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Support for UAV Communications in 3GPP Cellular Standards

Abstract

This report is written to help a broad audience, including experts in UAV operations and regulation, understand the technical features of the 3GPP standard that equips mobile cellular networks to support UAV communication needs. It will also help experts focused on only one part of the 3GPP standard to gain a broad appreciation of the whole scope of 3GPP activities related to UAVs.

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1. Introduction

Smartphone and Internet of Things (IoT) users benefit enormously from the ability of commercial mobile cellular networks to provide wide-area and high-capacity wireless data services at moderate prices. There is strong interest in using commercial cellular to provide support to Unmanned Aerial Vehicles (UAVs) for use in flight command and control systems as well as to support communication to payload applications. The ATIS report *UAV Utilization of Cellular Services – Enabling Safe and Scalable Operation* [1] describes some of the areas of application of cellular communication to UAVs and discusses advantages that cellular can offer.

Though cellular networks were originally designed for terrestrial communication, research discussed in this report, and in the previous ATIS report, has shown that they are already capable of providing good support to low altitude UAVs. Nevertheless, as the number of UAV cellular users increases, along with an increasing focus on the safety and reliability of both commercial and leisure UAV operations, the cellular industry is acting to make technical improvements to further enhance the services provided to UAVs.

Today's cellular networks are developed to comply with global technical standards that ensure that equipment from different vendors is interoperable. This creates a competitive market for cellular equipment by giving both network operators and consumers freedom to choose between multiple vendors while ensuring that reliable communications are still delivered. All major commercial cellular networks adhere to the standards developed by the global partnership 3GPP. 3GPP standards include the well-established 4G LTE standard and the recently defined 5G standard.

By adding features to support UAV communication requirements to the 3GPP standard the cellular industry is acting to ensure networks have a technical platform that can meet present and future needs of UAVs. This paper is written to help a broad audience, including experts in UAV operations and regulation, to understand the features that the 3GPP standard is introducing to support UAVs. The aim is to help bridge different silos of expertise by providing a common understanding of the capabilities 3GPP standard technology.

2. Mobile Cellular Generations and the Concept of 3GPP Releases.

Mobile cellular technology has evolved within a globally agreed framework that has defined different generations of technology, and specifically for 3GPP standards, the concept of incremental releases of a standard.

Each mobile cellular generation defines a set of system capabilities and performance targets. As technology, particularly with respect to the radio interface, has improved, each generation has advanced the capabilities over its predecessors. The current widely deployed generation of technology is the fourth generation (4G) which 3GPP has standardized under the name of "LTE". The generation currently under development and trials is the fifth generation (5G) which introduces the 3GPP New Radio (NR) standard.

To allow evolution of the 3GPP standards, they are regularly updated as 3GPP standard releases. Each release contains interoperable specifications for all the standardized system components and interfaces. 3GPP releases are backwards compatible with previous releases, so that implementations of the previous release will still work correctly when interfaced to implementations of the new release. 3GPP can continue to enhance existing generations, as well as working on new generations of technology. Thus, a 3GPP release contains specifications for multiple generations of mobile cellular technology.

In each 3GPP release, new features for the standard are developed using a "three stage model". In stage 1, the requirements are developed. In stage 2, the technical solution is elaborated at an architectural level. In stage 3, the protocols to support the solution are defined.

For this report the main standards releases of interest are 3GPP Release 15, 3GPP Release 16 and 3GPP Release 17. 3GPP Release 15 was approved in June 2018 and includes enhancements to LTE to support UAVs as well as introduction of the first version of 5G NR. Release 16 was started in September 2017 and is targeted for approval of stage 3 in December 2019. Release 16 includes work on UAV identification as described in section 4. The timetable for Release 17 is not yet set but will likely be 12-18 months later than Release 16.

The following diagram provides a high-level view of 3GPP releases 15 and 16.

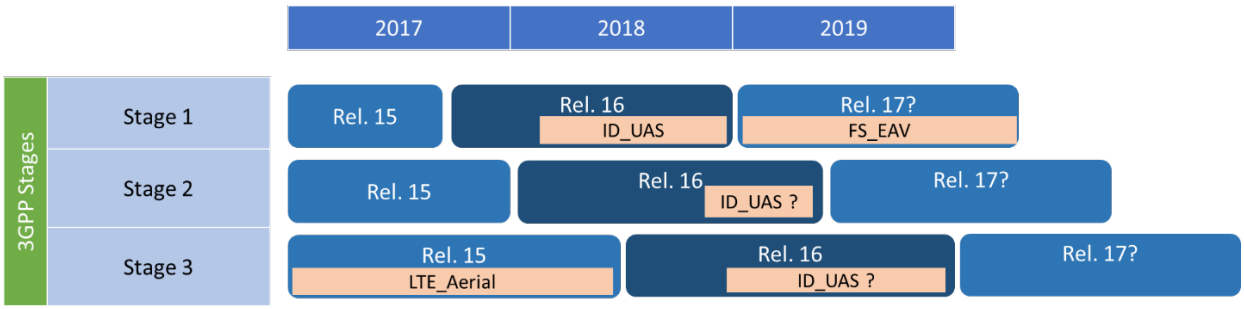

Figure 1: High-level timetable for 3GPP Releases and Work Items Related to UAVs

3. 3GPP Release 15 LTE Radio Enhancements for UAV Service

3GPP began studies in to the implications of serving low altitude UAVs using LTE radio in Release 15 of their standard *LTE_Aerial* [2]. This led to the publication of report 36.777 *Enhanced LTE Support for Aerial Vehicles* [3], approved in January 2018. The focus of the report is on how well the LTE radio network can provide services to low altitude UAVs and how the use of User Equipment (UE) in UAVs impacts overall LTE performance.

According to the experimental and simulation studies reported by 3GPP:

- In the case of low densities of conventional LTE users and UAV users (e.g., in rural environments) LTE performance is not significantly degraded by UAVs.
- As the density of both conventional and UAV users increases (e.g., in urban environments) LTE communication to UAVs can cause degradation in radio performance including interference on the uplink and downlink.
- Mitigations were found for improving both uplink and downlink interference. Some of these utilize already standardized LTE capabilities.

Following the Release 15 study, work was approved on enhancements to the LTE radio standard [4]. This work includes standardization of features including:

- Enhancements to support indication of the UE's airborne status and indication of the UE's support of UAV related functions in LTE network.
- Signaling support for subscription-based identification of UAV UEs.
- Enhancements to support improved mobility performance and interference detection in the following areas:

    - Enhancements to existing measurement reporting mechanisms such as definition of new events, enhanced triggering conditions, and mechanisms to control the amount of measurement reporting.
    - Enhancements to mobility for UAV UEs such as conditional handover and enhancements based on information such as location information, UE's airborne status, flight path plan, etc.
- Uplink power control enhancements.

This work will prepare the LTE radio standard to provide the coverage necessary for a growing population of low altitude UAVs in all types of environments.

4. 3GPP Release 16 UAV Identification

The work in 3GPP Release 15 was primarily concerned with radio aspects of support for UAVs. In 3GPP Release 16, work will include areas related to system and application layer aspects. At the time of publication of this report (4Q2018), 3GPP Release 16 is still under development, and that contents of this section reflects the current status of the work. Release 16 includes an initial study of service requirements for UAV identification under a work item *Remote Identification of Unmanned Aerial Systems* (FS_ID_UAS) [5]. This resulted in an approved report 22.825 *Study on Remote Identification of Unmanned Aerial Systems* [6].

Following on from that report, a new work item to advance normative work on service requirements for identification of UAVs was agreed in Release 16 under the title of *Remote Identification of Unmanned Aerial Systems* (ID_UAS) [7].

The goal of the Release 16 UAV study, and subsequent normative work, is to identify requirements to meet the worldwide needs of UAV operators, law enforcement, regulatory bodies and OEMs. The study is based on the concept of UAV identification by control data that can be transmitted via the 3GPP network between a UAV or a UAV controller and a centralized network-based UAV Traffic Management (UTM) function. The following diagram illustrates a high-level view of the concept.

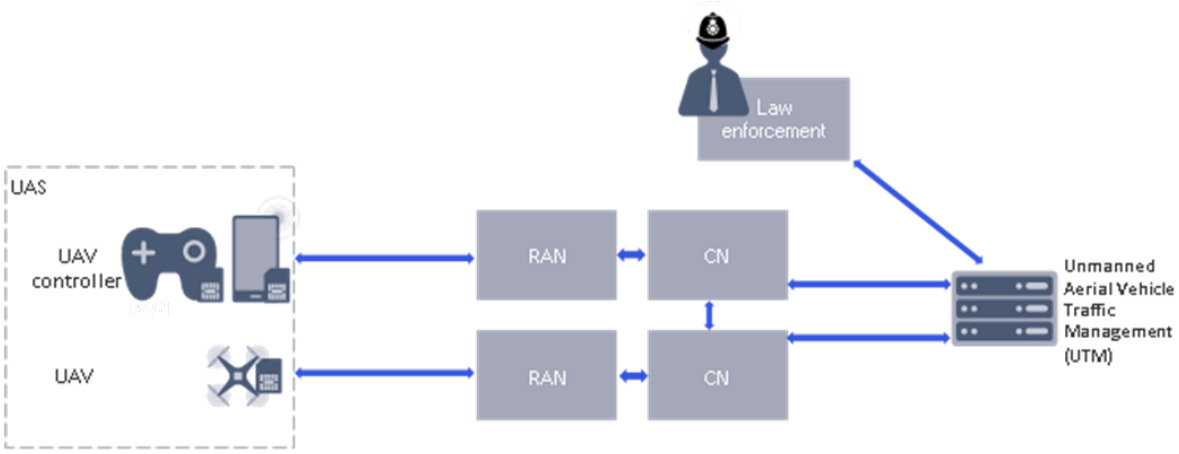

Figure 2: High level view of architecture of 3GPP Release 16 FS_ID_UAS work

Use cases under study in 3GPP include:

- Initial authorization to operate a UAV.
- Live data acquisition by UTM.
- Data acquisition from the UTM by law enforcement.
- Enforcement of no-fly zones.
- Enforcement of separation between UAVs operating in close proximity.
- Local broadcast of UAS identity.
- Differentiation between UAVs with integral cellular capabilities and conventional mobile phones attached to UAVs.
- Cloud-based Non-Line of Sight (NLOS) UAV operation.
- UAV based remote inspection of infrastructure.

Requirements are derived from these use cases, such as:

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

- The 3GPP system can help to enforce the authorization for an in-flight UAV to operate basing on UAV subscription information or under the instructions from UTM.

3GPP is also considering whether direct communication between UAVs, and between UAVs and ground-based personnel (particularly law enforcement), is required as part of the 3GPP standard. There are a variety of possible use cases where communication may be required to take place independently of the ground-based network infrastructure. These use cases include collision avoidance and the enforcement of rules pertaining to allowed UAV operation. In undertaking this work, 3GPP is being guided by the *UAS Identification and Tracking (UAS ID) Aviation Rulemaking Committee (ARC) Recommendations Final Report* [8], and other regions' regulatory work, as the basis for understanding the requirements in the USA.

Following completion of the requirements study it is expected that, subject to member agreement, 3GPP will undertake normative requirements work and the corresponding technical solution work in Release 16 to fulfil the goals that have been identified.

5. 3GPP Release 17 Enhanced UAV Requirements and Performance

In Release 17, 3GPP has agreed on a new study on enhanced requirements for UAV services including new Key Performance Indicators (KPIs) relevant to UAVs. This study is titled *Enhancements for UAVs* (FS_EAV).

The purpose of this study item is to propose more scenarios, new requirements and KPIs for UAV applications, to cover commercial and hobbyist applications of UAVs, including:

- Communication latency, reliability and mobility requirements for UAV applications (e.g., mapping, navigation, photographs and videography), including communication towards the UAV Traffic Manager (UTM) or cloud servers.
- UAV applications (e.g., security surveillance) which require very high uplink data rates for air to ground communication.
- Consideration of potential usages of the network slicing feature that allows mobile network infrastructure to be presented as virtualized slices with each slice dedicated to an application or customer.
- The KPIs of command and control traffic between the UAV and UAV controller.
- Discovery process between UAV controllers and UAVs.

This study will consider what can be supported using LTE and NR.

6. Support for UAVs in 5G New Radio

From Release 15 onwards, 3GPP standards include specifications for a 5G radio interface, referred to as "New Radio" (NR). The NR interface is designed to meet several different usage scenarios including Enhanced Mobile Broadband (eMBB), Massive Machine Type Communication (mMTC) and Ultra Reliable Low Latency Communication (URLLC).

In the Release 15 standard, the focus has been to specify the fundamental capabilities of NR to allow early deployments of 5G technology. As discussed below, there was work in Release 15 related to High Altitude Platforms, but 3GPP did not give detailed consideration to the support of low altitude UAVs by NR. In the work on LTE support for low-altitude UAVs, it was found that most problems were due to interference caused by the UAVs operating above the normal height of UEs. NR will make greater use of beamforming antennas which may reduce this interference but could introduce new problems. UAVs may also experience "coverage holes in the air" as network planning and design is directed to ground-based users.

Initial deployments of NR will be made alongside existing LTE coverage. During early deployments of NR it is suggested that LTE should continue to be used to serve low altitude UAVs as there is already extensive experience and standards support for using LTE in this application. As the NR standard matures, it is anticipated that standards and deployments will be readied to support low altitude UAVs.

7. Support for High Altitude Platforms (HAPs) in 5G

3GPP has studied the provision of 5G NR services from HAPs in Release 15 (TR 38.811) [10] and is continuing the work in Release 16. The studies consider platforms that operate at altitudes of between 8km and 50km and can provide services to either fixed, very narrow aperture receivers or to portable handheld receivers. HAPs are part of the Non-Terrestrial Networks (NTN) Study Item efforts. HAPs can serve User Equipment directly, or indirectly via a relay function.

The current Release 16 phase is aimed at further characterizing the impacts of, and evaluating solutions for, the currently identified 5G NR key impacts of NTN. In addition, it will further study the impacts on 5G RAN protocols and architecture.

In June 2018, the following points had been studied in 3GPP RAN working groups and were reported to 3GPP RAN Plenary:

- NTN reference deployment scenarios and related system parameters including altitude, mobility and motion/relative motion, doppler, delay, synchronization and more.
- Defined initial channel models leveraging the models defined in 3GPP TR 38.901 *Study on channel model for frequencies from 0.5 to 100 GHz (Release 14)*.
- Identification of potential key impact areas on all layers of NR to support NTN, including significant progress on initial solution principles to more rapidly kick off the Release 16 work.

It is worth noting that other 5G NR and RAN deployment scenarios based on aerial vehicles at different altitude or flight patterns may be explicitly considered in subsequent studies on NR supporting NTN. Further, low-altitude UAV efforts will already be able to leverage some NR NTN findings.

8. Conclusions

3GPP standards define the technical platform used by today's mobile cellular networks. The needs of UAVs for both communication services and other services, like identification and tracking, have been recognized in 3GPP. As a result, 3GPP has already, in Release 15, defined enhancements to LTE to improve the radio performance when UAVs are accessing cellular networks. In Release 16 work has been initiated to study how mobile cellular networks can support services that will provide features to enable safe and secure operation of UAVs in compliance with local regulations. The work in 3GPP will help prepare mobile cellular networks to meet the requirements of increased UAV traffic and to provide improved technical means to help enforce safe operation.

9. References

[1] ATIS-I-0000060 "UAV Utilization of Cellular Services – Enabling Safe and Scalable Operation"
(https://access.atis.org/apps/group_public/download.php/36134/ATIS-I-0000060.pdf)

[2] Work Item "Study on enhanced Support for Aerial Vehicles" RP-171050
(http://3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_76/Docs/RP-171050.zip)

[3] 3GPP 36.777 "Enhanced LTE support for aerial vehicles" (https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3231)

[4] Work Item "Enhanced LTE Support for Aerial Vehicles" RP-172826 (http://3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_78/Docs/RP-172826.zip)

[5] Study Item "Remote Identification of Unmanned Aerial Systems" SP-180172 (http://www.3gpp.org/ftp/tsg_sa/TSG_SA/TSGS_79/Docs//SP-180172.zip)

[6] 3GPP 22.825 "Study on Remote Identification of Unmanned Aerial Systems" (https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3527)

[7] Work Item "Remote Identification of Unmanned Aerial Systems" SP-180771 (http://3gpp.org/ftp/tsg_sa/TSG_SA/TSGS_81/Docs/SP-180771.zip)

[8] "UAS Identification and Tracking (UAS ID) Aviation Rulemaking Committee (ARC) ARC Recommendations Final Report" (https://www.faa.gov/regulations_policies/rulemaking/committees/documents/media/UAS%20ID%20ARC%20Final%20Report%20with%20Appendices.pdf)

[9] Study Item "Enhancements for UAVs" SP-180909 (http://3gpp.org/ftp/tsg_sa/TSG_SA/TSGS_81/Docs/SP-180909.zip)

[10] 3GPP 38.811 "Study on NR to support non-terrestrial networks" (https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3234)

10. Abbreviations

- 3GPP Third Generation Partnership Project
- 4G Fourth Generation
- 5G Fifth Generation
- ARC Aviation Rulemaking Committee
- eMBB Enhanced Mobile Broadband
- HAPs High Altitude Platforms
- IoT Internet of Things

- KPI Key Performance Indicators
- LTE Long Term Evolution
- mMTC Massive Machine Type Communication
- NLOS Non-Line Of Sight
- NR New Radio
- NTN Non-Terrestrial Network
- OEM Original Equipment Manufacturer
- RAN Radio Access Network
- UAV Unmanned Aerial Vehicle
- UAS Unmanned Aerial System
- URLLC Ultra Reliable Low Latency Communication
- UTM UAV Traffic Management
- UE User Equipment