Evaluating the Integration of 5G Technology in Aviation Communication Systems: A Theoretical Security and Performance Analysis

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This paper presents a theoretical evaluation of integrating 5G technology into existing aviation communication systems to determine whether 5G can meet future performance, reliability, and security requirements in both crewed and unmanned aviation communication systems. Key performance findings indicate that 5G can reduce end-to-end latency to less than 5-10 ms, lower outage rates from more 40% (LTE) to around 10% in dense UAV tests, and achieve per-aircraft throughputs up to 1 Gbps via network slicing, even if airspace becomes crowded. Security analysis shows that 5G's built-in features fulfill aviation security goals, although challenges remain around C-band interference with radar altimeters. Answering the three research questions, the study concludes that 5G offers clear advantages in performance (RQ1), aligns well with confidentiality, integrity, and availability requirements (RQ2), and can support next-generation UAV and UAM demands (RQ3). However, more trials are essential before large-scale implementation.

Additional Key Words and Phrases: 5G, Aviation Communication Systems, ACARS, CPDLC, ADS-B, Unmanned Aerial Vehicles (UAV), Urban Air Mobility (UAM), Ultra-Reliable Low-Latency Communication (URLLC), Enhanced Mobile Broadband (eMBB), Massive Machine-Type Communication (mMTC), Network Slicing, Edge Computing, Non-Terrestrial Networks (NTN), 5G-AKA Authentication, Aviation Security

1 INTRODUCTION

Aviation relies on several communication systems to ensure the safe and coordinated operation of flights. These include technologies such as the *Aircraft Communications Addressing and Reporting System* (ACARS), *Controller–Pilot Data Link Communications* (CPDLC), and *Automatic Dependent Surveillance–Broadcast* (ADS-B). These systems support a wide range of tasks, from aircraft tracking and flight planning to the exchange of weather data and controller instructions [9].

However, aviation's communication demands are changing rapidly. Although current data links work well for traditional crewed flights, they were never designed to handle the much larger volume of users and data expected in modern airspace. The rapid growth of *Unmanned Aerial Systems* (UAS), the rising data needs of increasingly connected aircraft, and new concepts such as *Urban Air Mobility* (UAM) all place additional pressure on existing infrastructure. These advancements require faster data transmission, more reliable connections, and stronger security measures, demands that current systems are not equipped to handle [12, 18].

Fortunately, at the same time, advancements in wireless technology are changing global communication standards, with 5G emerging as a powerful solution across many industries, including aviation. Designed to support *ultra-reliable low-latency communication* (URLLC), massive device connectivity, and high throughput, 5G addresses many of the limitations found in current aviation communication systems, such as low data rates and limited device connectivity [13, 16]. These constraints are expected to become even more critical as the deployment of UAS and UAM platforms increases. Unlike traditional aircraft, UAVs often operate in dense, low-altitude airspace, requiring real-time command-and-control communication and rapid data exchange. Current infrastructure is not equipped to handle the volume and speed of data transmission needed for large-scale UAV operations, highlighting the need for faster and more scalable communication technologies.

To overcome these limitations, 5G introduces near-instantaneous data transmission with latency as low as 1 millisecond, making it ideal for real-time applications like air-to-ground (A2G) data exchange, in-flight broadband, and UAS command and control [18]. These latency improvements will be analyzed later in this study to evaluate their potential impact on aviation communication reliability and safety. Additionally, 5G's capabilities are expected to significantly improve in-flight Wi-Fi, providing to passengers a faster connection. Initiatives like Gogo's 5G network aim to deliver high-speed, low-latency internet that supports streaming and real-time communication during flights[2].

International aviation authorities such as ICAO and IATA have identified several promising use cases for 5G in aviation networks[9]. These include secure air-to-ground (A2G) communication, enhanced *satellite backhaul*[1], and reliable command links for UAS. Preliminary studies suggest that 5G could address many of the limitations of current systems, but significant challenges remain. Key concerns include safety certification, *spectrum allocation* [2], and regulatory compliance, all of which must be addressed before large-scale implementation is possible. Overall, the goal is to assess how well 5G aligns with the evolving needs of the aviation sector [9].

2 RESEARCH GOAL AND RELEVANCE

2.1 Research Objective

The objective of this research is to examine whether 5G technology can be safely integrated into aviation communication systems, not only as a faster and more reliable alternative but also in terms of meeting and potentially improving aviation security goals. Specifically, this study will evaluate, from a theoretical standpoint, how well 5G aligns with (future) aviation's requirements for performance, reliability, and security compared to existing systems.

To complete this study and address the research goal, the following research questions will guide the analysis. Since there is currently no direct study that combines the performance and security evaluation of 5G integration into aviation communication systems, this research aims to fill that gap.

TScIT 43, July 4, 2025, Enschede, The Netherlands

[1]Enhanced satellite backhaul refers to the use of high-capacity satellite links to support data communication between aircraft and ground networks in regions where terrestrial infrastructure is limited.

[2]Spectrum allocation represents a major challenge, as 5G networks require dedicated frequency bands that do not interfere with critical aviation technologies like radar altimeters. Mismanagement of these frequencies could lead to safety risks, making regulatory approval and careful planning essential for integration.

This research will lead to the following main research question:

> *Does 5G technology offer advantages over existing aviation communication systems in terms of performance, reliability, and support for security goals?*

This question is further divided into three sub-questions:

- **RQ1:** To what extent can 5G improve the performance and reliability of aviation communication systems compared to current technologies?
- **RQ2:** How well does 5G align with the security goals of aviation communication, and what new risks or opportunities does it introduce?
- **RQ3:** Can 5G support the demands of next-generation aviation communication systems, particularly for UAVs?

2.2 Disclaimer

Since this is a theoretical study, and I am not in a position to conduct real-world testing or gather performance data directly, my research will rely entirely on existing literature and studies conducted by experts in the field.

2.3 Purpose and Relevance

The need for more advanced aviation communication systems is growing rapidly due to the increasing use of connected aircraft, the expected integration of unmanned aerial vehicles (UAVs), and emerging airspace concepts such as urban air mobility (UAM) [9, 12]. Existing systems were not designed to handle the volume, speed, and complexity of future air traffic scenarios. Meanwhile, 5G technology is being widely deployed across industries [16, 18]. Investigating whether 5G can address the limitations of current aviation communication networks is important not only for improving technical performance, but also for ensuring that communication security goals are met as airspace communication undergoes changes. This research could potentially contribute to ongoing efforts by regulators and industry bodies (e.g: ICAO, IATA, FAA) to improve aviation infrastructure [4, 9].

2.4 Methodology

To satisfy this research goal the study will first review current aviation communication systems to understand what challenges might occur over time due to increasingly dense airspace and higher data demands. Next, relevant 5G features such as low latency and high data throughput that are expected to offer benefits will be analyzed. Furthermore, this research will explore theoretical integration scenarios for 5G, including air-to-ground communication, UAV management, and even in-flight connectivity, to assess how effectively 5G meets or exceeds existing requirements. As the last and most important step, the compatibility of 5G with aviation security goals, along with any new security risks it may introduce, will be assessed to determine the overall feasibility and advantages of integrating 5G into aviation networks.

3 LITERATURE STUDY

3.1 Gathering Results

I began my literature search where in all of my searches I have limited the results to those published between 2020 and 2025 and reviewed each paper's abstract to determine its relevance before reading it. Although I read the abstracts of many more papers than those presented here, this section focuses solely on the search and selection process for the studies I included. For example, in the search terms where I include *5G* some of the results did not focus on aviation integration. Papers were included if they (a) explicitly discussed 5G in an aviation context, (b) reported quantitative performance or security data, and (c) were published 2020–2025. The engines that I used to perform the research was arXiv, Google scholar and IEEE Xplore. All searches performed between April 29 and June 10, 2025.

Since I had the knowledge before starting my thesis that 5G is considered a strong candidate for aviation communication systems, the first step for me was to explore general insights. I started searching with the keyword "5G in aviation". This result returned 8 records in arXiv, 3.360 in Google Scholar and IEEE Xplore 201. I wanted to understand why 5G has become a topic of interest, and from this initial search, I found *Ullah et al. (2025)* [18]. I chose *Ullah et al. (2025)* [18], because of its visionary framework on how 5G can integrate core aviation services; Communication, Navigation, and Surveillance complete with quantitative simulations of sub-5 ms latency and high reliability. Using the same search term, in Google I identified a regulatory and technical analysis by ICAO (2023) [9] which I selected because ICAO is the leading authority on aviation safety. Their report shows that 5G coverage is expected to reach 71% of the global population by 2027 and deliver average latencies below 60 ms which are key figures when planning for the rapid growth of UAV operations. Also, *ICAO (2023)* [9], highlighted the fact that legacy aviation communication systems will not be enough for future aviation needs.

Building on *Ullah et al. (2025)* [18] discussion of 5G connectivity via non-terrestrial networks(NTNs), and since I wanted to evalute 5G also in terms of in-flight connectivity, I conducted a search using the term "5g connectivity". This gave query gave me a result of 350 articles. From the title, I could not find any useful articles regarding aviation and changed the search query to "5g connectivity satellites". This led me to Parada et al. (2025) [16], which I selected because it shows a comprehensive study of hybrid terrestrial–LEO satellite network architectures and their results show that the proposed LEO satellite configurations enhance coverage and reduce latency, directly addressing the connectivity challenges I aimed to explore. Having identified that 5G is currently being studied for integration with UAV operations, I searched with "5G urban air mobility". In IEEE Xplore this query gave me 43 interesting results. However, from these results, I selected *Mazzenga et al. (2024)* [12] because it provides detailed system-level simulations of 5G network slicing in urban air mobility scenarios, quantifying per-aircraft throughput (up to 1 Gbps) and latency (<20 ms) under high-density conditions, data directly relevant to evaluating the capability of 5G to support UAM operations. From the same search query but from Google Scholar I also found *Geraci et al. (2022)* [6]. This paper was included in my research findings because it included the technical limitations of 5G standards in aviation, particularly in relation to handover reliability. Since I wanted to include studies that included experiments using (NTNs) and UAVs, I searched with the term "5G UAV NTN". This query gave me 75 number of results. I identified the author of *León et al.* [10] using that term, but in another article where they studied satellitte communications for rotatory aircraft. Because that was almost relevant, I browsed the authors' profile and found another paper which was more relevant to UAM. This paper was *León et al. (2024)* [10]. I selected this paper, because the study presented empirical data comparing 5G and LTE performance for

UAV operations in urban areas. Because I wanted to complete the relevance part of my research, I wanted to support my arguments by providing the reader with information about the growth of UAV. I used the search term "UAV growth". This result gave me a very large number of articles. However, I wanted to include articles from regulatory organizations, and hence after filtering the results, I found *FAA (2023)* [4]. I selected it because it is the official U.S. aviation regulator's report, offering authoritative data on commercial UAV growth projections (0.8 M to 2.4 M by 2028). In articles like *ICAO, FAA (2023), and León et. al* [4, 9, 10] I discovered that current communication systems will not be able to handle the load under future UAV operations. Since I wanted to get more insights into how current aviation systems work I searched with "acars explained". This result gave me 102 number of results, but I chose the *Pilot Institute (2025)"ACARS Explained"* [8], because it offers a clear, and most importantly simple overview of how ACARS operates in practice. Moreover, I chose *Ferrag et al .* [5] because this paper outline why aviation communication systems lack security needs for future aviation demands.

Furthermore, security was very major to consider when making changes to such systems. That was also my initial thought when I started this thesis, hence I also wanted to evaluate from a security perspective, the possible integration of 5G to communication systems. Given that legacy aviation communication systems lack strong security measures (for future needs) [5, 15], it was essential to investigate how 5G could address or enhance security, particularly as modern aviation moves toward denser airspaces with increased UAV operations. Therefore, with the search term "5g aviation security" I was able to find *Trend Micro (2022)*, *Mäurer et al. (2022)*, *Ferrag et al. (2017)*, and *Whitworth et al. (2023)* [5, 13, 15, 19]. I chose those for the following reasons: *Trend Micro (2022)* [13] was chosen for its industry-driven overview of practical 5G security challenges and mitigation solutions. *Mäurer et al. (2022)* [15] offers a detailed gap analysis of legacy aviation datalink protocols, clearly identifying missing encryption and authentication features that 5G must address. *Ferrag et al. (2017)* [5] reviewd 5G authentication and privacy features, showing how they can fix the security weaknesses of legacy aviation systems, and *Whitworth et al. (2023)* [19] demonstrates the application of AI and ML for detecting and mitigating DDoS and spoofing attacks, showcasing an advanced threat-detection model for 5G aviation networks. Table 1 shows a summary of the search quries, and the number of results along with selected sources.

Table 1. Search Queries, Databases, Results, and Selected Sources

Search Query	**Database**	**Results**	**Selected**
5G in aviation	arXiv	8	1
5G in aviation	IEEE Xplore	201	0
5G connectivity	Google Scholar	350	0
5G connectivity satellites	Google Scholar	350	1
5G urban air mobility	IEEE Xplore	43	1
5G UAV NTN	Google Scholar	75	1
UAV growth	Google Scholar	120	2
ACARS explained	Google Search	102	2
5G aviation security	Google Scholar	14,600	4

4 RELATED WORK

This section reviews the most important research and industry work related to 5G technology in aviation. It covers three main areas: (1) existing aviation communication systems, (2) 5G integration into aviation networks, and (3) security and safety challenges related to 5G use in aviation.

4.1 Existing Aviation Communication Systems

Aviation communication today depends on several long-established systems

These include the Aircraft Communications Addressing and Reporting System (ACARS), Controller–Pilot Data Link Communications (CPDLC), and Automatic Dependent Surveillance–Broadcast (ADS-B). Their features support flight tracking, sending weather data, and communication with the air traffic control (ATC) [9]. ACARS, for example, is widely used to transmit short messages between aircraft and ground stations, while CPDLC enables digital dialogue between pilots and air traffic controllers, helping to reduce radio congestion on busy routes. ADS-B plays an important role in surveillance by continuously broadcasting an aircraft's position and velocity to ground stations and nearby aircraft, allowing for more precise tracking in both controlled and remote airspaces. Each system was developed for specific operational needs and has proven reliable within its scope. However, as aviation demands evolve, these systems face limitations in areas such as scalability, speed, and adaptability. In the next session, I will explain how these protocols function in more detail to be able to illustrate how 5G may offer advantages in complementing or enhancing their capabilities.

4.2 5G Integration into Aviation

Researchers have proposed using 5G as a solution to the limits of current systems. Ullah et al. [18] describe how 5G could support not only faster and more reliable communication but also allow integration of aviation's Communication, Navigation, and Surveillance (CNS) services. Other papers like Mazzenga et al. [12] show that 5G can be used to manage emerging services like Urban Air Mobility (UAM), where many small aircraft or drones may share low-altitude airspace in cities.

Parada et al. [16] explain how 5G can work together with low Earth orbit (LEO) satellites to provide high-speed internet on airplanes, even over oceans or remote areas. Their system offers consistent and fast connections by handing off traffic between satellites, improving in-flight Wi-Fi. Studies by Mafakheri et al. [11] and Albagory [1] also explore different 5G network architectures, including using satellites or high-altitude platforms to provide 5G to aircraft in flight.

In UAV communication, Geraci et al. [6] and León et al. [10] present how 5G can support real-time control of drones by offering low latency and better signal coverage, even at low altitudes or in areas with poor traditional infrastructure. These works emphasize that 5G is not just faster, but it enables new use cases like drone corridors[3].

4.3 Security and Safety Considerations

Security is a major topic in 5G research for aviation. Trend Micro [13] and Mäurer et al. [15] highlights that many legacy aviation

[3]Drone corridors are designated flight paths set up to support the safe, structured operation of UAVs, particularly for logistics or urban transport. See: https://www.investmentmonitor.ai/sectors/logistics/what-is-a-drone-corridors/

communication systems, such as ADS-B and ACARS, transmit data in plain text and do not support authentication or encryption by default, making them vulnerable to eavesdropping and spoofing. With 5G, new protections such as network slicing, encrypted connections, and traffic isolation offers better security.

Still, new risks also appear. Whitworth et al. [19] focus on how 5G-based aviation networks can be targets for cyberattacks such as distributed denial-of-service (DDoS). The IATA and ICAO have issued guidelines asking for safer use of 5G near airports and recommend enhanced filtering of avionics equipment and regulation [9]. These show that integrating 5G is not only a technical challenge but also a regulatory one.

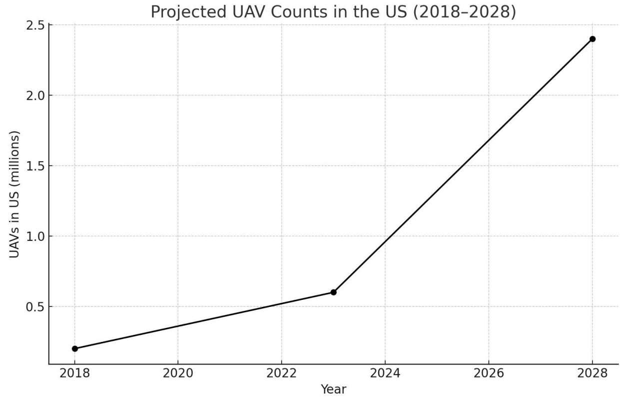

Fig. 1. Projected UAV Counts In The US (2018–2028)

4.4 Summary of Research Gap

Although many papers focus on individual parts of the 5G and aviation question like UAV communication, in-flight Wi-Fi, or 5G-related cyberattacks few studies combine these into a broad, theoretical look at both the performance and security of integrating 5G into aviation networks. This research aims to fill that gap by comparing 5G's advantages over current systems while considering both technical improvements and the risks or new requirements that might come with it.

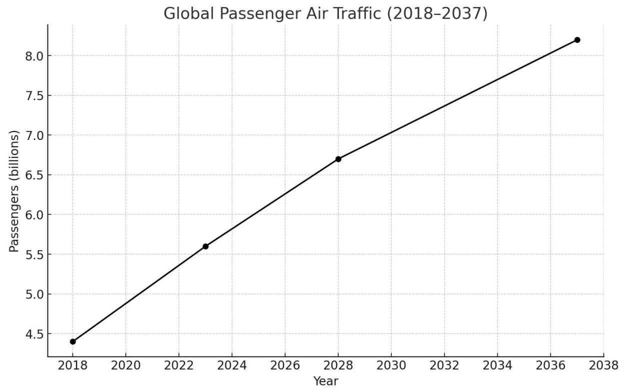

Fig. 2. Growth in Aviation Demand and Network Requirements

5 CURRENT STATE OF COMMUNICATION SYSTEMS

5.1 UAV Growth and the Future of Aviation Networks

Manned and unmanned aviation requires upgrades in their communication systems due to a significant rise in air traffic volumes, particularly involving unmanned aerial vehicles (UAVs). According to the Federal Aviation Administration (FAA), the commercial UAV fleet in the United States is expected to increase from approximately 800,000 units (number of individual commercial drones) in 2023 to about 2.4 million by 2028 [4]. This dramatic growth in UAV density underscores the need of network power and bandwidth, especially for densely populated airspaces. For example, recent studies highlight that dense UAV operations, such as urban drone networks, will demand data transmission capabilities that exceed 1 Gbps to reliably manage precise navigation and real-time communication[12, 18].

This need is not limited to the United States. In Europe, EASA is helping to test air taxis in cities through its U-space program[3]. In the Asia-Pacific region, China reported 1.27 million registered UAVs and over 23 million drone flight hours in 2023 alone, while South Korea aims to commercialize urban air taxis by 2025 [7, 14]. The UAE is planning advanced air corridors and using 5G-powered drones for surveillance and cargo transport [17]. This evidence clearly shows the need to upgrade aviation communication systems to keep pace with the growth of UAVs and the emergence of new types of air operations.

The projected UAV growth figures, global passenger-traffic forecasts, and network-capacity requirements are summarized in Figures 1, 2, and 3, respectively.

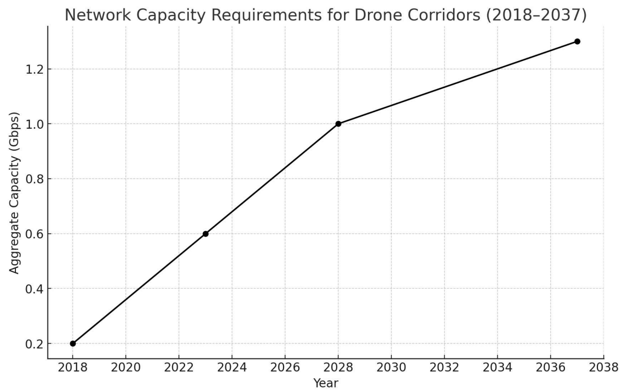

Fig. 3. Network Capacity Requirements For Drone Corridors (2018–2037)

Figure 1 shows the projected growth of unmanned aerial vehicles (UAVs) registered in the United States, rising from approximately 0.2 million in 2018 to 2.4 million by 2028. Figure 2 shows global passenger air-traffic increases from 4.4 billion in 2018 to 6.7 billion in 2028 and 8.2 billion by 2037. Finally, Figure 3 shows the network capacity requirements to support high-density drone corridors: aggregate throughput escalates from 0.2 Gbps in 2018 to 1.0 Gbps in 2028 and reaches 1.3 Gbps by 2037.

5.2 Legacy Aviation Communication Systems

5.2.1 ACARS. The Aircraft Communications Addressing and Reporting System (ACARS) is a digital datalink system introduced in the 1970s to automate short text-based messages between aircraft and ground stations. It is primarily used in manned aviation for transmitting air traffic control clearances, flight plans, weather updates, and maintenance data. Communication occurs over VHF, HF, or satellite links, depending on aircraft location and infrastructure availability.

While ACARS has proven reliable for routine operations, its technical limitations are significant in the context of modern aviation needs. The original system supports data rates of only around 2.4 kbps, with upgraded versions such as VHF Data Link Mode 2 (VDL Mode 2) reaching 31.5 kbps [8]. These speeds are sufficient for short, low-priority messages but are entirely inadequate for real-time applications such as UAV command-and-control or high-bandwidth data transmission.

Furthermore, ACARS lacks built-in encryption or authentication by default, making it vulnerable to spoofing and eavesdropping [15]. As unmanned aerial systems (UAS) and urban air mobility (UAM) platforms become more prevalent, the system's limited bandwidth, lack of scalability, and outdated security model highlight the need for more advanced communication networks[8]. Figure 4 illustrates how ACARS messages are transmitted between an aircraft and ground systems using a satellite link. The aircraft sends a message up to a geostationary satellite, approximately 36,000 km above Earth, which then relays it down to a ground station. From there, the message enters the ACARS network and is delivered to destinations such as airline operations, maintenance, or air traffic control. The same process works in reverse; when airline operations need to send a message to the aircraft, it travels through the ACARS network to the ground station, up to the satellite, and back down to the aircraft.

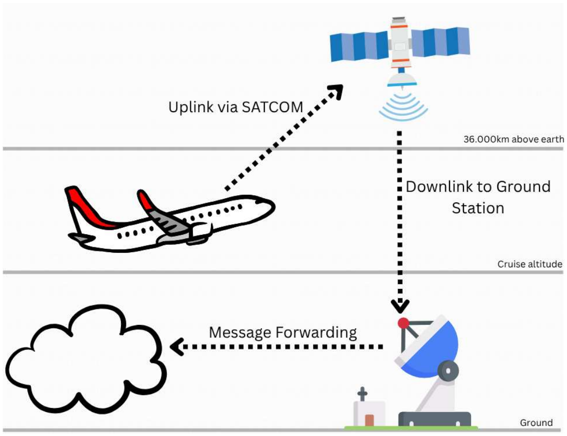

Fig. 4. ACARS Communication Flow using SATCOM

5.2.2 CPDLC. Controller-Pilot Data Link Communications(CPDLC) is a text-based messaging system used between air traffic controllers and pilots, primarily in areas where voice communication is limited or overloaded, such as oceanic or remote airspace. It allows the exchange of standard instructions like altitude changes or route adjustments using predefined message formats, reducing radio congestion and miscommunication.

While CPDLC improves communication for manned aviation, it is not suitable for unmanned aerial vehicles (UAVs) or urban air mobility (UAM) operations. First, CPDLC was designed with the assumption of a human pilot interacting with a controller, and it does not support autonomous or machine-to-machine communication. Second, the system lacks the scalability needed to handle thousands of simultaneous UAVs in dense airspace. Finally, CPDLC does not provide the low latency or high throughput required for real-time UAV control or telemetry[4]. For these reasons, it is unlikely to play a role in future UAV communication architectures, further emphasizing the need for more flexible, high-performance systems such as those based on 5G technologies.

5.2.3 ADS-B. Automatic Dependent Surveillance–Broadcast (ADS-B) is a surveillance technology that allows aircrafts to broadcast their position, velocity, and identification in real time. This data are derived from onboard GPS systems, and are transmitted periodically over a 1090 MHz frequency and can be received by both ground stations and other aircraft equipped with ADS-B IN. UAVs also use ADS-B for tracking and visibility[4].

Furthermore, ADS-B is a surveillance-only system, which means that it broadcasts the position of an aircraft but does not support two-way data exchange or command and control capabilities functions that are essential for real-time UAV operations. As such, ADS-B alone cannot meet the communication needs of future aviation environments, especially with the expected rise of UAVs and UAM platforms. It must be complemented or replaced by more scalable and secure technologies, such as 5G, which can support interactive communication. Figure 5 shows how ADS-B (Automatic Dependent Surveillance–Broadcast) works in aviation. Aircraft use GPS signals from satellites to determine their position, speed, and direction. They then broadcast this information automatically over a 1090 MHz frequency. These broadcasts, known as "squitters," are picked up by ground stations and nearby aircraft equipped with ADS-B In. Ground stations can also send signals to aircraft using 1030 MHz, to which the aircraft respond with additional data. The system helps air traffic control and other aircraft track positions in real time, improving safety and situational awareness without relying on radar.

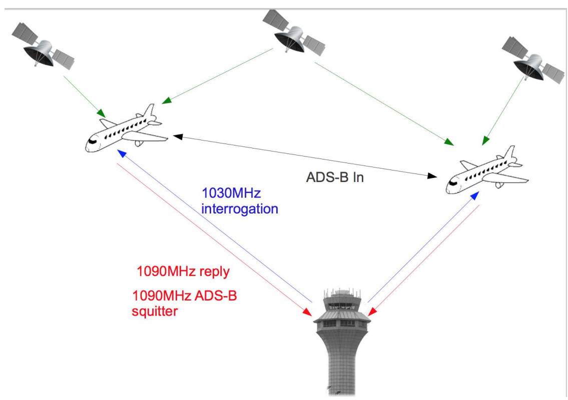

Fig. 5. Illustration of the ADS-B communication structure. Source: https://web.stanford.edu/class/ee179/labs/Lab7.html

[4]Telemetry is the process of automatically transmitting, collecting, and measuring data from remote sources

5.3 Performance and Security Analysis of 5G in Aviation

5.3.1 Key 5G Capabilities. 5G technology offers several features designed to support the communication needs of new applications, including those in aviation. Among these, *Ultra-Reliable Low-Latency Communication (URLLC)* is designed to ensure minimal delays and highly reliable data transfer, supporting critical tasks such as real-time aircraft (UAV) control or safety information exchanges, where even small delays can be unacceptable [6, 18]. Another essential feature is *Massive Machine-Type Communication (mMTC)*, which allows the simultaneous connection of a vast number of devices within a limited geographic area, ideal for managing dense UAV fleets [10, 12]. Additionally, *Enhanced Mobile Broadband (eMBB)* significantly increases available bandwidth, providing the high data rates needed for applications such as comprehensive telemetry data and passenger in-flight entertainment[16, 16].

Furthermore, 5G introduces *Network Slicing*, one of its most important features, that allows the creation of multiple virtual networks within a single physical infrastructure. Each "slice" can be optimized and dedicated to specific applications, thereby isolating critical aviation communication such as aircraft commands from non-critical data streams like passenger internet traffic. Thus, it is improving security, reliability, and overall network management [13, 18]. *Edge Computing* works together with network slicing to improve performance by processing data close to where it is created; on aircraft or at ground stations instead of sending it to faraway data centers thereby significantly reducing latency and most importantly enhancing real-time processing capabilities, which is vital for time-sensitive aviation applications such as UAV guidance [10, 12].

Last but not least, 5G supports *Non-Terrestrial Networks (NTN)*, integrating satellite and high-altitude platforms (HAPS) to provide reliable connectivity in remote or oceanic regions, where terrestrial networks are unavailable or inadequate.

5.3.2 5G Deployment Models in Aviation Context. The successful integration of 5G in aviation relies on deploying models that are appropriately aligned with varying operational needs. One primary deployment scenario involves using terrestrial-based 5G ground stations to support air-to-ground (A2G) communication. In this scenario, aircraft equipped with 5G-compatible antennas communicate directly with ground stations, eliminating the need for intermediate infrastructure. This allows for high-speed data transmission and low-latency communication, which is important within densely populated regions [12, 18]. This scenario can provide real-time communication for short and medium-range flights, particularly beneficial for UAM applications and UAV environments [10].

Another model involves combining terrestrial 5G networks with non-terrestrial platforms such as satellites and high-altitude platform stations (HAPS). Hybrid 5G-satellite solutions can provide robust coverage in remote areas, over oceans, and along transcontinental routes where terrestrial coverage is impractical or nonexistent [16]. Low Earth Orbit (LEO) satellites integrated with 5G technology offer improved bandwidth and reliability compared to traditional satellite services, thus enhancing passenger experience through reliable in-flight Wi-Fi and operational connectivity [10, 16].

Additionally, onboard 5G receivers and dedicated private networks at airports constitute another important deployment model. Airports are starting to deploy private (localized) 5G networks to support various ground and airport operations, including logistics, asset tracking, and ground-handling processes. [13, 15].

5.3.3 Security Mechanisms Built into 5G. 5G introduces several built-in security mechanisms that significantly improve confidentiality, integrity, and authentication compared to legacy aviation infrastructure. First and foremost, 5G employs *encryption and integrity protection* algorithms such as AES with 128-bit keys, SNOW 3G, and ZUC to secure both user plane and control plane data over the air interface. These algorithms are applied end-to-end after keys are established during the authentication procedure, ensuring that messages exchanged between aircraft and ground infrastructure cannot be intercepted or tampered [15, 18].

For *authentication*, 5G uses the 5G-AKA protocol (5G Authentication and Key Agreement) or EAP-AKA methods defined by 3GPP, providing mutual authentication between the user equipment (e.g., onboard modem) and the network. This verifies both ends before secure communication is allowed, preventing unauthorized devices from connecting and mitigating impersonation attacks [5, 18].

Moreover, building on the earlier introduction of network slicing, its role in enhancing security lies in the ability to dedicate specific slices to safety-critical traffic such as command-and-control links or ATC data with strict performance and security parameters, while other slices manage non-critical services like passenger internet. This separation ensures that issues or attacks on non-critical traffic do not affect critical functions, and each slice can have its own security settings[13, 18].

Additionally, 5G supports *advanced threat detection.* Using AI based monitoring at the network edge and within core network functions nodes can analyze traffic patterns and detect anomalies in real time such as unusual command sequences to UAVs or signs of distributed denial-of-service attacks—and trigger mitigation actions (e.g., isolating compromised elements or rerouting traffic) before they impact safety or reliability. [15, 19].

6 LITERATURE RESULTS

6.1 Summary of Findings on Performance

Across the body of work surveyed, 5G consistently demonstrates substantial gains over legacy aeronautical links in three key performance domains: latency, throughput, and reliability.

A study by Ullah et al. (2025)[18] conducted simulations focused on integrating 5G into Communication, Navigation, and Surveillance (CNS) applications, demonstrating ultra-reliable low-latency communication (URLLC) capabilities with simulated latency consistently below 5 ms [18]. León et al. (2024) [10] performed real-world field tests using UAVs in dense urban environments and reported that while LTE-based systems experienced outage rates as high as 41%, the introduction of 5G reduced these outages significantly to approximately 10%. An “outage rate” of 10% means that during the field tests, the UAVs lost their network connection roughly 10% of the time. In other words, for about one out of every ten minutes, the communication link dropped below a usable threshold. So telemetry, control messages, or data could not be exchanged.

What is more, Parada et al. (2025) [16] conducted a study of a hybrid connectivity model that combines terrestrial 5G base stations with Low Earth Orbit (LEO) satellite links to provide truly global airborne coverage. In their simulations, aircraft and UAVs seamlessly exchanged data sessions between ground-based 5G cells when flying over land and LEO satellites when flying over water or remote regions, maintaining continuous connectivity for more than 99% of flight time. This high availability is due to the complementary strengths of each segment: terrestrial 5G delivers very low latency (on the order of 10–20 ms) and high throughput (tens to hundreds of Mbps) in populated areas, while LEO satellites bridge coverage gaps with slightly higher latency (30–50 ms) [16]. On the other hand, Geraci et al. (2022) [6] investigated how standard 5G handover procedures perform when used by aircraft and drones moving at typical flight altitudes and speeds. In a cellular network, a handover is the process of transferring an ongoing connection from one base station's coverage area to another without interrupting service. Geraci and colleagues flew a UAV at various heights ranging from 10 until 150 meters while measuring the number of handovers per minute. They found that handovers increased from about one per minute at 10 meters to nearly five per minute at 150 meters [6]. Each handover introduces a brief interruption, and at higher altitudes the rapid succession of these events led to more frequent connection drops and reduced reliability. Their research revealed that 5G's existing mobility management optimized for slower ground vehicles should be adapted for fast-moving aerial platforms as well to ensure stable communications.

Mazzenga et al. [12] conducted a study of a simple 5G uplink shared among several drones. Each drone transmits a 272-bit position message every 100 ms. The 20 MHz uplink is divided into equally sized Physical Resource Blocks (PRBs), with each PRB statically assigned to a single drone, ensuring dedicated transmission resources and eliminating dynamic scheduling delays. Their system-level simulations show that this arrangement can reliably support very large fleets: as the density of distributed radio units increases, the 0.5-percentile spectral efficiency improves from approximately 2 bits/s/Hz to about 3.5 bits/s/Hz, corresponding to minimal message-error probabilities even under high device densities.

To conclude the synthesis, industry stakeholders, such as FAA and ICAO [4, 9], warn that 5G deployments can interfere with aircraft radar altimeters. 5G is increasingly deployed in the C-band (3.7 to 3.98 GHz) because this mid-range spectrum offers an optimal balance of coverage and capacity. It provides wider-area reach than higher frequencies and at the same time supports data rates ranging from hundreds of megabits to several gigabits per second. However, these C-band signals sit directly next to the 4.2–4.4 GHz frequencies used by radar altimeters, which measure the height of an aircraft above the ground, which is important during low-visibility approaches. When a high-power 5G transmitter operates nearby, its signals can interfere into the altimeter's band, causing false readings or nuisance alerts. After reviewing hundreds of incident reports and identifying over 100 cases of degraded altimeter performance, the FAA imposed reduced power limits and established buffer zones[5] around major airports to protect safety-critical systems [4]. ICAO has issued similar guidance, urging countries to coordinate spectrum use carefully and to upgrade or retest radar altimeters for immunity to out-of-band emissions before permitting 5G operations near runways [9].

[5]Buffer zones are areas around airports where 5G transmitters must reduce power to avoid interfering with aircraft radar altimeters.

6.2 Summary of Findings on Security

The literature shows that 5G brings strong security improvements to aviation communications but also creates new challenges. Built-in encryption (AES, SNOW 3G) and integrity protection secure both user and control data, addressing the lack of encryption in legacy systems like ADS-B and ACARS [13, 15]. Mutual authentication using 5G-AKA or EAP-AKA prevents unauthorized devices from joining the network [5]. Network slicing isolates safety-critical traffic from passenger to prevent interference [13, 18].

Last but not least, Advanced threat detection using AI at the network edge can spot attacks like DDoS or spoofing in real time and respond quickly, improving overall resilience [19]. However, relying on public 5G networks also creates new vulnerabilities, and regulators must ensure these networks do not interfere with critical avionics systems like radar altimeters [4, 9]. In other words, although 5G's built-in security is a big step forward, safely using it in aviation requires continuous monitoring, and close coordination across the industry.

6.2.1 Why Security Is Important for Future Aviation. Future aviation systems will rely on digital communication links for aircraft control, navigation, surveillance, and passenger services. As aviation moves toward greater connectivity, with unmanned aerial vehicles (UAVs), urban air mobility (UAM) platforms, and in-flight broadband, the number of networked devices and services will grow, allowing for potential attacks [13, 18]. Ensuring confidentiality prevents sensitive data such as control commands from being intercepted; integrity guarantees that (control) messages are not altered in transit, and availability ensures that communication links remain operational even under attempted denial-of-service attacks [5, 15].

Regulators and industry bodies (e.g., ICAO, FAA) have made clear that any integration of 5G or other advanced networks must meet security requirements before equipment and protocols can be certified for operational use [4, 9]. Without robust security measures aviation networks risk service disruptions, unauthorized access, and safety-critical failures. Therefore, security is not an optional add-on but a fundamental requirement for protecting passengers, crew, and aircraft in the increasingly connected skies.

6.3 Comparison with Legacy Systems

When compared to legacy aviation communication systems, such as ACARS and ADS-B, 5G demonstrates clear technical and security advantages. ACARS relies on multi-hop message forwarding (see Figure 2), while ADS-B continuously broadcasts position data without any return link (see Figure 3). While they handle current traffic levels they risk severe congestion when scaled to large UAV fleets, where each vehicle generates frequent updates and control messages. In the past, limited message volumes meant confidentiality and integrity were lesser concerns. Nowadays, however, the growing number of UAVs makes unencrypted broadcasts and unauthenticated links a serious risk. In contrast, 5G supports data rates from tens of megabits to gigabits per second, ultra-reliable low-latency communication (URLLC), and massive machine-type connectivity (mMTC), enabling both high-throughput passenger services and secure, real-time control of unmanned aerial systems [16, 18]. Its security is enforced by end-to-end encryption, strong mutual authentication (5G-AKA/EAP-AKA), and network slicing to separate UAV command channels from other traffic [13, 15]. Together, these features provide a much more robust foundation for the performance, reliability, and security demands of modern and future aviation networks.

6.4 Gaps and Open Questions

Despite the progress in exploring 5G for aviation, several gaps and uncertainties remain. First, most of the literature that I have found rely on simulations or small-scale studies rather than extensive real-world flight tests. Thus, leaving questions about how 5G behaves under diverse operational conditions such as extreme weather or very congested airspace unanswered [6, 10].

Secondly, there is still debate over which radio frequencies 5G can use near airports without disrupting aircraft systems. In particular, regulators and operators must settle rules for the C-band to prevent its signals from interfering with radar altimeters. Last but not least, while 5G's security capabilities look strong in theory, the industry has yet to perform aviation-specific security tests. A study performing a "red-team" [6] attack of live 5G links in real flight conditions is still missing.

Thirdly, the process for certifying 5G equipment in aircraft and on the ground is still unclear. Current aviation certification rules were not written with cellular networks in mind, so regulators, network operators, and equipment manufacturers must work together to create clear guidelines and standards for 5G deployment in aviation [4, 9].

6.5 Conclusion

In conclusion, this literature search showed that 5G can enhance aviation communications through ultra-low latency, high data rates, and built-in security mechanisms, features that the current systems lack. Simulation and field studies show clear performance gains for both manned and unmanned aircraft, and advanced security features analyzed, address future security needs. To translate these benefits into practice, aviation stakeholders must conduct comprehensive real-world trials. With these steps in place, 5G can become the foundation for safer, more reliable, and future-ready aviation networks.

6.5.1 Answer to RQ1. For RQ1, the answer is clearly yes: simulation and field studies show dramatic gains: end-to-end latency consistently below 5–10 ms (compared to hundreds of milliseconds in legacy links) and outage rates reduced from over 40% on LTE to around 10% on 5G in dense UAV tests [10, 18]. [16].

6.5.2 Answer to RQ2. For RQ2, the answer is yes aswell. 5G's native end-to-end encryption, mutual authentication (5G-AKA/EAP-AKA), and network slicing fulfill confidentiality, integrity, and availability requirements missing legacy systems. [4, 15, 19].

6.5.3 Answer to RQ3. For RQ3, the evidence is positive: mMTC and URLLC capabilities support dense UAV fleets with per-aircraft throughputs up to 1 Gbps and low packet loss, while dedicated network slices ensure reliable command-and-control links even under heavy load [6, 12]. Nonetheless, real-world trials and certification processes remain essential to validate these findings in operational environments.

7 ACKNOWLEDGEMENTS

I would like to thank my supervisors Dr. Jeroen van der Ham – de Vos and Dr. Pieter-Tjerk de Boer for their guidance and support in conducting this literature research. Their advice was essential to this work.

[6] Simulates a realistic, multi-stage attack against the entire network

APPENDIX A: ACRONYMS

Acronym	Meaning
5G	Fifth-generation mobile networks
3GPP	3rd Generation Partnership Project (standards body for 3G/4G/5G)
5G-AKA	5G Authentication and Key Agreement
AES	Advanced Encryption Standard
ADS-B	Automatic Dependent Surveillance–Broadcast
A2G	Air-to-Ground communications
ACARS	Aircraft Communications Addressing and Reporting System
AI	Artificial Intelligence
ATC	Air Traffic Control
CIA	Confidentiality, Integrity, and Availability
CPDLC	Controller–Pilot Data Link Communications
CNS	Communications, Navigation, and Surveillance
DDoS	Distributed Denial of Service
EASA	European Union Aviation Safety Agency
eMBB	Enhanced Mobile Broadband
FAA	Federal Aviation Administration
HF	High Frequency (3–30 MHz band)
HAPS	High-Altitude Platform Station
ICAO	International Civil Aviation Organization
IATA	International Air Transport Association
LTE	Long-Term Evolution (4G cellular technology)
mMTC	Massive Machine-Type Communications
ML	Machine Learning
NTN	Non-Terrestrial Network
NTRIP	Networked Transport of RTCM via Internet Protocol
URLLC	Ultra-Reliable Low-Latency Communication
UAM	Urban Air Mobility
UAV	Unmanned Aerial Vehicle
UAS	Unmanned Aerial System
VHF	Very High Frequency (30–300 MHz band)
ZUC	ZUC Stream Cipher (used in 3GPP confidentiality/integrity)

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