace, Mobile Edge Computing for ultra-low latency USSP-services).[91] At this early stage of aerial connectivity for aircraft, operations and procedures must be in place, which comply with the given network architecture and its limits. As an example, in high-risk areas where mobile connectivity cannot be fully guaranteed, backup systems based on ISM-band could be considered.

As unadjusted aerial usage of mobile network can affect the ground network extensively, network service providers should explicitly agree to the usage patterns. International and European standardization bodies are working towards network compliance and referring Telco-standards since 2015, but as most of the parties were waiting for the outcome of the U-space regulation, no direct pressure was felt. This lack of standards so far also leads to a lack of explicit contracting in the roaming agreements between the mobile network operators. Therefore, it cannot be recommended to use national and international roaming enabled SIM-Cards unless every roaming partner agrees to the aerial usage patterns.

Recommendation

The study identifies three major complications that need to be considered and addressed:

1. Interferences through unpredictable data upload: When considering an application-based tracking with a mobile phone, it needs to be taken into account, that an app cannot easily eliminate other apps or functions that might run in the background of a mobile phone. This might lead to an unpredictably higher consumption of bandwidth than needed for the tracking service and thus, can seriously affect the ground network with interferences.
2. Lagging roaming agreements: National and international roaming agreements rely on a basic understanding of the roamed services (SMS, Voice Streaming etc.) which cannot be presumed for aerial services. These aerial services are currently concluded in international and European standardization bodies. Once these aerial services are concluded, these concerns could be dropped (probably finished 2022/23).
3. Frequency restrictions: There are country specific restrictions in the use of certain frequencies below 1 GHz for aeronautical services. However, mobile phones are made to cover the widest range of frequency bands possible and do not allow to exclude frequency bands from usage. The Electronic

[91] (Ivancic, 2019)

Communication Committee (ECC) aims for a European decision until November 2022. Afterwards, the national authorities are supposed to implement this decision.

To use mobile telecommunication technology for making manned aircraft electronically conspicuous in U-space we recommend to take three measures. All measures need to be completed:

1. Interferences through unpredictable data upload: When recommending to use mobile devices in aircraft we expect this to be interpreted for aerial usage of mobile phones for any purposes. Authorities should explicitly focus the recommendation on using a tracking app only. To avoid Telco reluctance, it should be mandatory to shut down other background apps while using the tracking service.[92]
2. Lagging roaming agreements: In the case users stick to the recommended usage pattern (see 1.), it can be avoided that neighbour networks will be harmed. Accordingly, it could presumably also be recommended to use roaming services to achieve a higher coverage across Europe for the users.
3. Frequency restrictions: There are three alternative options to deal with this issue:

    a. Wait for ECC decision (expected Nov 2022) and their implementation in national legislation. The discussion could be stimulated via U-space implementation to prepare an early consensus of all Member States to follow the ECC decision.
    b. Start to recommend tracking apps based on mobile devices for regions where aerial use of these frequency bands is or will be at least tolerated. As a first step this does not necessarily need to happen on a national basis but can be ruled around areas where U-spaces are gradually planned to be implemented.
    c. Set up a conditional policy which refers and only comes into force once the ECC has harmonized the frequencies for aerial usage and this decision is adopted by the national radio authorities. Raise awareness at Member State level of economic potential of U-spaces (recommended option).

    We recommend to engage in this process as soon as possible for two reasons:

    - The use of frequencies from the air (co-existence of radioastronomy stations, weather satellites and radio altimeters) is currently under discussion.
    - It is not a given, that national radio authorities will implement the ECC decision (right away).

    To ensure these measures are completed in time and to accelerate the process so that the required coordination is achieved, it is recommended to approach officially ECC board directly and share the idea of making manned aircraft electronically conspicuous with mobile telephony technology. Within the ECC area PT1 (responsible for mobile issues and preparing ECC decisions) and FM59 (unmanned aerial systems) deal with aerial connectivity.

    In case there is no way forward in measure 3, a fallback could be to recommend affordable[93] dedicated mobile tracking devices with the capability to switch off the critical frequencies. The devices should comply with respective radio standards to achieve CE-certification, such as RED and EMC (electromagnetic compliance). Both, tracking modules and smartphone apps need to be "certified/ aligned" with the USSP in order to make the device "talking" to the UTM for the operating aircraft in the respective U-space.

We expect that the Telcos, the ECC-Board and the national authorities that are responsible for the implementation of the ECC recommendations, will react in a positive and constructive way on the recommended measures. Setting up a clear framework on the use of mobile telecommunication technology for aerial services, is beneficial for all parties involved, especially as there such applications are already in the market.

[92] There are dedicated apps available, e.g., www.appblock.app, that can shut down other apps however, it is still up to the user to set-up and execute these apps. Furthermore, these apps do not have an effect on background execution of the operating systems. Alternatively, the app programmers could include a function that makes the user aware regarding which apps are still running in the background.

[93] In mass production for all lower airspace users the device should not cost more than 150 EUR. Standardized devices across Europe would keep the prices low and with one single communication protocol reducing complexity for USSPs.

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7. Imprint

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Our specialists support companies and top executives with extensive competence in business models, organizational structures, processes and systems to successfully align their organizations for the future. We combine passion and effective implementation to turn change into success across whole companies, in individual business areas or in functions such as sales, operations, procurement, controlling & finance, HR and IT. Horváth stands for project results which create sustainable benefits and value. That is why our consultants accompany their customers from the business management concept and anchoring in processes and systems through to change management and training of managers and employees.

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