Research on AeroMACS Technology Development and System Field Test

Tian TAN[*], Ao LIU and Yi ZHANG

The Second Research Institute of CAAC, No.1 Shenglong St. Chengdu, China

Abstract. Under the background of the current ever-increasing air traffic flow, the legacy airport ground communication system is unable to meet the needs of the business and service; it is difficult to ensure the safety and efficiency of the operation of large busy airport. As a broadband wireless communication system that specialized in airport surface communication, AeroMACS is regarded as the most reliable and efficient solution for the future. This paper introduces the AeroMACS development and the structure of the system. The potential services that are able to be supported and international standardization process are summarized. At last, two field testing are introduced, providing a reference for test and practical application of the system at airports in the future.

Introduction

At present, ground-to-ground communication on the airport surface is based on very high frequency (VHF) and the frequency band is 117.975MHz to 137MHz. However, the crowded spectrum and the frequency band designed for analog voice communication makes the existing system unable to meet the growing needs of airport business and service. The continuous growth of air traffic flow has put forward higher requirements for the management of ground equipment, the transmission and acquisition of various information including weather information, and the safe operation of the airport and aircraft. In recent years, broadband wireless communication is regarded as a kind of communication mode that can satisfy and guarantee the safety and standardization of the flight service in the future. Therefore, the International Telecommunication Union (ITU) and the International Civil Aviation Organization (ICAO) proposed the Mobile Airport Communications System Aeronautical, also known as AeroMACS [1].

AeroMACS is a broadband wireless communication system dedicated to airport surface deployment and application, which works on 5G frequency band. It will significantly improve efficiency of airport operations if the ground-to-ground communication on airport surface is carried by AeroMACS. The cost of system installation and maintenance of AeroMACS is lower that of traditional wire communication systems. In addition, the flexibility of wireless communications will make the applications of new technologies related to airport and aircraft become simpler.

AeroMACS Outline

At the 2007 World Radiocommunication Conference, ITU specifically allocated 5150MHz to 5091MHz (C band) to airport surface wireless communication worldwide. In the final report of the study in future communication (FCS) that jointly promoted by EUROCONTROL and FAA, a system based on IEEE 802.16-2009, usually known as WiMAX standard, and works on the C band is recommended as the solution for high data rate wireless communication at short range on the airport surface, and that is AeroMACS.

AeroMACS can support a variety of data, video and voice transmission and information exchange between mobile users on the airport surface. The system will focus on supporting services that related to flight safety and operation specification, by enhancing the security, availability and diversity of the system, for example, the development and operation of CNS infrastructure and ATM and ATC services will all be improved. AeroMACS supports quasi real-time transmission of image and video

that will significantly improve the situational awareness and traffic flow processing capability of the airport surface, while reducing the congestion and delays and preventing runway incursion. Other applications of AeroMACS include: provide short-term emergency communication during constructions or cable power supply interruption, strengthen collaborative decision making ability, provide the latest weather image and navigation information and time critical consultation information for the cockpit, etc. Applications from three aspects of ATC&ATM, airline and airport are summarized in Table 1.

Table 1. AeroMACS applications.

ATC&ATM	Airline	Airport
• Surface Guidance • Clearance • CNS Data Transmission • Weather Sensor Data Transmission	• AOC • Consultancy information • MET • AAC	• Security Video • Routine and emergency command • Aircraft De-icing and Runway Snow Removal

The standardization of AeroMACS is in progress. RTCA SC-233 working group and EUROCAE WG-82 have completed the Minimum Operational Performance Standards (MOPS), and EUROCAE also completed the Minimum Aviation System Performance Standards (MASPS). On the basis of the above work, the ACP WG-S ICAO working group is working on AeroMACS technical manual and Standards and Recommended Practices (SARPS), the latter's draft has been written into annex 10. At present, the development and promotion of the AeroMACS standards are in progress with the goal of global interoperability and compatibility of AeroMACS.

AeroMACS System

MASPS defines the system performance requirements of AeroMACS, and describes the possible implementation approach including the network reference model based on WiMAX [2]. The network reference model of AeroMACS represents the logical structure of AeroMACS network. As can be seen from Figure 1, the model contains three major functional entities: SS, ASN and CSN.
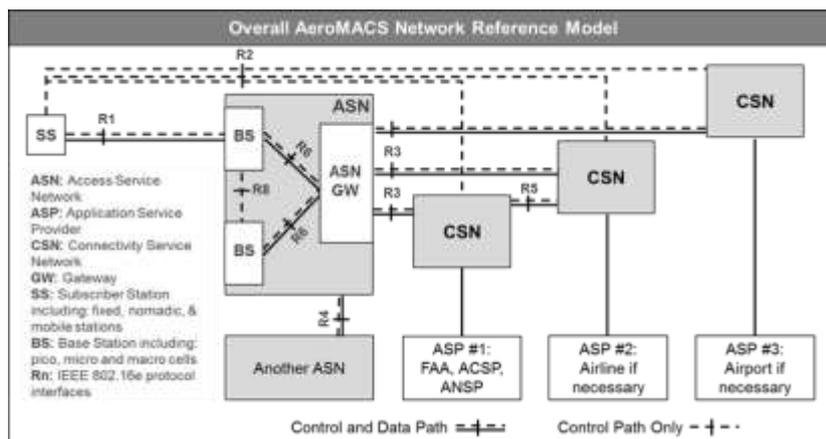
Figure 1. AeroMACS reference network model.

Here, SS provides wireless connection between the user equipment and the base station, the SS with mobility is also called a mobile station (MS); ASN is comprised of the base station, ASN-GW and other network element, providing user equipment with wireless access to AeroMACS; CSN is a set of network functions, such as AAA and core router, providing IP connectivity service for AeroMACS.

IEEE 802.16e based protocol interface (Rn) design ensures the interoperability among different function entities. Every entity (such as ASN, SS and CSN) is a set of many other function entities,

which can be implemented on the same physical function entity, or distributed on different physical function entities.
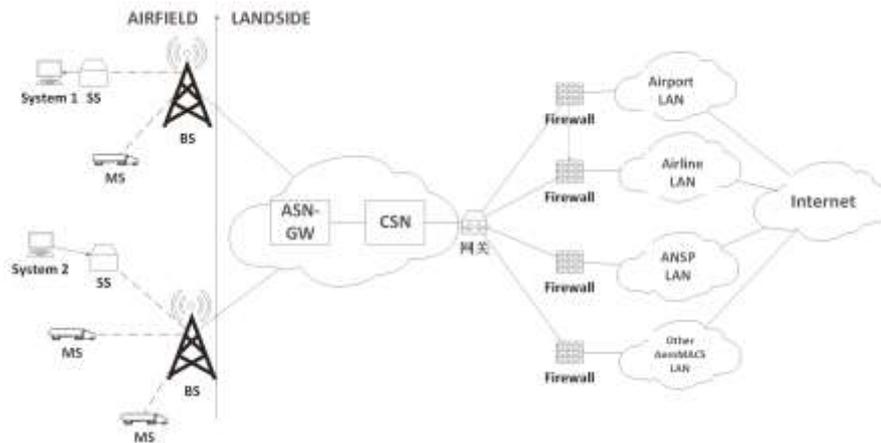
Figure 2. AeroMACS physical network architecture.

Each component of the AeroMACS network must be logically and physically separated from each other by firewalls, as shown in Figure 2. So the operation of the airport local network will not be affected if anything goes wrong within AeroMACS network.

Field Tests

With the support of NASA and FAA, ITT built the world's first AeroMACS prototype network at Cleveland Airport, America in 2009, followed by a series of test activities in 2010, including fixed site transmission test, mobile communication test, channelization test and transmission power test. The corresponding outcomes of these tests in the airport environment provide support for AeroMACS MOPS development activities [3]. In the next few years, many European countries, Japan and China have carried out performance and application tests related to AeroMACS. Up to now, dozens of airports around the world have conducted relevant system test, providing extensive support for the actual operation of the future application of AeroMACS.

Based on the investigations and studies of China airports' actual needs of business and service applications of AeroMACS, while referring to AeroMACS related international standard that either has been made or in the development, two low-power and short-time tests have been conducted on a small scale, corresponding to the emulated application scenario of fixed and mobile terminal, respectively. Test contents and results are introduced in the following sub sections.

System Installation

As a precondition, in order to avoid the mutual interference between equipment and the environment, the Xinjin base of the Second Research Institute of China Civil Aviation Administration (CASRI) is selected as the field test site. AeroMACS base station location is on the roof of Xinjin base building (hereinafter referred to as the "main building"), the location of the main building (red circle marked) and surrounding environment is shown in Figure 3.

Figure 3. Satellite map of Xinjin base of CASRI.

The main building is about 50 meters high, parallel to Xincai 28 Road with a distance of 60 meters in the middle. Xincai 28 Road runs from West to East, with an orientation angle of 80 degrees South East and a total length of about 2 kilometers. The far East and West sides of Xincai 28 Road are about 1.2 kilometers and 800 meters from the main building, respectively.

The base station adopts a compact design which is an outdoor WiMAX Base Transceiver Station. The BTS is comprised of BS, antenna, power module, ASN-GW and GPS receiver, etc. The supporting antenna of the BTS is an outdoor RF antenna with 120-degree-sector, the vertical sector range is ±8 degrees, the frequency range is from 4900MHz to 5200MHz, and the antenna gain is 15dBi.

Mobile and fixed Customer Premise Equipment (CPE) contains the modem, radio, data processing and user management components, and connect to other user equipment through the 10/100 BaseT Ethernet port. Fixed CPE contains a built-in high-gain flat antenna, and mobile CPE is equipped with an outdoor omnidirectional antenna with a frequency range from 4900MHz to 5200MHz, and the antenna gain is 12dBi.

Single-Sector Communication Capacity Test with Multiple Fixed CPEs

AeroMACS can be used to support not only the wireless mobile communications, but also the wireless communications of fixed CPEs. In order to simulate the operation of fixed CPEs supported by AeroMACS, the following test has been conducted.

Table 2. Weather condition and system parameters.

Weather	Fine
BTS Mode	Single Sector Single Antenna
BTS Frequency	Center Frequency 5.11GHz
Bandwidth	5MHz
TDD split	UL: DL=65:35
Antenna down-tilt	0°
Fixed CPE Location	1200 meters east to the BTS, antenna height 2 meters
CPE transmit modulation	Fixed to 64QAM 5/6

The relative position between CPEs and BTS is shown in Figure 4, and there is no building block between them, which is a Line of Sight (LOS) test environment. Connect and configure the system according to the system block diagram in Figure 5 and the parameters in Table 2. After the radio link communication is confirmed normal, measure the UDP uplink communication capacity of each CPE at the same time through IxChariot installed on each PC.

Figure 4. Position relation between BTS and CPEs.
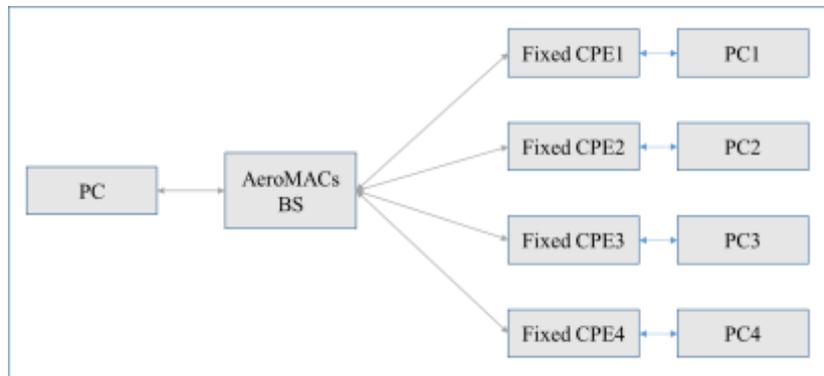
Figure 5. System block diagram of AeroMACS fixed CPSs test.

The testing process was recorded during the whole test length of 5 minutes by PC1, 2, 3 and 4, respectively. The test results are as follows.

Figure 6. Fixed CPE1 throughput rate.

Figure 7. Fixed CPE2 throughput rate.
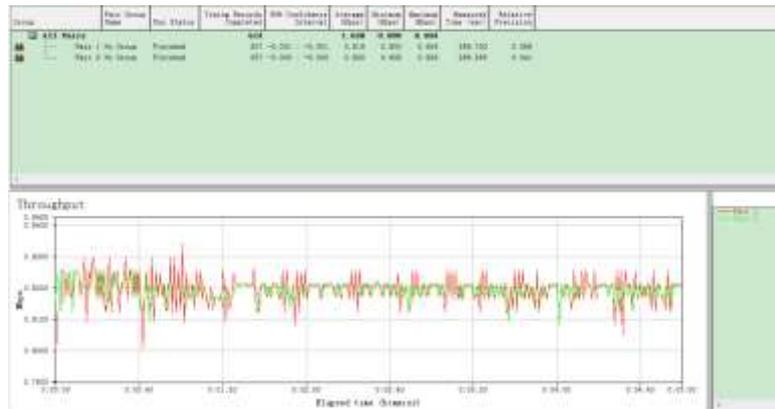
Figure 8. Fixed CPE3 throughput rate.

Figure 9. Fixed CPE4 throughput rate.

The UDP uplink communication capacities of the four CPEs are 1.638Mbps, 1.638Mbps, 1.637Mbps and 1.617Mbps, respectively. The numerical difference is small, the communication status of CPE1 and CPE2 are very stable, while the throughput rates of CPE3 and CPE4 have fluctuated slightly due to the individual differences. However, the overall performance can be considered relatively stable.

Vehicle Location Information Upload Test

In order to verify the supporting capacity of mobile communication service of AeroMACS on the airport surface, this paper focus on simulating and testing one of the key services on airport surface, which is called vehicle location information uploading and displaying on the tower, or just vehicle surveillance.

The equipment used for testing includes ADS-B integrated information processing module, display console and other BTS terminal equipment. ADS-B integrated information processing module is

located on the CPE side, obtaining location information through GPS and uploading to BTS via the wireless link. On the BTS side, real-time surveillance of the CPE geographic position and movement information is implemented by the display console.

The ADS-B integrated information processing module used for testing belongs to the research achievements of the multi-mode communication, navigation and surveillance technology developed by CASRI. Application of this module in the test on the one hand can simplify the testing process while giving a better test output, on the other hand can make the test results more reliable by introducing the practical application of airborne equipment.

In addition to the use of two antennas of the BTS, other configurations remain the same with those in Table 2. Xincai 28 Road, which is the testing path, runs from West to East, with an orientation angle of 80 degrees South East, while the orientation angles of the two antennas are 57 degrees North East and 20 degrees North West, respectively.

Install and connect the system according to Figure 10, after the radio link communication is confirmed normal, the vehicle starts driving along the testing path in a constant speed of 40km/h. On the BTS side, the movement of the CPE is being monitored and recorded through the display console. The gain of the omnidirectional antenna connected to mobile CPE is 12dBi, the initial position of the CPE is 1200 meters east to the BTS (Figure 11) and the height of the antenna is 3 meters from the ground.
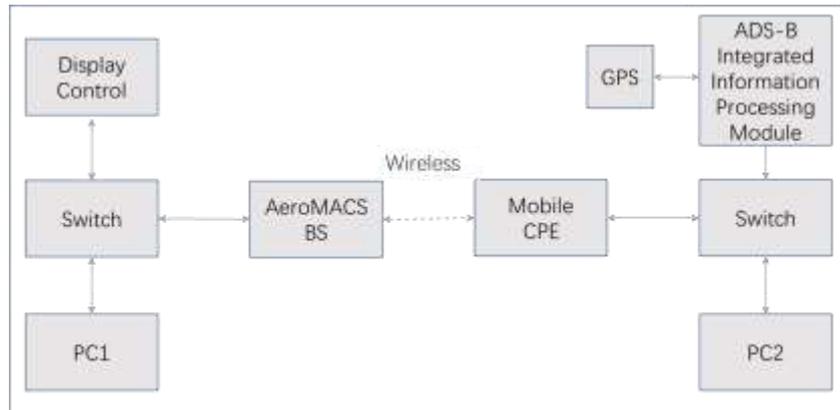
Figure 10. System block diagram of AeroMACS vehicle surveillance test.
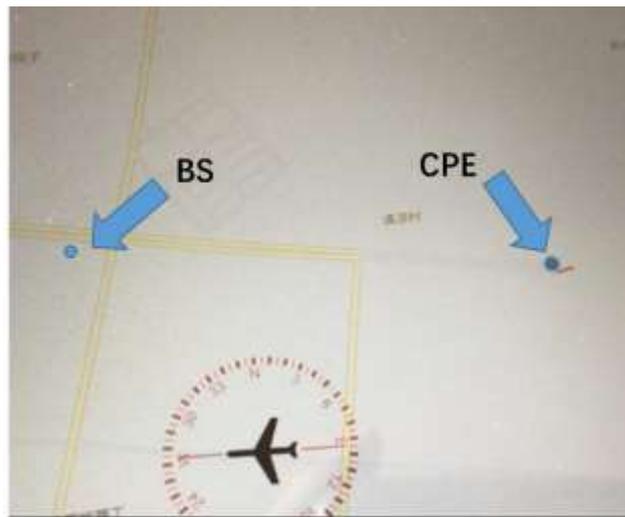
Figure 11. Vehicle surveillance test (a)
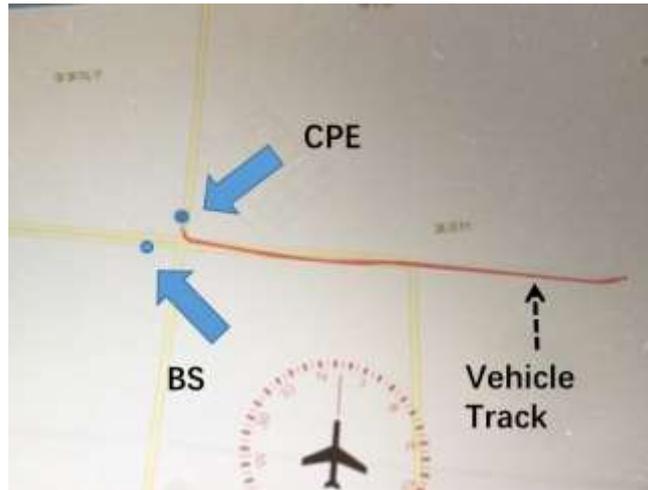
Figure 12. Vehicle surveillance test (b)

Firstly, the mobile CPE moves to the location denoted in Figure 12 from east to west, and then the heading direction is changed to the north, that is moving away from the BTS. During this period, the data transmission is normal and the vehicle surveillance video transmission and display is very smooth.

Figure 13. Vehicle surveillance test (c)

Figure 14. Vehicle surveillance test (d)

When the mobile CPE moves to the location in Figure 13, at this point the direction of the vehicle is heading west, CPE position stops updating in the surveillance video. At this time linear distance between the BTS and the vehicle is about 1500 meters and the communication environment has become Non-Line of Sight (NLOS). The vehicle maintains a constant speed, about 47 seconds later, the wireless communication returns to normal and the CPE position is updated as shown in Figure 14, the linear distance between the BTS and the vehicle is about 1800 meters (NLOS). Then the vehicle takes a U-turn and moves back, communication interruption takes place again in the above-mentioned NLOS area and returns to normal later.

Test Conclusion

The purpose of Single-Sector Communication Capacity Test with Multiple Fixed CPEs is to verify that AeroMACS is capable of supporting wireless communications of fixed CPEs, for example, data backhaul of the MLAT system. Each CPE's uplink communication capacity was higher than 1.6Mbps, which indicates that system has sufficient capacity and transmission rate to support such operations under the premise of a reasonable layout of the BTS(s), such as a controlled interval between BTS and CPEs and LOS.

The results of Vehicle Location Information Upload Test shows that the system can support the uploading, tracking and displaying of the vehicle's geographical position information, even in some remote NLOS area, it can also support the location service normally. In case of the situation that the system cannot maintain connection or upload the location information of the vehicle, which is relatively rare on the airport surface, additional BTS(s) deployment is one of the many solutions during the implementation process in the future.

Summary

The paper introduces the emergence, development and standards developing progress of AeroMACS. The system architecture of AeroMACS is described and two field tests are shown, the results verify that AeroMACS is able to play a key role in supporting both mobile and fixed services on the airport surface in the future.

Acknowledgement

References

[1] Budinger, J. M. and Hall, E. Aeronautical Mobile Airport Communications System (AeroMACS), Future Aeronautical Communications. U. S.: InTech, 2011: 235-262.

[2] Gray, D., PourNejatian, N. AeroMACS: Delivering Next Generation Communications to the Airport Surface. U. S.: WiMAX Forum, 2015: 1-23.

[3] Hall, E., Magner, J. C-Band Airport Surface Communications System Standards Development, Phase II Final Report, Volume 2 Test Bed Performance Evaluation and Final AeroMACS Recommendations. U. S.: NASA, 2011: 1-99.