Wireless Technology Contribution for Aviation Safety

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Abstract Advanced wireless technologies are in more demand for the efficient and safe air travel. Increased air traffic congestion along with unpredicted weather conditions, poses lot of challenges for the safe air travels. Today's advanced wireless technologies could help us to achieve that required level of accuracy by providing better connectivity and communication among different airplanes and air-traffic control stations. In this paper, we have discussed various wireless technologies like 5G, Augmented Reality (AR), Aeronautical Mobile Airport Communication System (AeroMACS), Wireless Avionics Intra-Communications (WAIC), Internet of Things (IoT), System Wide Information Management (SWIM). After this study, we analyzed that each technology has its own capability and is able to transmit the data among different on board systems in the plane and air traffic control systems on the ground. These technologies are going to play a key role to improve the communication among ground controllers and other aircraft.

Keywords Wireless technologies · Aviation safety · 5G · IoT · Augmented reality · Aeronautical Mobile Airport Communication System · Wireless Avionics Intra-Communications

1 Introduction

For safe and effective airline operations, new wireless communication techniques and technologies are required. Wireless technologies are becoming increasingly signifi-

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cant in aviation. For safe flights, the National Aeronautics and Space Administration (NASA) is trying to improve hyper spectral communications, air traffic controlling and networking schemes. On-board aviation control and communications data are critical for aircraft monitoring and safety. The airplanes should be connected to ground airport tracking and monitoring systems, where several measurements of these aircraft subsystems should be sent for analysis during flight to reduce flight accidents or the likelihood of any on-board subsystem failures [3]. Wireless communication is being investigated for use in the aerospace sector to replace various cable connections since it offers a number of benefits, including low weight, resilience, system maintenance, ability to expand, modularity and lesser cost [6, 7, 22]. Wireless on-board communications systems are gaining traction in the aerospace industry, with the goal of improving flight safety, lowering aircraft costs, and reducing environmental impact. However, there are other concerns, including security, coexistence, navigation, surveillance, engine performance, air-to-ground communication and aircraft-to-aircraft communication as shown in Fig. 1. In complex missions and risky locations, this development in wireless technology is extremely valuable and mission-enhancing for army aircraft [14].

In aerospace, wireless applications range from in-flight entertainment (IFE), which requires a lot of multiuser, multimedia-grade bandwidth, to wireless sensing, command, control, and Prognostics Health Monitoring (PHM) systems, which demand a lot of reliability but not a lot of capacity. In addition, non interference with aircraft electronics, anti-jamming property, high level of security and a dedicated reserved frequency band are among critical requirements needed for emerging wireless applications in aerospace [23].

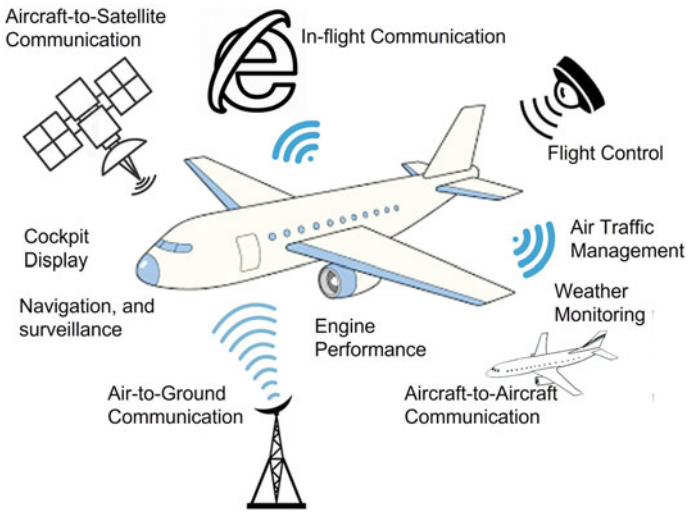

Fig. 1 Wireless technology in aviation

This research aims to provide an overview of associated wireless technologies which can be implemented for aircraft-safety essential applications.

Rest of the paper is organized as follows: Sect. 2 describes the wireless technologies suitable for aviation safety enhancement, Sect. 3 gives an overview of research challenges to be faced during implementation of these technologies and concluding remarks with future scope are given in Sect. 4.

2 Wireless Technologies for Aviation Safety

For its use, the wireless technological solutions should be cost-efficient and able to provide real time data transmission with more accuracy and security. There could be many challenges to the implementation of these solutions like design constraints, operational constraints and overall system cost. Those must be able to ensure safety of higher priority with the ability to detect the real time behavior of the aircraft of the aircraft and send the information to the control room ensuring minimum congestion in the wireless spectrum [16, 20].

2.1 5G

5G is an intangible but increasingly important technology in our life. The radio frequency spectrum underpins our dependency on wireless communications, and radio frequencies are critical for business, mobile phones, autonomous technologies, and aircraft. A prospective communication system based on 5G stratospheric platforms can provide efficient and increased communication performance, as well as be a cost-effective solution for constructing aviation communication networks [3, 9]. The Federal Aviation Administration (FAA) and NASA are carrying out some program like Integration Pilot Program to gain a better understanding of the safety argument for employing wireless networks for data exchange in low-altitude airspace [11]. COVID-19 is a watershed moment in aviation history, posing new challenges for airport stakeholders. Early adopters can use the rise of 4G private networks and 5G in aviation to limit pandemic risks and optimization hygiene practices at airports while lowering congestion and streamlining ground operations. 5G-enabled devices can help to promote preventative actions and best practices. Passenger tracking systems and flow management solutions (such as XOVIS), which are now used to measure queue times and handle capacity restrictions, can detect congested regions where social distancing has to be improved.

2.2 Wireless Augmented Reality (AR)

In the aviation industry, wireless augmented reality is seen as one of the necessary advances to ensure that processes are safe. In terms of safety, the aviation sector has come a long way. There is, however, still potential for development. The most critical areas that require improvement are pilot errors which accounts for 85% of all aircraft accidents [18]. These devices provide more advanced visualization, allowing the pilot to take the best decisions and ensure a safe and secure journey. By making use of AR, the pilots can have 360-degree view with virtual images to have clear visibility of the air traffic and other environmental changes. In terms of aircraft maintenance, AR offers real time information using 3D scanning and sensors. This proper maintenance of the aircrafts will result into setting the higher safety standards in aviation industry [2].

2.3 AeroMACS

AeroMACS, or Aeronautical Mobile Airport Communication System, is a wireless broadband system designed to assist airport communication. AeroMACS is a wireless technology that offers security, flexibility, scalability, and compatibility. It's utilized for ground-to-aircraft communications in Air Traffic Control (ATC) and Air Traffic Management (ATM) systems, as well as airline operations applications like Airline Operational Control (AOC) and other airport infrastructure applications. This technology is projected to improve safety and provide for the need for an effective broadband communication system to ensure secure and safe flight management, as well as give connectivity to A/C, operational support vehicles, and workers on the airport surface [5, 21].

2.4 Wireless Avionics Intra-Communications (WAIC)

For decades, wired technology has been used in the aerospace industry as a means of intra-unit communication. WAIC is a type of radio communication that allows two or more points on a single aircraft to communicate with each other. It uses low transmission power. WAIC has the potential to reduce aircraft wiring by 30% by using wireless devices to communicate data between aircraft systems that function for safety and regularity of flight over radio frequencies rather than wires. By eliminating electrical wire between aircraft systems, WAIC technology increases aircraft safety and efficiency. The implementation of WAIC system would result into reliable monitoring of the moving and rotating parts along with weight reduction and improving fuel efficiency due to reduction in complexity of the electrical wiring on the aircraft. The observation of behavior of moving parts includes keeping an eye

on brake conditions, tyre pressure, etc. The real time status of these functions is provided to the pilot for any required action in case of any failure. Other potential safety applications of the WAIC system include smoke detection, cabin pressure, emergency lighting, door sensors, engine sensors, humidity detection, flight control position feedback, etc. WAIC devices may be used to replace or supplement future applications that cannot be served by wires alone [10, 17].

2.5 IoT in Aviation Safety

This technology has changed the aviation industry in many ways. Specifically, this technology can provide support for regular monitoring of the aircrafts. This would result into more reliable and efficient operation of the aircraft with higher predictive and preventive maintenance. For a long time, the Internet of Things (IoT) has held immense potential, but the convergence of 5G, mature AI programmes, and the ubiquity of sensors embedded in lower-cost hardware is bringing this vision to reality. Today's aircraft are designed with large numbers of IoT sensors. These sensors can monitor pressure, temperature, vibration and other environmental measurements. After this, the whole computations can be streamlined to different supporting facilities on the ground for further analysis. This inspection would help in early detection of any deviation from the normal, unexpected variation and failure of any hardware. So, this predictive maintenance using IoT sensors can boost aviation safety standards. The Internet of Things (IoT) provides a network of data-producing devices and assets that communicate and boost airport efficiency. IoT could also be the connection that connects developing technologies in the aviation industry, allowing the digital era of aviation to completely thrive. Dysfunctional parts might be recognized in mid-flight and a signal sent to the ground, where a repair part could be quickly made and delivered to the repair station via an autonomous vehicle or drone [15, 19].

2.6 System Wide Information Management (SWIM)

In civil aviation, a new technology called System Wide Information Management (SWIM) allows for efficient and secure information sharing. This system is created to support NextGen Air Transportation System. This will revolutionize the data exchange to enable National Airspace System (NAS) innovations and operational excellence. SWIM was established by the FAA in 2007 to create an information-sharing platform and to offer a single access point for aviation data. It allows for the efficient integration of current air traffic monitoring systems, resulting in global services that are seamless. The concept's purpose is to create a platform for open data sharing among operators, airports, ANSPs, and meteorology services. The SWIM protocol provides a platform for any actor to design solutions based on a defined database of parameters that all subscribers can comprehend [13, 22].

3 Challenges with Wireless Technology for Aviation

Wireless technology has the ability to transform how our world connects and how quickly we interact online. The aerospace and defense sector is enthused about wireless potential to alter so many aspects of our life, but it must be implemented safely. Alarm bells have been sounding from reliable sources in recent years about how the deployment of wireless technology could significantly influence the safety of low-level aviation operations.

3.1 Radar Altimeters

This instrument is used to give an idea about height of the airplane above the ground to the pilot. The altimeter uses radio frequencies just above the 4 GHz band to measure the height of the aircraft and the ground. An altimeter is an essential instrument for takeoffs, landings, and low-altitude flying, as well as providing essential input to other systems like collision avoidance systems. There is a significant possibility that 5G communication systems operating in the 3.7–3.98 GHz range may interfere with radar altimeters on all types of aircraft planes and pilots were unaware of their distance from the ground due to a full altimeter malfunction [4].

3.2 Managing the RF Emissions of Consumer Electronics

When it comes to RF emission rules for consumer devices, the FCC currently does not consult with the FAA. This kind of collaboration would be ideal. If the predicted rise of wireless technology results in sufficiently serious interference concerns, then severe control measures may be required. The FCC, for example, might mandate wireless device manufacturers to incorporate override capability so that they can be switched off by a centrally broadcast control signal during key fight phases like takeoff and final approach.

3.3 Radio Interference

The term “radio interference” refers to a variety of situations in which transmissions from sources, other than authorized users of an RTF frequency, interfere with radio reception. Commercial radio stations on the ground frequently cause radio interference. Interference can make communication difficult, if not impossible, leading to communication breakdown. The workload on pilots and Air Traffic Control offices (ATCO) has also increased as a result of radio interference.

3.4 Security

Wireless networks are naturally vulnerable to security risks due to their broadcast nature. Data integrity and authentication are crucial parts of ensuring the aircraft's safety-critical functions. In the context of wireless-enabled avionics, security attacks were investigated using an adversarial model. Jamming attack, Man-in-the-Middle assault, and False alarm are the most common attacks for WAIC [16].

3.5 Reliability and Latency

To estimate and control the state of the aircraft, fight control systems rely on the network's high reliability and restricted latency. Noise generated by the avionics, multi-path from the walls, and interference from other aircraft, on the other hand, have a significant impact on the signal strength of avionics environments. The criteria for wireless aviation are more demanding than those for typical monitoring and open-loop control applications using industrial wireless networks in terms of reliability and timeliness [16].

3.6 Energy Efficiency

Another major challenge for wireless technology implementation is energy constraint. For flawless operation of any wireless technology, all the nodes must be able to operate for longer duration. However, the wireless nodes or devices are generally battery operated. Hence, there is a need to properly choose the energy resources to improve the overall efficiency of the system installed on the airplane. Furthermore, there will be a need to replace used batteries by the aircraft operators. This might be resulting in an increased overall cost of maintaining wireless nodes in comparison to nodes which are able to communicate by only using wireless mediums [8].

3.7 Natural Disturbing Factors

The aircraft might be operational in poor weather conditions and harsh environments. This could result in various temperature, humidity, air pressure conditions and solar activities. Wireless communications systems are generally highly vulnerable to natural disturbance factors in comparison to shielded wired communication systems. These natural disasters can be variations in atmospheric gases, various solar activities, lightning or thunderstorms and hydrometer activities. All these natural activities possibly deteriorate the transmitted signal quality [12].

4 Conclusion and Future Scopes

Safety is going to be the key factor behind the future success and growth of the aviation industry. In this paper, various existing wireless technologies for aviation safety have been discussed along with benefits and challenges. Advancements and developments in sensors and communication technologies are playing a big role in improving the overall implementation strategies of the aviation sector in the world. Now, it's time to develop more advanced wireless technologies to take the existing infrastructures to the next level by keeping in focus the safety of the passengers and staff. Lots of promising wireless technologies are available today but still further research is required to develop a specific wireless technology which can promise to be successful in terms of security, safety predictions, ability to deal with different environmental condition and communication range.

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