MITRE ENGENUITY

MAKING DETECT AND AVOID A REALITY FOR UAS

INVESTIGATING LEVERAGING 3GPP C-V2X TECHNOLOGY FOR AERIAL APPLICATIONS

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INTRODUCTION

The Open Generation 5G Consortium was created to accelerate 5G enterprise innovation by convening industry leaders alongside technology innovators and academia to identify and solve hard challenges through use case innovation. The Open Generation 5G Consortium operates three dedicated working groups that each contribute to designated stages of the discovery, development, and experimentation of transcendent enterprise use cases. Results can be used to inform technology standards organizations and help members bring new solutions to market faster.

SCOPE

The objective of this document is to describe the development of a prototype and set of experiments the Open Generation 5G Consortium performed to assist in providing industry input in an ongoing 3rd Generation Partnership Project (3GPP) Release 18. This activity looks at how to support detect and avoid (DAA), collision avoidance, and broadcast Remote Identification (Remote ID) as detailed in Federal Aviation Administration (FAA) regulations [1] and U-Space regulations EASA NPA 2021-14 [2] communications using cellular technologies in reserved spectrum.

OVERVIEW—SYSTEMS AND STANDARDS

Aviation

Background

In recent years, the demand for commercial use of small uncrewed aircraft (UA) has grown significantly. As a result, the FAA has established a set of rules for these aircraft. In 2016, 14 CFR §107 was first published defining a "small, unmanned aircraft system" as one that has a UA whose weight is less than 55 pounds (25 kg) [5]. These rules allow for commercial use of uncrewed aerial systems (UAS) within operational limitations, including flight within 400 feet of the ground or a ground obstacle, daytime operations unless appropriate lights are onboard, no flight over people, and flight within visual line of sight of the pilot (14 CFR §107). Each of these restrictions can be assigned waivers through a safety mitigation process; however, waivers granted to these restrictions are less common.

The limitations listed in the preceding paragraph face some of the following common challenges that may be addressed by 5G and beyond:

- **Reliable and uninterrupted communications:** A key challenge is the need to improve the connectivity and reliability of the command and control (C2) channel beyond existing methods to ensure consistent and continuously available communications.
- **Aircraft separation:** A key challenge is the need to support the ability for aircraft to first detect and then avoid other aircraft (crewed and uncrewed) and obstacles.
- **UA identification**: A key challenge is to be able to identify a UA to ensure that it is complying with regulations.

This paper will discuss DAA and to a somewhat less extent UA identification and one technology that looks very promising.

Detect and Avoid

Background

One of the oldest rules of flight since the invention of the airplane is that "vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft" (14 CFR §91.113). The introduction of UAs makes this more challenging, as there is no pilot onboard to perform this task. An obvious solution might be to add a camera onboard the UA; however, the FAA legal office has ruled that the human eyeball performing "see and avoid" may be augmented only by normal glasses and not by any electronic means [6]. Thus, the term "detect and avoid" was coined as a replacement concept. However, DAA is not yet recognized via regulation, and thus waivers must be granted to either 14 CFR §91.113 or 14 CFR §107.31.

Since the development of the radar system during World War II, aviation has had a requirement to differentiate "friend from foe" [7]. The traditional primary technology used for this requirement has been the transponder. A ground-based secondary surveillance radar can interrogate an aircraft transponder and, by measuring the round-trip time and the angle, determine the position of the aircraft. Automatic Dependent Surveillance Broadcast (ADS-B) evolves the surveillance concept by broadcasting the onboard global positioning system position of the aircraft. If all crewed aircraft had ADS-B equipage, then DAA would not be that difficult an issue. Unfortunately, the mandate to carry ADS-B equipment is required only in certain airspaces (14 CFR §91.225) and the cost of equipage is expensive. UAs must be able to detect aircraft that are not equipped with transponders or ADS-B, which are called "noncooperative" aircraft.

Noncooperative DAA is divided into systems that work onboard the aircraft and those that work from the ground. Radar is generally recognized as the most reliable, but most expensive, detection method[8]. Camera-based systems are often referred to as "electro-optical systems," and have generally required augmentation because the speed of aircraft makes them less effective. There has also been some success with acoustic systems.

DAA in Standards

Detect and avoid requirements are currently under development as the FAA works to adopt standards that will provide a means of compliance to fly beyond visual line of sight (BVLOS). Currently, the two primary DAA published standards are RTCA DO 365B and ASTM F3442/F3442M-20, each of which takes a different but complementary approach.

The RTCA standard starts with identifying the two surveillance types needed to support DAA (i.e., cooperative and noncooperative) and the sensors that comprise them. It then provides architecture alternatives that combine various subcomponents to achieve sufficient DAA. The limitations of the current RTCA standard are its scope and its specificity. This standard does not apply to small UASs operating below 400 feet, but rather focuses on integrating UASs into other portions of the National Airspace System, where they will frequently interact with crewed aircraft. It also restricts possible DAA solutions that may achieve performance without conforming to one of the RTCA-proposed architectures.

The ASTM standard is architecture agnostic, instead focusing on performance-based DAA requirements. The limitation of this standard is again scope, with the requirements being solely for separation of the UA and crewed aircraft, not UA-UA or other obstacle avoidance.

UA Identification—Remote ID

Overview

The FAA describes Remote ID as the ability of a drone in flight to provide identification and location information that can be received by other parties, and says that the Remote ID helps the FAA, law enforcement, and other federal agencies find the control station when a drone appears to be flying in an unsafe manner or where it is not allowed to fly.

Remote ID allows governmental and civil identification of UASs for safety, security, and compliance purposes. The objective is to increase UAS remote pilot accountability by removing anonymity while preserving operational privacy for remote pilots, businesses, and their customers. Remote ID enables enhanced operations such as BVLOS operations and operations over people.

The FAA's Notice of Proposed Rulemaking on Remote Identification of Uncrewed Aircraft Systems, which was published on December 31, 2019, included the Limited Remote Identification UAS category to transmit Remote ID messages through an internet connection to a Remote ID USS.

In the FAA Final Rule (Part 89), the Limited Remote ID UAS was eliminated and replaced with Remote ID Broadcast Module requirements to enable existing UAs to comply. Though this resulted in the elimination of the network-based or internet transmission requirements in the Final Rule, the use of Network Remote ID is not precluded in future FAA regulations.

ASTM Standards

ASTM Standard F3411 covers the performance requirements for Remote ID of UASs and was designed to be applicable to UASs that operate at low altitude over diverse environments regardless of airspace class. F3411 defines message formats, transmission methods, and minimum performance standards for two forms of Remote ID: broadcast and network.

Broadcast Remote ID is based on the transmission of radio signals directly from a UA to receivers in the UA's vicinity. The Remote ID rule requires that the UA broadcast ID messages can be received by commonly available devices that support Remote ID standards. This has resulted in F3411-19 concentrating on the use of Bluetooth and Wi-Fi over an unlicensed spectrum. However, the standard is not strictly limited to these technologies, so it is possible that future standards could meet the Remote ID broadcast ID requirements and be accepted by the FAA as a means of compliance with the rule.

Network Remote ID is based on communication by means of the internet from a network Remote ID service provider that interfaces directly or indirectly with the UAS, or with other sources in the case of non-equipped network participants.

F3411-19 is currently in the process of being updated with changes required to accommodate the final FAA rule on Remote ID. As previously stated, this rule does not require a network solution. However, this option has not been removed from future FAA rulemaking, and the updated F3411 standard will still include the network Remote ID requirements.

3GPP System

Background

The 3GPP unites seven telecommunications standards development organizations known as Organizational Partners, and provides their members with a stable environment to produce the reports and specifications that define 3GPP technologies. The Organizational Partners are:

- Association of Radio Industries and Businesses
- Alliance for Telecommunications Industry Solutions (ATIS)
- China Communications Standards Association
- European Telecommunications Standards Institute
- Telecommunications Standards Development Society
- Telecommunications Technology Association
- Telecommunication Technology Committee

The project covers cellular telecommunications technologies including radio access and core network and service capabilities, which provide a complete system description for mobile telecommunications. The 3GPP specifications also provide hooks for non-radio access to the core network and for interworking with non-3GPP networks.

3GPP specifications and studies are contribution—driven by member companies, in working groups, and at the Technical Specification Group level.

The three Technical Specification Groups in 3GPP are:

- Radio Access Network (RAN)
- Services & Systems Aspects (SA)
- Core Network & Terminals (CT)

The diagram in **Figure 1** shows components of 3GPP systems for 4G and 5G technology. See 3GPP TS 23.401 for LTE Evolved Packet System (EPS) architecture (top figure) and 3GPP TS 23.501 and 3GPP TS 23.502 for more details for 5G architecture (bottom figure).

Figure 2 shows a high-level architecture diagram of UAS over 3GPP systems.

Support of UASs in 3GPP started in Release 15 with the RAN group first studying functionality (see Study Item Description [SID] in RP-171050 and 3GPP TS 36.777) that would allow the RAN the opportunity to try and mitigate interference caused by UASs on terrestrial users, followed by doing normative work (see Work Item Description [WID] RP-172826). Further functionality was developed in Rel-16 and Rel-17 to further support the UAS ecosystem, which all stems from service requirements that are detailed in 3GPP TS 22.125. A good overview of the Release 17 functionality that was subsequently designed from 3GPP TS 22.125 can be found in an ATIS white paper on Release 17 Building Blocks for UAV[10].

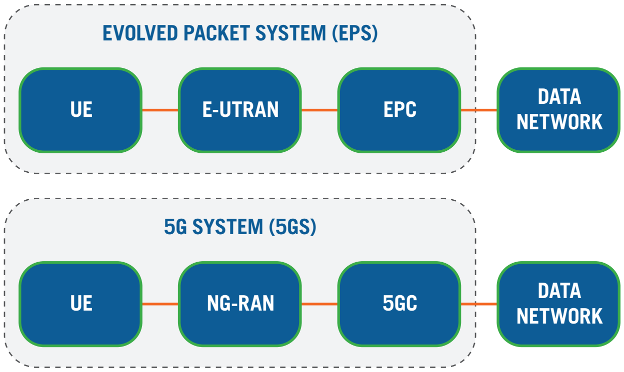

FIGURE 1. LTE EPS [TOP] AND 5G [BOTTOM] SYSTEM

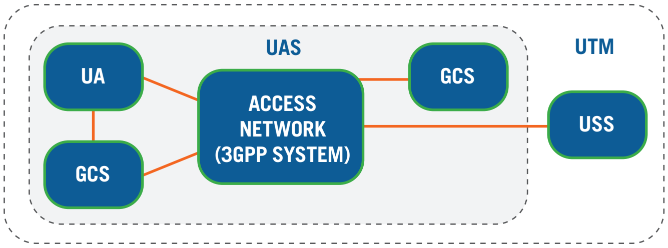

FIGURE 2. SHOWS A HIGH-LEVEL ARCHITECTURE DIAGRAM OF UAS OVER 3GPP SYSTEMS.

Detect and Avoid in 3GPP and Broadcast Remote ID

In Release 18, 3GPP is continuing its development of functionality using requirements in 3GPP TS 22.125 to support the UAS ecosystem and is investigating how the support of DAA and broadcast Remote ID could be supported in the 3GPP system. The core network aspects of this work have been studied (SP-211632) in 3GPP TR 23.700-58, with normative work being specified in 3GPP TS 23.256. The RAN aspects of this work are being investigated and specified under the work item “WI on NR Support for UAV” RP-213600.

PROTOTYPING A 3GPP DAA AND REMOTE ID SOLUTION

Background

Open Generation and one of its core members, Qualcomm, saw an opportunity to prototype one of the solutions being proposed in 3GPP TR 23.700-58. The functionality in question is device-to-device communications and goes by several different terms depending on which part of 3GPP you are investigating. In RAN groups, it is known as sidelink, whereas in SA and CT groups it might be more commonly known as PC5; however, both terms mean the same thing. This functionality has its origins in 3GPP Release 12, when it was developed for the ProSe feature 3GPP TS 23.303, which was initially targeted at the "Public Safety" vertical. ProSe consisted of the RAN functionality to support PC5/sidelink and network functionality that would allow a device to be authorized and subsequently discover other devices. One could envisage that a user of the ProSe feature could discover other users that might subsequently come into proximity of the discovering party. ProSe was subsequently adapted for the automotive industry (3GPP TS 23.285), commonly called Cellular Vehicle to Everything (C-V2X),[1] the latter being incorporated first into 5G (3GPP TS 23.287), followed by the more feature-rich ProSe version in a subsequent release of 5G functionality (3GPP TS 23.304). The PC5/sidelink supports unicast, sidelink groupcast, and sidelink broadcast. It must be noted that unicast is a 5G enhancement to the PC5/sidelink set of features. PC5/sidelink also supports a "relay" capability (UE-to-Network Relay and UE-to-UE Relay) that allows one device to use another device as a relay to either reach the cellular network or reach another device.

Solutions leveraging the PC5/sidelink functionality operating in an appropriate spectrum are now considered a natural solution for allowing UAs to communicate directly with one another, with other infrastructure, or with other vehicles that are within the vicinity of the UA. A good overview of C-V2X for automotive applications can be found in a C-V2X white paper [9], where the reader can get more information about the capabilities of C-V2X and its radio frequency performance in the 5.895-5.925 GHz band.

It must be mentioned for sake of clarity that the intention is not to leverage PC5 solutions operating in the 5.9 GHz band for aerial applications. The authors expect that an appropriate band will be made available for the use of PC5-based UA applications that does not interfere with the 5.9 GHz band currently assigned for automotive applications.

Pre-Experiment Setup

The prototype DAA solution using cellular technology was built using existing commercial C-V2X modems. One commercially available C-V2X modem is the Quectel AG15 board, which uses existing spectrum (5.895–5.925 GHz). A successful result would be when at least two devices (e.g., UA and Ground Control Station [GCS]) could accurately receive the position and velocity of the other aerial devices. The experiments were conducted with an experimental license to operate in the 5.9 GHz band for the sake of simplicity and re-used commercially available products, even though it is expected that PC5-based applications for UAs will operate on a separate spectrum band than the 5.9 GHz band allocated to automotive applications.

[1] Some in the industry may also consider the application layer developed by SAE to be part of this encompassing acronym. The first SAE specification that was developed was J3161, which uses 3GPP PC5/sidelink but does not use the core network components that can be found in 3GPP TS 23.285.

Given that C-V2X is designed to be used with ground-based vehicles and it was impractical to retool existing commercial C-V2X solutions, an Federal Communications Commission experimental license was obtained at one of the MITRE facilities to allow C-V2X to be used for UA operations. Two small quad UAs and one GCS were equipped with the Quectel AG15 modem. The Quectel AG15 can work autonomously, meaning that one can start a software daemon on the Quectel AG15 and it will broadcast pseudo SAE J3161 [3] messages[2] while also storing logs of the messages it sends and receives.

Each message contains at least the following information: device identifier, longitude, latitude, velocity, altitude, and Global Navigation Satellite System (GNSS) confidence.

To simulate messages that would be signed with certificates, the message length was set to 300 bytes.

The device identifier can be set by issuing a command to the modem. Altitude is determined by GNSS on the aerial vehicle.

The advantage of using off-the-shelf components means that the integration effort with the drone is limited by essentially attaching a self-contained module onto an existing drone as a payload and using appropriate software. Existing drone communication mechanisms (e.g., radio control [RC] controllers to steer the drone or software such as QGroundControl) were used to pre-configure a flight path.

The experiment was performed in the geographical area described in **Table 1**.

County	Lat/Log of Operational Center Point	Operational Area Description	Altitude
Middlesex	42- 30- 10.74 N 71- 14- 4.86 W	MITRE Bedford Ballfield covers an area of 0.034 square miles, as seen in **Figure 3**.	113' MSL

TABLE 1. EXPERIMENTAL AREA LOCATION

FIGURE 3. MAP OF EXPERIMENTAL MITRE BEDFORD CAMPUS

The objective was to collect data at three devices and demonstrate that the data received (e.g., flight path) was the same as the data sent. In addition, the drones were flown, freeform,[3] as far as allowed by the geographical area from the GCS to see if a maximum distance could be achieved before any data was lost.

[2] Messages are defined in SAE J2735 [4].
[3] Freeform was letting the pilots fly the drones at speeds, altitudes, and trajectories as allowed by 14 CFR §107.

The drone setups used are depicted in **Figure 4**.

Each drone consisted of:

- Holybro X500 v2 drone with Pixhawk flight controller: PX4 Development Kit - X500 v2,Development Kit (holybro.com)
- Taranis X9D RC controller: Amazon.com: FrSky Taranis X9D Plus 2019 Transmitter with Latest Access with Battery (Silver) : Toys & Games
- GNSS antenna Taoglas Magma X2 AA.175

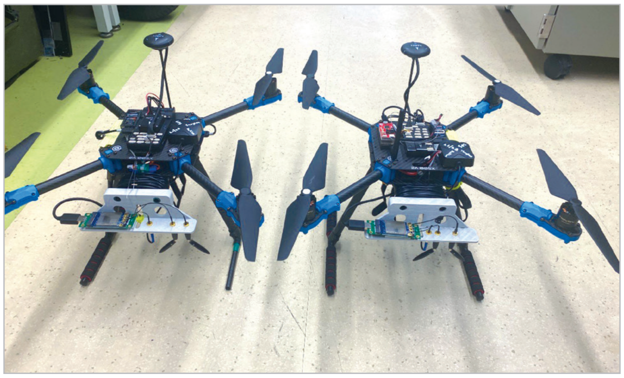

FIGURE 4. TWO UAS WITH C-V2X MODEM

The setup used for the GCS is depicted in **Figure 5**.

The GCS consisted of:

- A Dell laptop with Linux and QGroundControl software
- Communications technology: RFD900x radios: RFD900 TXMOD V2 Bundle—IR-LOCK (irlock.com)
- GNSS antenna Taoglas Magma X2 AA.175

FIGURE 5. GCS ANTENNA SETUP

While performing experiments, a FieldFox spectrum analyzer was used to ensure that there were no incumbent users in the band.

Experiment Execution

The purpose of the experiment was to determine if PC5/sidelink functionality could provide a framework for UA-to-UA and UA-to-ground broadcast[4] communications. To make this determination, a GCS was situated within the test location, as shown in **Figure 3**, and then two drones were flown freeform within this test area by 14 CFR §107-qualified pilots. One drone was pre-programmed with a flight path while the other was flown manually. Before flying the drones, the C-V2X modems where set up to broadcast and receive information as described in clause 5.2. The modems automatically logged the data they sent as well as data received.

Experimental Results

The results of the experiments are shown as flight paths on a map with different coloration to highlight the difference in altitude in meters above ground.

Flight path data sent by UA 1 can be seen in **Figure 6**.

Flight path data sent by UA 2 can be seen in **Figure 7**.

Data received from UA 2 can be seen in **Figure 8**.

Key Takeaways

The results from the experiment support the hypothesis that PC5/sidelink can be used as a transport mechanism to support Remote ID. The application layer contents of the PC5/sidelink message already contains most of what is required by the FAA (e.g., UA ID, UA location and altitude, UA velocity, time mark).[5] It would be simple to extend the application layer to contain additional information (e.g., GCS location and elevation, emergency status, or takeoff location).

The plots of drone activity clearly demonstrate that a receiving entity (e.g., UA 2) can receive and decode data from a transmitting entity (e.g., UA 1) and vice versa. Such capability could be used as input to DAA algorithms.

Only three devices were used in the testing, and there was no loss in packets transferred. However, the system was not loaded/stressed, nor were the UAs flown far enough away from one another that the system could detect lost data.

Careful analysis of the data sent from a UA shows that there are some gaps. Further investigation is needed to determine if this could be related to the broadcast rate and the velocity of the UA.

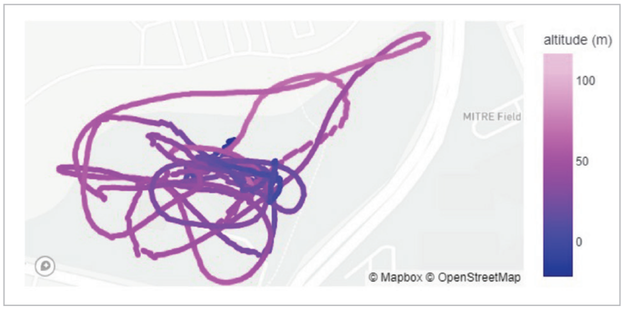

FIGURE 6. FLIGHT PATH DATA SENT BY UA 1 ON OCTOBER 25, 2022

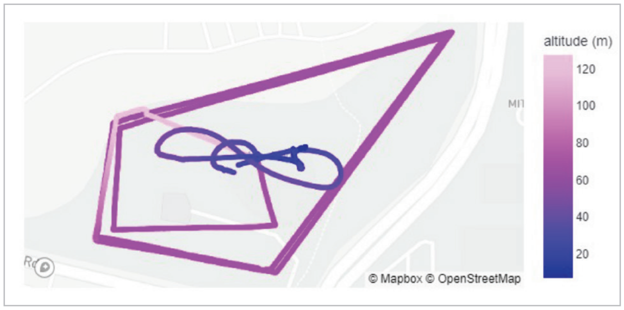

FIGURE 7. FLIGHT PATH DATA SENT BY UA 2 ON OCTOBER 25, 2022

FIGURE 8. FLIGHT PATH DATA OF UA 1 RECEIVED BY UA 2 FROM UA 1 VIA DRONE-TO-DRONE PC5/SIDELINK

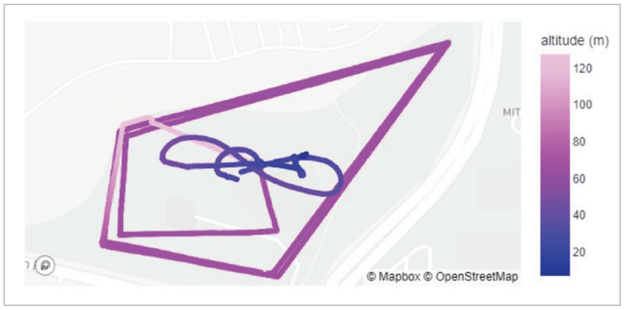

FIGURE 9. FLIGHT PATH DATA OF UA 2 RECEIVED BY UA 1 FROM UA 2 VIA DRONE-TO-DRONE PC5/SIDELINK ON OCTOBER 25, 2022

[4] Later versions of PC5/sidelink support unicast. However, this functionality was not available to test in the modems being used.

[5] A good visual representation of this can be found at https://www.faa.gov/uas/getting_started/remote_id/industry.

SUGGESTED FUTURE WORK

Due to the limited size of the test site location, similar experiments should be performed in a larger area to see how much further reliable communications can be received through the air. This will give the industry an approximation of how well an existing band can perform when used in an aviation environment.

A full Intelligent Transport System stack with security capabilities can be integrated to determine to what extent existing SAE automotive message sets/capabilities would need to be extended to support UAs.

Information received from other UAs (see Figure 8 and Figure 9) could be used as an input to existing DAA features in UA software to see how UAs could avoid one another in the air. The information broadcast could also be used as potential input in a UTM system.

While ideally a self-contained onboard DAA system, as demonstrated in these experiments, would have the benefits of being fully independent and portable, the technology still needs to find an appropriate set of frequencies to work in that are not widely available at this point. More than likely, the first UAs to obtain an Airworthiness Certificate will use at least some elements of ground-based detection of aircraft and obstacles (e.g., an onboard noncooperative sensor and ADS-B In sensors placed throughout a city).

Onboard sensors may not require any 5G Systems. However, any ground-based systems will need to convey their traffic information to either the UA or GCS, depending on where the avoidance algorithm is handled. Figure 10 proposes a high-level flow of DAA information from a ground-based DAA system to GCS and GCS to UA over a 5G network using the 5G Uu interface (shown in blue) and SGi interface (shown in green) that could also be investigated and eventually combined with the PC5/sidelink technology. Here, the 5G system provides transport for the DAA information.

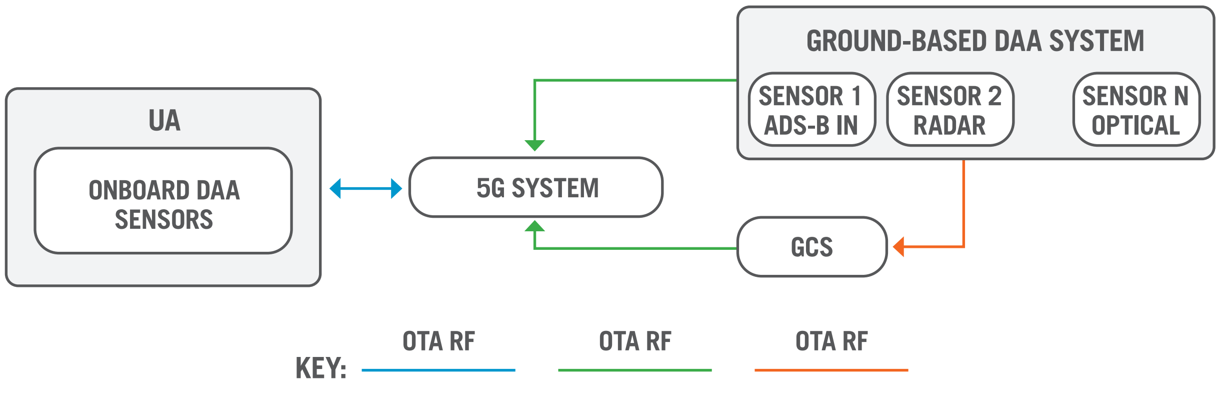

FIGURE 10. UAS AND 5G REFERENCE ARCHITECTURE WITH DAA

ABBREVIATIONS

ACRONYM	EXPLANATION
3GPP	3rd Generation Partnership Project
5GC	5G Core network
5GS	5G System
ADS-B	Automatic Dependent Surveillance Broadcast
ASTM	American Society for Testing and Materials
ATIS	Alliance for Telecommunications Industry Solutions
BVLOS	Beyond Visual Line of Sight
C2	Command and Control
CT	Core Network & Terminals (see 3GPP CT group)
C-V2X	Cellular Vehicle to Everything
DAA	Detect and Avoid
EPC	Enhanced Packet Core
EPS	Evolved Packet System
E-UTRAN	Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access or Evolved Universal Terrestrial Radio Access Network
FAA	Federal Aviation Administration
GCS	Ground Control Station
GNSS	Global Navigation Satellite System
GPRS	General Packet Radio Service
ID	Identification
IP	Internet Protocol
MASPS	Minimum Aviation System Performance Standards
MOPS	Minimum Operations Performance Standards
NG-RAN	Next Generation Radio Access Network
NR	New Radio
OTA	Over the Air
ProSe	Proximity Services or Proximity based services
RAN	Radio Access Network
RC	Radio Control
RID	Remote Identification (Remote ID)
RTCA	Radio Technical Commission for Aeronautics
SA	Services & Systems Aspects (see 3GPP SA group)
UA	Uncrewed Aircraft
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System (referred to in 3GPP as Uncrewed Aerial System or Unammed Aerial System)
UAV	Unmanned Aerial Vehicle (referred to in 3GPP as Uncrewed Aerial Vehicle)
UE	User Equipment
USS	UAS Service Supplier
UTM	Uncrewed Aircraft Systems Traffic Management
V2X	Vehicle-to-Everything
WI	Work Item

DEFINTIONS

TERM	DEFINITION
C2	The user plane link to convey messages with information of command and control for UAV operation between an unmanned aerial vehicle controller and a UA.
PC5	PC5 refers to a reference point where the user equipment (UE)—for example, mobile handset—directly communicates with another UE over the direct channel. In this case, the communication with the base station is not required.
Remote ID of UAS	The ability of a UAS in flight to provide identification and tracking information that can be received by other parties; to facilitate advanced operations for the UAS (such as beyond visual line of sight operations as well as operations over people); and to assist regulatory agencies, air traffic management agencies, law enforcement, and security agencies when a UAS appears to be flying in an unsafe manner or where the UAS is not allowed to fly. The Remote ID information payload may include the serial number or session ID assigned to the UA, location of the ground-station controller, emergency status indication, and so on.
UA Controller	Enables a drone pilot to control a UA.
UAS	Composed of UA and related functionality, including C2 links between the UA and the controller, the UA, and the network, and for Remote ID. A UAS is composed of a UA and a UA controller.
Uncrewed	An aircraft operated without the possibility of direct human intervention from within or on the aircraft (14 CFR §1.1, changed “unmanned” to “uncrewed”).
UAS Service Supplier (USS)	An entity that provides services to support the safe and efficient use of airspace by providing services to the operator/pilot of a UAS in meeting Uncrewed Aircraft Systems Traffic Management (UTM) operational requirements. A USS can provide any subset of functionality to meet the provider's business objectives (e.g., UTM, Remote ID).

REFERENCES

References in this document are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.

- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.

3GPP Standards

TS 22.125	Unmanned Aerial System (UAS) support in 3GPP; Stage 1
TS 22.261	Service requirements for the 5G system
TS 23.256	Support of UAS connectivity, identification, and tracking; Stage 2 (R17)
TS 23.285	Architecture enhancements for V2X [Vehicle-to-Everything] services
TS 23.287	Architecture enhancements for 5G System (5GS) to support Vehicle-to-Everything (V2X) services
TS 23.303	Proximity-based services (ProSe); Stage 2
TS 23.304	Proximity based Services (ProSe) in the 5G System (5GS)
TS 23.401	General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access
TS 23.501	System architecture for the 5G System (5GS)
TS 23.502	Procedures for the 5G System (5GS)
TS 23.700-58	Study of further architecture enhancements for uncrewed aerial systems and urban air mobility
TS 33.256	Security aspects of Uncrewed Aerial Systems (UAS) (Release 17)
TR 36.777	Enhanced LTE support for aerial vehicles
RP-171050	Study on enhanced support for aerial vehicles
RP-172826	Enhanced LTE support for aerial vehicles
RP-213600	Release 18, NR [new radio] support for UAV (Uncrewed Aerial Vehicles)
SP-211632	Study on Phase 2 for UAS, UAV and UAM

Radio Technical Commission for Aeronautics (RTCA)

DO 365B	MOPS for detect and avoid (DAA) systems
DO 377A	MASPS for C2 [command and control] link systems supporting operations of UAS in U.S. airspace

American Society for Testing and Materials (ASTM)

F3411	Standard specification for Remote ID (RID) and tracking
F3442	Standard specification for detect and avoid system performance requirements

Others

1. DEPARTMENT OF TRANSPORTATION Federal Aviation Administration 14 CFR Parts 1, 11, 47, 48, 89, 91, and 107 [Docket No.: FAA-2019-1100; Amdt. Nos. 1-75, 11-63, 47-31, 48-3, 89-1, 91-361, and 107-7] RIN 2120-AL31 Remote Identification of Unmanned Aircraft.
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8. https://www.aircraftspruce.com/menus/av/adsb.html
9. https://www.qualcomm.com/research/5g/cellular-v2x
10. https://access.atis.org/apps/group_public/download.php/66824/ATIS-I-0000092.pdf

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