Analysis of Aeronautical Mobile Airport Communication System

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Abstract: Air traffic is doubling every 15 years. Aeronautical technologies are changing and developing every year and with it the global Air navigation systems needs to adapt to the increased air traffic, to the move of more than one hundred thousand commercial flights daily and this number is expected to increase in the future. Increased flights in early 2000s, caused the saturation in the Air Traffic Management communications capacity that uses the VHF data link provided by International Telecommunication Union in Europe and in the United States. The situation created a need for new research to find new communication systems to help release the pressure, and that can eventually replace the current aeronautical communication system. It led to the use of Aeronautical Airport Communication System. The aim of this paper is to analyse the Aeronautical Airport Communications System.

1 INTRODUCTION

Aeronautical Airport Communications System (AeroMACS) is the next generation aeronautical Communication system, and it is being deployed internationally to help airlines increase capacity, to cope with the people's demand for travels and flights (Kalapos et al., 2019). The purpose of this paper is to analyse AeroMACS, their coverage area, benefits, SWOT analysis, researching problems if they exist and to provide best practices for safety.

The main problem that the aeronautical communication system facing is the congestion of the VHF datalinks (Bartoli et al., 2013).

It seems that a new system of communication is needed now more than ever to lower the congestion in VHF datalink including all assigned by the 4 modes, Aeronautical VHF data links use the band 117.975–137 MHz that is used for the aircraft and airport communication systems, the congestion problem was more severe in Europe than in the United States (Hall et al., 2012). However, both made taken steps to lower/reduce the congestion by significantly reducing the channel spacing (50 to 25khz in the U.S. and from 25 to 8.33khz in Europe), this reduction allowed for more application and services to work simultaneously in the crowded VHF spectrum, some countries got ICAO approval independently on some Air/Ground data links, but non achieved global reach (Budinger & Hall, 2011).

In the ICAO's 11th Air Navigation Conference held in Montréal, Quebec, Canada in late 2003, about advanced work for the development of global future (ATM) related to communication systems, the committee made a report including several observations and recommendations related to the matter (Tang et al., 2021). It included the gradual introduction of new communication systems to help/complement and eventually replace the existing communication system, and the need for the existing aeronautical communication infrastructure, to take in new services and applications, as well as the globalization and harmonization of the A/G communication systems (Shin et al., 2021).

2 VHF DATALINK MODE 2 PROBLEMS

The VHF VDL-M2 is outdated and old and it has been congested especially in Europe, it has been criticized for its limited speed and usage of outdated data link

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methods especially the Open Systems Interconnection (OSI) based communication system with the presence of the Internet Protocol (IP) based network, as well as security issues which weren't considered when the datalink was designed to be used in the (ATC).

The security issues with this Datalink are significant, especially with the advanced cyber-attacks that can attack even more secured networks than the VDL-M2, attacks on power grids, financial institutions and even oil pipelines, ATC running on the outdated datalink makes it very vulnerable for cyber-attacks (Hruz et al., 2022).

VHF is not able to integrate advanced applications and services, (compared to the AeroMACS) due to the architecture/technology of it and the very low throughput. VHF has unstable latency as well and it has relatively higher packet loss.

3 FUTURE COMMUNICATION STUDY

Some recommendations included the search for new communication system put under criteria before they are approved and standardize for the future A/G communication systems (Budinger & Hall, 2011).

These recommendations helped establishing goals for both EUROCONTROL and FAA to establish a joint investigation and working closely to find the possibility of development and introduction of new aeronautical communication systems, and the Future Communications Study (FCS) was conducted, which led to the beginning of (2004) both NASA Glenn and its contractor ITT, and EUROCONTROL and its contractor QinetiQ conducting the study and working closely together in multiple phases (Budinger & Hall, 2011). First phase which studied the possibility to use some candidates, the seconds phase included detailed investigation of a smaller set of candidates, and the third phase led to harmonization of small list of candidates and common recommendations between the U.S. and Europe. The process is illustrated in Figure 1 (Naganawa et al., 2017).

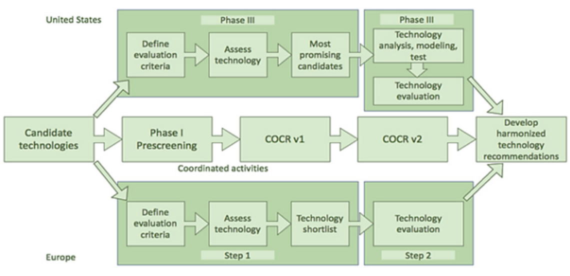

Figure 1: The technology assessment process.

The conducted FCS assessment considered technology candidates in three flight domains continental, oceanic and remote airspace, and airport (pre-departure and post-arrival on the surface) it is summarized in Figure 2.

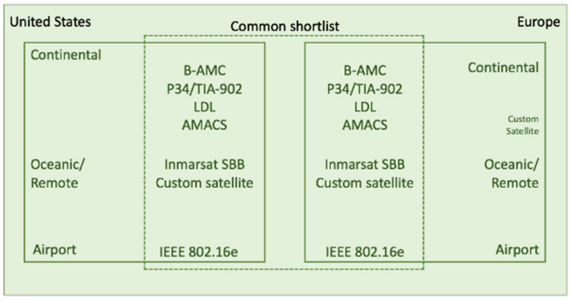

Figure 2: The common technology recommendations of the Future Communications Study.

The common starting point which was recommended to be used for aeronautical wireless communication in the airport was the IEEE 802.16e AeroMACS (Bartoli et al., 2013).

4 AeroMACS TECHNOLOGY

Aeronautical Mobile Airport Communication System is based on the Institute of Electrical and Electronics Engineers standard known as Wireless Worldwide Interoperability. Microwave Access or WiMax, is a wireless broadband technology, AeroMACS operates in the licensed aviation spectrum band from 5091 MHz to 5150 MHz (Naganawa et al., 2017).

AeroMACS is one of the three elements of the of the Future Communications Infrastructure which is a new Internet Protocol Suite system to provide the secure communication Base infrastructure for the Air traffic communication as it provides the network functionality necessary to connect air and ground via multiple IP datalink (Budinger & Hall, 2011).

EUROCONTROL supporting the research for the development of the European datalink system which includes/integrates the AeroMACS into the FCI as well as the Open systems interconnection. AeroMACS has been already certified by EUROCAE, RTCA, AEEC, and ICAO.

AeroMACS uses the 512 subcarriers in 5-MHz channel, it supports multiple access modulation, and multiple channel bandwidth from1.25- 20-MHz with peak data rate of 50Mbps (Materna & Galierikova, 2019).

Some of the IEEE 802.16e features that the NASA found which made it a good candidate are in Table 1.

Table 1: IEEE 802.16e features.

Feature	Advantage
Mobility	Supports vehicle speeds of up to 120 km/h, sufficient for aircraft Taxiing and emergency vehicles speed.
Range	Covers up to approximately 10 km in line-of-sight communications, which is enough for most airports.
Quality of Service (QoS)	Enables QoS based on throughput rate, packet error deletion, scheduling time delay and jitter up to 50Mbpd speed per wireless channel for both fixed and portable apps and under 1% packet loss.
Security	Includes user authentication, authorization, key-management protocol (strong encryption and digital certificates), protection of control messages and fast handover.
Open Sourced	supports modern Internet based network protocols and further developments.
Cost Efficiency	It is efficient when it comes to industry and reduced physical infrastructure compared to the ACARS VHF technology that uses buried copper/fiber cables.
Privacy	Supports private VLANs.
Link Obstruction Tolerance	Exploits multipath to enable non-line-of-site communications especially at the big airports.
Scalability	Includes flexible bandwidth and support channelization, and different configurations depending on the need.

4.1 Possible AeroMACS Application

AeroMACS uses a specific profile of WiMAX forums, the WiMAX forum is an industry-led non profitable consortium whose primary technical function and sole purpose is to develop the technical specifications underlying WiMAX Forum Certified products. It has developed several profiles that will be in future be developed on and used by device manufacturers (Budinger & Hall, 2011).

IEEE 802.16e can support a wide variety of voice, video and data communications among fixed and mobile users at the airport, AeroMACS services can be provided to aircraft anywhere on the airport surface, as long as wheels are in contact with the surface (Hruz et al., 2022).

The infrastructure suggested for the AeroMACS in the airport, is to have multiple Base stations (AeroMACS communication towers provided with antennas) around the airport to cover it. The summary of Some of the Possible uses that AeroMACS can provide:

1. The near real-time video that the AeroMACS provide can aid a lot in improving the surface traffic movement to reduce delays.
2. AeroMACS can provide temporary communication capabilities during outages and during construction.
3. AeroMACS can reduce the cost of connectivity as stated in the last table (scalability) compared to the ACARS (underground buried cable)
4. AeroMACS can enhance the collaborative decision making.
5. AeroMACS can ease updating of large databases of loading of flights plans.
6. AeroMACS can enable aircraft access to system wide information management for delivery of "time-critical" information to the cockpit (Budinger & Hall, 2011).

FAA with ICAO with the help of the FCS categorized the Possible applications into three major categories (Budinger & Hall, 2011).

1. ATC/ATM and infrastructure,
2. Airline operations,
3. Airport and / or port authority operations.

Since AeroMACS is flexible and can provide communication of moving vehicles of up to 120km per hour made it perfect to be used for the mobile applications in the airport (Bartoli et al., 2013). And even with aircrafts in the taxi and runways, so it can provide connection for both fixed and mobile hence why the applications and services within the three major categories mentioned above can be described as either fixed or mobile application, these applications are summarized in Figure 3 and examples given By NASA Glenn in Table 2.

Table 2: Applications of AeroMACS.

Air Traffic Services	
-Selected air traffic control and air traffic management	Mobile
-Surface communications, navigation, surveillance, weather sensors	Fixed
Airline Services	
Aeronautical operational control (AOC)	Mobile
Advisory information -Aeronautical information services (AIS) -Meteorological (MET) data services -System wide information management (SWIM)	Mobile
-Airline administrative communications (AAC)	Mobile
Airport Operator	
-Security video	Fixed
-Routine and emergency operations	Mobile
-Aircraft de-icing and snow removal	Mobile

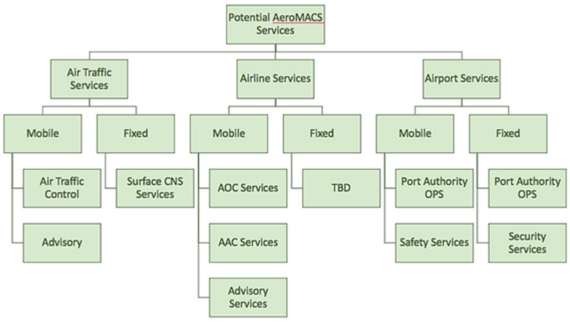

Figure 3: Applications of AeroMACS.

4.1.1 Possible Air Traffic Services Applications

Many applications and services are under consideration in the AeroMACS for the ATC and ATM, examples are:

- Communications addressing and reporting system (e.g., Pre-Departure Clearance PDC).
- Selected Controller Pilot Data Link Communications (e.g., four-dimensional trajectory negotiations 4D-TRAD).
- Selected COCR Services (e.g., Surface Information Guidance D-SIG).
- Other Safety-Critical Applications (e.g., Activate Runway Lighting Systems from the Cockpit DLIGHTING).

Possible fixed applications in the U.S.:

- Communications (e.g., controller-to-pilot voice via Remote Transmit Receiver).
- Navigation Aids (e.g., instrument landing system data).
- Surveillance (e.g., airport surface movement detection and Airport Surveillance Radar).
- Convey Electronic equipment performance data for remote maintenance and monitoring.

4.1.2 Airline Services

Mobile AIS/MET services these include:

- AIS baseline synchronization service (e.g., uploading flight plans to the FMS and updating terrain).
- Airport/Runway configuration information.
- Data delivery to the cockpit (e.g., Data link Aeronautical Update Services.
- Convective weather information (e.g., graphical turbulence guidance data and maps).
- Navigational databases and aerodrome charts to Electronic Flight Bag.

Airline services provide big amount of data and services transmitted with a possibility to be integrated into AeroMACS:

- Aircraft and company operations (e.g., Weight and balance information required for takeoff).
- Sharing of maintenance information (e.g., offload of flight operational quality assurance data).
- Ground operations and services (e.g., coordination of refueling and deicing operations).

4.1.3 Airport Operator Services

Airport operator provides the last category in the Possible applications that can be integrated into AeroMACS these includes:

- Video applications for safety applications (e.g., cameras inside the vehicles, surveillance cameras, mobile cameras for live video and voice stream, which can be useful during de-icing, and emergency operations like rescue and fire situations).
- It helps with airport runway and taxiway inspection, time critical operations, monitoring of the taxiway and the runway and their maintenance.

Most of these applications are used right now with a mix of land radio services, data and voice links on the VHF datalinks modes, and even commercial local area networks, these services are very important and critical. U.S. is studying the possibility of adding detection devices like radars to the IEEE 802.16e infrastructure in the airports.

These applications and services can be provided by governmental and commercially licensed, some of them can be provided by the airlines service provisions.

4.2 Data Rate and Channel Modelling

Data Rate Needed for Mobile Applications/ Services:
The needed date transmission rate needed to run mobile applications in airport network and location equipment was estimated to be 20 Mbps and this include the, and onboard electronic flight bags, Radio frequency identification, and Voice-over-Internet-Protocol between the airlines and airport personnel. The AOC account for approximately more than half of the 20 Mbps.
Data Rate needed for Fixed Applications/Services:
It was estimated to be over ~51 Mbps and they include applications like sensor communications,

surveillance camera, weather data products, data from radars and ASDE-X sensors, and AOC to RTR voice over (Budinger & Hall, 2011).

Channel Modelling:

It was Planned that the channel is 5091-5150 MHz provided by ITU, and that it can be divided to 5-MHz Channels, so it can fit up to 11 channels in this band range, and in the future, this plan can be extended, for the band range would include new 5-MHz Channels between 5000-5030 MHz for possible national allocations.

Table 3: Band channelling.

Lower AeroMACS Band (5000-5030 MHz)	
Channel Number	Channel Frequency
1	5005 MHz
2	5010 MHz
3	5015 MHz
4	5020 MHz
5	5025 MHz
Upper AeroMACS Core-Band (5091-5150 MHz)	
Channel Number	Channel Frequency
6	5095 MHz
7	5100 MHz
8	5105 MHz
9	5110 MHz
10	5115 MHz
11	5120 MHz
12	5125 MHz
13	5130 MHz
14	5135 MHz
15	5140 MHz
16	5145 MHz

4.3 Network Configuration and Coverage

To provide airports with AeroMACS, base stations have to be installed in the airport sometimes even two to cover the whole airport, and it is an infrastructure proposed for the WiMAX (Kanada et al., 2013).

2 base stations to provide the scalability, coverage range and protection, this infrastructure allows the ATC and Management to be physically far/isolated from the airport authority and airlines (Kanada et al., 2013). The architecture is the common Internet Protocol I.P, depends on the IP addresses to provide connection between users and base station to the services, so it works with the Dynamic Host Configuration Protocol to provide private IP address for each subscriber station.

The AeroMACS wireless network architecture suggested for the connection in the airport consists mainly of mobile and stationary Subscriber sides Base stations, and the connectivity services network (Naganawa et al., 2017).

4.4 Network Security

AeroMACS provides great security, as the Public Key Infrastructure provides the certificate system needed for aircrafts, and between all devices, ground-to-air, air-to-ground, ground-to-ground-authentication, it provides the instrument for safe connections, access control, and key management protocol (Materna, 2019).

- It lessens hacking threats, like cyberattacks and cyberterrorism.
- Provides secure connectivity with encryption and certificates.
- Collects data securely from mobile and fixed devices.
- Maintains connection with aircraft and staff.

4.5 Network Speed

Now that we talked about AeroMACS, it is also worth to note that the Very high frequency data link, VDL-M2, is considered slow, old and outdated compared to the AeroMACS, even when it comes to the budget for installing it, wireless connection is much cost efficient compared to the buried copper cables and fiber optics.

AeroMACS has the capacity, bandwidth, speed, security, scalability, and performance compared to the Wi-Fi, VDL-M2 and even Swift BB (Skultety et al., 2018).

In a study performed by ICAO, demonstrated that even at aircraft moving at 200 km/h with 3000m direct distance, the maximum thorough put of the system was able to obtain up to 6.5 Mbps, a throughput of 3-4 Mbps is enough to use real time video applications which can be achieved with 8000m direct distance with 200 km/h speed moving aircraft (Koman et al., 2018).

In summary it is able to achieve 6000-7000 kbps in best conditions, which can provide excellent data communication, compared to the VDL-M2, 31.5 Kbps, Swift BB 432 Kbps, and Wi-Fi Gatelink 2000 Kbps.

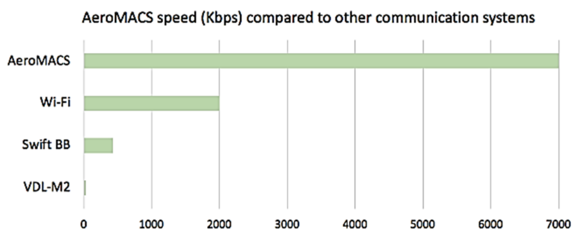

Figure 4: AeroMACS speed compared to other communication systems.

4.6 AeroMACS DEployment

AeroMACS is already deployed in Lisbon Airport in Portugal, some Airports in Japan, USA, Argentina, and China.

FAA in the USA in contract to deploy Airport Surface Surveillance Capability at 9 airports, 3 support systems.

In China the WiMAX frequency is centrally controlled and regulated at the Chinese central State by Radio Regulatory Commission and the Civil Aviation Administration of China, as the aviation data communication corporation in China authorized AeroMACS in 2017, to setup and operate it in 110 airports. AeroMACS is already setup in more than 41 airports in China as of 2019 so by now it already exceeded at least +55 airports (Rostas & Skultety, 2017).

4.7 SWOT Analysis

The AeroMACS SWOT analysis can be summarized down below:

Strengths:

1. LoS and NLoS connections
2. Scalability and security
3. Fast wireless connection up to 7000Kbps for optimum use in the airport.
4. Industrial efficiency compared to the existing VDL-M2
5. Quality of Service
6. Range and Mobility

Weaknesses:

1. The range can be a weakness compared to the VHF but it offers much more benefits than the VHF so it can be ignored, and with today and possibly future technology developments which can improve it, wireless after all is best option better than the buried cable.

Opportunities:

1. FAA and EUROCONTROL identified more than 330 applications to be used in the air traffic.
2. Possibility to be used in Unmanned aircraft vehicles in the future.
3. Release the congestion on the existing VHF datalink, especially in Europe.
4. Europe and USA are studying opportunities to use the AeroMACS in further application, services and the possibility of integration with other communication technologies.
5. In the future Artificial Intelligence (AI) applications and services like AI analytics and prediction systems can be added/integrated into AeroMACS, because of the relatively low latency, high throughput and QoS.

Threats:

1. The 5-GHz is attractive, and many competitors will seek to acquire the 5091-5150 MHz band, so some regulation will be needed in all countries. As the C-band started to be congested due to the use of (Wi-Fi).
2. Hence the AeroMACS will be used in Airports, it is going to be an open line of sight, with open surface, some degradation, dB noise and fading can happen because of the reflection of the AeroMACS wireless waves off the ground surface and moving vehicles.

4.8 Possibility to use in UAV

Studies and analysis show that AeroMACS can also be taken advantage of to be used in Unmanned Aircraft Vehicles in the future, as AeroMACS has been recognized as an important technology, and it can open new horizons in Controlling these vehicles with its fast speed.

5 CONCLUSION

The VHF datalinks security is bad even with attempts to improve the security it is still not a great system in today’s technology and it is vulnerable to cyberattacks, as well as the congestion of the VHF datalinks, Europe and the U.S. worked closely on studies, to research and develop new systems to be used in the aeronautical communication systems, to help and improve the existing systems, the implementation of new systems which can eventually replace the systems that rely on the VHF frequencies. One of these systems suggested was WiMAX forums (IEEE 802.16).

AeroMACS (IEEE 802.16e) WiMAX is going to be an important part of the FAA and ICAO vision for the future of communication in aviation, which will be fully implemented by 2025, it offers high throughput, low latency, QoS, IP protocol-based architecture, security and protection. And can be used with fixed and mobile applications and services in the airport ATC/ATM, airline services, and Airport

Operator/Port Authority Services, it offers AI integration for analytics and prediction systems. And it is a candidate for many future research and studies to be implemented in other areas like Unmanned aerial Vehicles.

AeroMACS has been implemented in many airports and it is showing a great promise and potential.

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