FULL APRON VISIBILITY DESIGN

Leonhard Korowajczuk, CelPlan Technologies, Inc., Reston, VA, USA

Abstract

The apron area is key for an airport operation, but today it lacks automation and visibility. The industry has assigned to it a valuable exclusive spectrum under ITU AM(R)S (Aeronautical Mobile (Radiocommunication) Service) and a dedicated technology known as Aeronautical Mobile Airport Communication System (AeroMACS), which should be used to provide the required automation and visibility. However, this spectrum must be used wisely, and the worst decision is to allow it to be used on as required basis. The spectrum usage should provide enough capacity for all applications that can be developed over time, including video capability across the apron surface. The visibility referred here, refers not only to the visual content, but also its analytical analysis and all kinds of data that can be beneficial to the airport operation. This information must be made available to airplanes and across the entire apron area, so it can be accessed from anywhere. This accessibility requires that the wireless coverage be planned from start to support the long-term technological applications that will be developed. This will allow the incremental implementation in a consistent and coherent manner. The apron design should address the requirements of the next 20 years, so its implementation will not be disruptive over time.

In this paper, we analyze the impact of video streaming and how it can be addressed in a large airport. We also analyze the usage of available spectrum in the apron and dimension the wireless facilities required to cope with this demand.

The proposed plan foresees the future demand and allows for its gradual implementation over the years without disruption.

We suggest that a pilot deployment be done to validate/improve the assumptions and establish the guidelines for implementing apron visibility in the airports.

Full Apron Visibility

Airport operations will greatly benefit by the implementation of several apron related applications, covering the following areas:

- Sensor connectivity across the entire apron,
- Airplane connectivity to ground network when on apron surface,
- Video monitoring of entire apron and surrounding areas, with video analytic features,
- Asset location tracking on the apron area;
- Central storage of apron information with selective access, and
- Full apron visualization with combined multi-source data.

To implement these features in a seamless way the apron must provide ubiquitous wireless connectivity.

The amount of data to be transferred is extremely large, mainly considering video coverage. The same data can be beneficial to many users, which leads to a centralized repository architecture.

The available data is beneficial to several groups of users in the airport, nominally:

- Air Traffic Control and Air Traffic Management,
- Airport Authority, and
- Airlines

The amount of spectrum available is limited and has different attributes, so spectrum resources should be well planned and rely on high reuse cellular coverage. Spectrum is a common asset and its usage should be planned agnostically to provide service to all users over a period of many years to come.

Full apron visibility means that the communication network should provide access across the entire apron area, so new applications can be deployed as they are developed with no delay. This

978-1-7281-7270-5/20/$31.00 ©2020 IEEE

communication network must be reliable and should have wired and wireless components.

Airspace Modernization Efforts

The technological evolution has been overwhelming in the last decades, but little of it has migrated to the aeronautical field, as its introduction is slowed down by security concerns. Semiconductor electronics, computing power, wired and wireless communications, video capabilities and many other developments open the doors to thousands of new applications.

In this article we will focus on the airport surface operations. or the apron.

The airport apron is the area of an airport where aircraft are parked, unloaded or loaded, refueled, and boarded. The term apron is also used to identify the air traffic control position responsible for coordinating movement on this surface. The use of the apron may be controlled by the apron management service (apron control or apron advisory) to provide coordination between users.

The Federal aviation Administration (FAA) and EUROCONTROL established in 2004 a joint R&D effort to be implemented through Action Plans (AP). In 2007 Action Plan 17 (AP17): Future Communication Study, was established to identify potential future communication technologies to meet communication requirements for safety and regularity of flight. The goal was to establish the Future Communication Infrastructure (FCI) for:

- New SATCOM system
- New Terrestrial System
- New Airport Surface System

In the USA the FAA established the NextGen (Next Generation Air Transportation System) study for a comprehensive overhaul of the National Airspace System (NAS). It is an ongoing modernization project that started in 2003 and plans to have all major components in place by 2025.

In Europe a collaborative project to completely overhaul European airspace and its air traffic management (ATM) was formed under the Single European Sky ATM Research (SESAR). The actual program is managed by the SESAR Joint Undertaking as a public–private partnership.

The International Telecommunication Union (ITU) at the World Radiocommunication Conference in 2007, defined in a worldwide basis the band from 5091 to 5150 MHz for Aeronautical Mobile (Radiocommunication) Service (AM(R)S).

AP17 defined the FCI technology to be used in the airport surface as AeroMACS (Aeronautical Mobile Airport Communication System), based on IEEE specification 802.16e (WiMAX). The details of this technology would be further defined by the RTCA (Radio Technical Commission for Aeronautics) and ICAO (International Civil Aviation Organization).

The RTCA issued in 2009 the document SC-223 for communications on the airport surface, covering the following main applications:

- Data communication development for collaborative decision making (CDM),
- Surveillance broadcast system (SBS),
- System wide information management (SWIM), and
- Weather and flight information systems (FIS).

The International Civil Aviation Organization (ICAO) issued, in 2017, document Doc 10044-2017, Manual on the Aeronautical Mobile Airport Communications System (AeroMACS).

The WiMAX Forum offers product certification at the AeroMACS Designated Certification Laboratory (ADCL) based on requirements defined in aviation industry standards.

AeroMACS is internationally standardized and globally harmonized. It is the only wireless technology that has been validated by EUROCONTROL, FAA, and ICAO to support the safety and regularity of flight. AeroMACS is one of the essential enablers of the global Air Traffic Management (ATM) initiatives and one of the three required communication technologies under the ICAO Global Air Navigation Plan (GANP).

ICAO has approved the AeroMACS Standards and Recommended Practices (SARP) resulting in Amendment 90 to ICAO Annex 10, which has been endorsed by 192 ICAO nations and will help ensure manufacturer interoperability, global harmonization and security through certified equipment. This

Amendment was effective in November 2016 and is now included in Chapter 7 of Volume III of Annex 10. ICAO has also developed the AeroMACS Technical Manual and guidance document.

The AeroMACS Minimum Operational Performance Standards (MOPS), AeroMACS Minimum Aviation System Performance Standards (MASPS) and the AeroMACS Profile documents have been jointly developed and approved by RTCA and EUROCAE. The ARINC AEEC has published ARINC 766: Aeronautical Mobile Airport Communications System (AeroMACS) Transceiver and Aircraft Installation Standard that will enable the system to be installed in Commercial type aircrafts. The initial applications will be used to support the existing Electronic Flight Bags (EFB) in the cockpits.

Apron Applications

Apron (Ramp) is a defined area on an airport intended to accommodate aircraft for purposes of loading or unloading passengers or cargo, refueling, parking, or maintenance.

The apron area includes the following components (reference AIM and AC 150/5340- G):

(1) Aircraft Parking Positions: Intended for parking aircraft to enplane/deplane passengers, load or unload cargo.

(2) Aircraft Service Areas: On or adjacent to an aircraft parking position.

Intended for use by personnel/equipment for servicing aircraft and staging of equipment to facilitate loading and unloading of aircraft.

(3) Taxi Lanes: Apron areas which provide taxiing aircraft access to and from parking positions.

(4) Vehicle Roadways Markings: Identified rights of way on the apron area designated for service and Aircraft Rescue and Fire Fighting (ARFF) vehicles.

Operations currently performed in airports on a regular basis can benefit from a wireless communications system.

The FAA has catalogued at least the following number of applications per segment:

- ACARS (Aircraft Communications Addressing and Reporting System): 47
- Flight Deck: 96
- Ground Operations & Services: 123
- FAR (Federal Airport Certification Regulation) 139
- Safety Self Inspection: 33
- Airport Surface Infrastructure: 33

In addition to the above list, there are many applications that are not available today, but can be implemented once a reliable wireless communication system is in place.

CelPlan has more than 20 years designing wireless communication systems and providing video surveillance systems. This allowed us to conceive some very powerful applications that will improve traffic flow, reduce costs and increase safety. Several of these technologies are based on video monitoring allied with powerful analytics.

These applications are listed next.

Apron Asset Tracking and Location

Throughout the airport apron one finds thousands of devices that are constantly moved around it. Managing these assets is not an easy task, but this difficulty can be easily solved with a communication network and a specific application developed for this purpose.

Each asset can be tagged with a device that will send a beacon announcing its presence periodically.

A set of nodes will track the assets and send their position to a centralized server. The application will allow to locate any asset or set of assets.

Assets will have attributes that specify authorized locations and other characteristics.

The application can be programmed to display assets locations, find an asset, reserve assets, give alarms and so on. Combined with video monitoring, not identified assets can be located and alarmed.

Airplane Marshaling

When an aircraft approaches or leaves a jet bridge it must be marshalled to/from its parking space. This procedure has been done in the same manner for years. It requires manpower and must be done under all weather conditions. Today, it cannot be done when there is a possibility of lightning within a specific radius and this may stop an entire airport for hours.

We propose a standalone or centrally controlled marshalling system that does not require physical presence at the apron.

In this system, a video feed is sent to the aircraft displaying the aircraft approach and provides the pilot with approach/exit lines. It can even propose course corrections. An alarm should be given when the aircraft violates the approach/exit lines. Clearance within approach/exit areas can be verified through image analytics.

This solution will benefit from a broadband wireless airplane to ground connectivity in the airport apron because the video feeds require a large bandwidth.

This application will reduce personnel costs, increase operational efficiency, reduce operation interruptions, resulting in hundreds of millions of dollars in savings.

Jet Bridge Automation

Jet Bridge requires today personnel to maneuver and connect it to the airplane. This application can allow the aircraft crew to command the approach/separation of the jet bridge, so it will not require ground personnel.

This application will benefit from the wireless ground connectivity on airport apron and the aircraft video feed applications.

The pilot or co-pilot can command the bridge remotely and using similar video feeds used during the marshalling process, command the bridge approach.

This procedure will reduce manpower, increase efficiency and increase customer satisfaction.

Periphery Monitoring and Intrusion

Access to Apron is limited to the public, but it can be easily breached through the fence that surrounds the area.

The airport perimeter can be monitored by regular and infrared video, so any intrusion is detected and informed.

Video analytics can also detect loitering and detect unauthorized objects left on the apron.

Nearby Airspace Intrusion

The airspace surrounding the landing and takeoff airspace can be monitored for wildlife, drones and other kind of intrusions (fireworks, balloons, missiles, ...). Video analytics can be used to analyze the images and generate immediate alarms.

Aircraft Video Feeds

Aircraft pilots have an extremely limited view of their surroundings when on the ground. They must often rely on someone else orienting them and must move in nearly blind conditions.

What we propose is a series of video feeds that can display the aircraft from outside. Front, back and side views can be beneficial and provide situational awareness. A ground view can provide information about operations going on under the aircraft, like loading and unloading, fueling and obstructions to aircraft movement.

A top view of the aircraft and its immediate surroundings can be generated from the video feeds and provide the pilot with situational awareness.

Analytics can use the top view to provide alarms, based on proximity of static devices and considering the speed and predicted trajectory of moving devices.

Additionally, video feeds from inside the plane can provide essential information in case of incidents. These views may be activated only in case of incidents.

All video feeds can be stored for training or investigating purposes.

Airport Surface real time mapping

All the visual and logical information can be used to construct a real time surface map of the entire airport. It can be used to map aircraft routes, identify locations, post warnings and many other applications.

Video Streams

All the applications above, and several existing ones, require video streams. These video streams can be stored either locally or remotely. We will assume for now that a maximum stream that can be sent wirelessly by an RF channel is 5 Mbps. Table 1 estimates the throughput required for different resolutions, using H265 compression. The video resolution will then vary from 1 Mega Pixel High Definition-HD stream to a 5 MPixel stream.

The video resolution to be used by each application depends on the type of observation intended as defined in standard EN 62676-4. This standard defines the zone types (in pixels/m) per observation type, as shown in Figure 1.

Table 2 gives the maximum distance for each zone for different video resolutions and focal lengths (view angle).

Table 1. Video Feed Characteristics

Video Resolution	Horizontal	Vertical	MPixel	Compression		Complexity	Motion	FPS	Mbps
1 MP (HD)	1280	720	0.9	High Quality	H265-10	50%	50%	24	1.49
2 MP (Full HD)	1920	1080	2.1	High Quality	H265-10	50%	50%	24	3.34
4 MP	2288	1712	3.9	Good Quality	H265-20	50%	50%	24	4.95
5 MP	2600	1950	5.1	Average Quality	H265-30	50%	50%	24	5.31

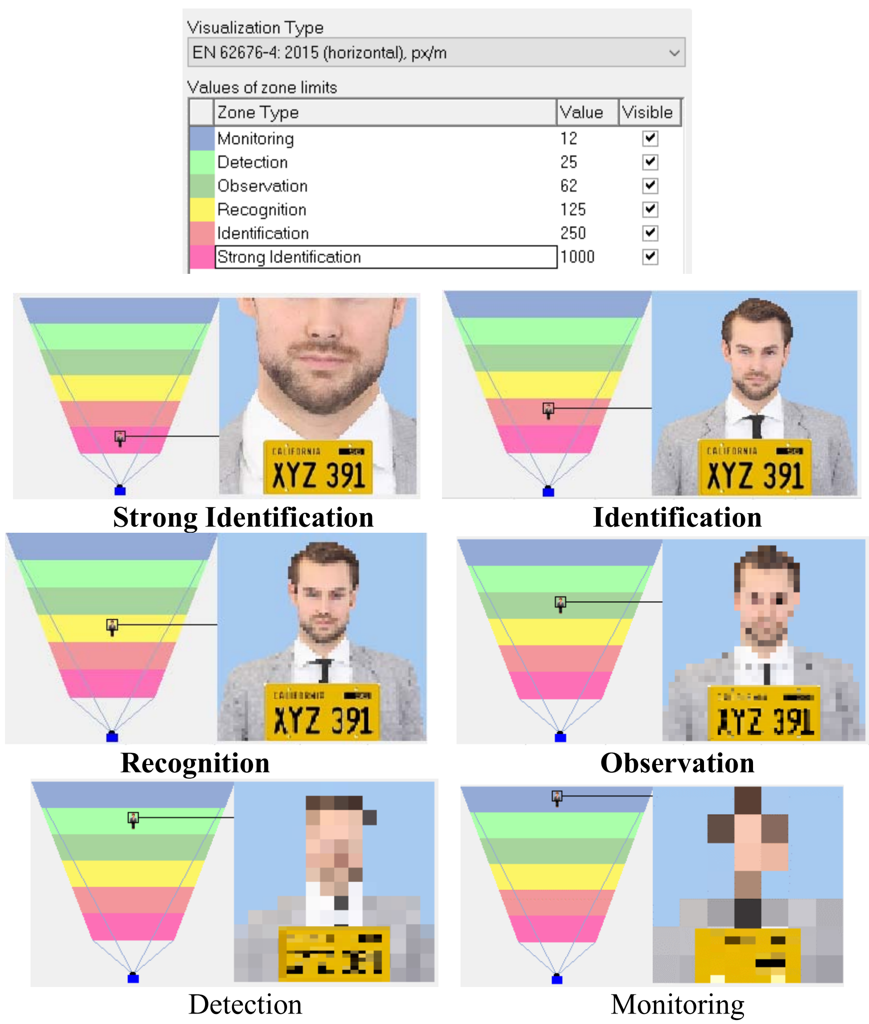

Figure 1. Visualization Zones and Image Definition

Table 2. Visualization Zone Distance for Different Video Resolutions and Focal Lengths

Height = 4 m	Tilt= 16.7		Pink	Carmine	Yellow	Green Gray	Light Green	Blue
			Zone Limit Distance (m)					
	Focal Length	Angle	Strong ID	ID	Recognition	Observation	Detection	Monitoring
1 MP (HD)	1.6	126.9				3	14	35
	3	93.7			2.5	8	25	55
	4	77.3			5	12	32	70
	6	56.1			10	20	50	100
	8	43.6			12	25	65	130
	16	22.6			20	45	120	250
	50	7.3			75	160	400	800
2 MP (Full HD)	1.6	126.9			1.5	7	24	38
	3	93.7			6	14	38	72
	4	77.3			8	18	50	110
	6	56.1		6	15	30	75	150
	8	43.6		8	18	38	90	200
	16	22.6		10	35	75	185	400
	50	7.3		50	120	240	600	1020
4 MP	1.6	126.9			2	10	35	80
	3	93.7		2	8	20	50	110
	4	77.3		4	12	25	65	135
	6	56.1		5	15	35	90	180
	8	43.6		12	24	45	120	240
	16	22.6		26	50	80	225	460
	50	7.3	10	70	120	270	720	1100
5 MP	1.6	126.9			5	14	40	90
	3	93.7		2.5	10	20	60	125
	4	77.3		5	14	28	72	150
	6	56.1		9	20	40	105	170
	8	43.6		12	25	55	135	260
	16	22.6		25	52	110	260	520
	50	7.3	20	80	160	320	800	1600

The Spectrum

The 5,091 to 5,150 MHz spectrum assigned by ITU for Aeronautical Mobile (Radiocommunication) Service (AM(R)S) is a worldwide spectrum that can be used by airplanes on the ground, when travelling in different countries, so it must be reserved for airplane applications. The accepted technology to be used in this spectrum is AeroMACS. This allows for the exchange of information, but the applications need to be standardized, for it to be useful. We call this spectrum AeroMACS P, for preferential.

Additional spectrum from 5,000 to 5,030 MHz (AeroMACS S1) may be made available for AeroMACS per country, as well as the range from 5,091 to 5,150 MHz (AeroMACS S2).

This band is not enough to provide the spectrum required for all suggested/possible apron applications, so additional bands should be considered.

Table 3 lists the available licensed and unlicensed frequencies that can be used in the apron.

Table 3. Licensed and Unlicensed Bands and Related Standards

IEEE WLAN	Range (MHz)		Bandwidth (MHz)	Channels	Restrictions	License	Application Type	Users
802.11ah	902	928	2	13		No	telemetry	
802.11b/g/n/ax (Wi-Fi)	2,401	2,495	20	11		No	personal	smart phones
802.15.1 (Bluetooth 5.2)	2,400	2,485	1	1	hopping	No	location	device location (beacons)
802.11y	3,655	3,695	10	4		Yes	backhaul	
802.11j (Public Safety)	4,940	4,990	20	2		Yes	safety	video and data streaming
802.11e (AeroMACS S1)	5,000	5,030	5	6		Yes	ground- ground	video and data streaming
802.11e (AeroMACS S2)	5,030	5,091	5	12		Yes	ground- ground	video and data streaming
802.11e (AeroMACS P)	5,091	5,150	5	11		Yes	airplane- ground	video and data streaming
802.11a/h/n/ac/ax (Wi-Fi)	5,250	5,350	20	5	indoor/DFS	No	indoor- ground	luggage handling
802.11a/h/n/ac/ax (Wi-Fi)	5,470	5,725	20	12	DFS/TPC	No	ground- ground	PCs
802.11p (ITS)	5,850	5,925	10	7		Yes	ground vehicles	video and data streaming

IEEE WLAN	Range (MHz)		Bandwidth (MHz)	Channels	Restrictions	License	Application Type	Users
6/7 GHz	5,925	7,125				No	backhaul	
11 GHz	10,700	11,700				Yes	backhaul	
13 GHz	12,700	13,150				Yes	backhaul	
18 GHz	18,000					Yes	backhaul	
23 GHz	23,000					Yes	backhaul	
24 GHz	24,000					No	backhaul	
31 GHz	31,000					Yes	backhaul	
38 GHz	38,000					Yes	backhaul	
802.11ad/ay (WiGig)	57,240	70,200	2,160	6		No	backhaul	

Band 802.11ah

This is an unlicensed band that can be used to connect remote sensors. This frequency propagates well, and just few high bases stations can cover the entire airport.

Band 802.11b/g/n/ax (Wi-Fi) and 802.15.1 (Bluetooth Beacons)

This is an unlicensed band and can be used for smart phones and Bluetooth beacons. Both applications can share the same band and each cell should be restricted to small areas, such as a gate area. At least two cells are required, so triangulation can be done.

The Wi-Fi connection should be restricted to the apron locations and should not have external connectivity to the Internet. It will allow users to exchange text messages and do voice connections, related to work performed on the apron.

The Bluetooth Beacons should be used to identify and locate assets, which will allow to populate a data base and compare it to the expected asset database. Displaced assets and not authorized assets can be alarmed.

Band 802.11y

This is a licensed band that can be used for special high capacity LOS backhaul needs.

Band 802.11j (Public Safety)

This is a licensed Public Safety band that can be used for any public safety application, such as perimeter and air space surveillance.

Band 802.11e (AeroMACS)

This is a licensed band that must be divided in three categories.

The Primary category covers 5,091 to 5,150 MHz and is internationally assigned. It should be reserved for communications to and from the aircraft. It has eleven 5 MHz channels available, with an average capacity of 5 Mbps.

The best use of this band is to divide the channels in three categories, allowing its distribution in a cellular pattern, minimizing interference. This distribution is shown in Table 4.

Table 4. Channel Assignment for AeroMACS P

Cells	Channels
Micro Cells (50 m radius)	2
Small Cells (100 m radius)	3
Medium Cells (400 m radius)	3
Large Cells (1 km radius)	3
Total	11

Three channels should be allocated to macro cells covering runways, taxiways, and airplane parking lots. Three channels allocated to medium cells covering ramps and gate access areas. Three channels allocated to small cells covering a gate area and two channels allocated to micro cells covering the surroundings of the jet bridge.

The Secondary category covers 5,000 to 5,030 MHz and may be available or not at an airport. It has 6 channels and can be used to provide services to ground workers, for portable video cameras and other scanning devices.

The Tertiary category covers 5,030 to 5,091 MHz and may be available only in some airports. It has 12 channels and can provide additional services for ground to ground transmissions.

Band 80211.a/h/n/ac/ax (Wi-Fi)

This is an unlicensed band and can be used for smart phones. The Wi-Fi connection should be restricted to the apron locations and should not have external connectivity (Internet). It will allow users to exchange text messages and establish voice connections, related to work performed on the apron.

Band 802.11p (ITS- Intelligent Transportation System)

This is a licensed band and applies to ITS, so it can be used to control vehicle traffic on the apron.

Microwave Backhaul Bands

There are several unlicensed (6/7, 24 GHz) and licensed bands (11, 12, 18, 23, 31, 38 GHz), that can be used for backhauling.

Band 802.11ad/ay (WiGig)

This is an unlicensed band that can be used for short backhauls. It is available in the 57,240 to 70,200 GHz band and supports 6 channels.

Propagation and Capacity

There are several bands around 5 GHz, so a propagation study was done for the AeroMACS 5.15 GHz. The apron surface is flat, but there are several obstructions, many of which are mobile. The obstructions can be modelled by the exponent of the attenuation (n):

- Free space: n=2 (full line of sight)
- Light obstructions: n=2.5 (few carts, people, vehicles)
- Medium obstructions: n=3.0 (several carts, people, vehicles)
- Heavy obstructions: n=3.2 (airplane body, bus, ramp)

The estimated path loss for the different level of obstruction is shown in Table 5.

The link budget parameters considered are listed in Table 6. The same link budget was considered for downlink and uplink, for estimation purposes only.

The AeroMACS receiver (Rx) sensitivities are listed in Table 7, as well as the composite effective throughput (downlink and uplink) for large packets (>1,000 Bytes), typically used in video transmission. This throughput is reduced with the reduction of the packet size.

Figure 2 shows the path loss for different obstruction levels and the path loss limits of each modulation, listed also in Table 8, that summarizes the cell reach for each required throughput. It is assumed that the cells are properly dimensioned to handle the traffic.

Table 5. Path Loss for Different Path Loss Exponents

Path loss (dB)				
	N (path loss exponent)			
d (m)	2.0	2.5	3.0	3.2
10	66.7	83.4	100.0	106.7
20	72.7	90.9	109.1	116.3
50	80.7	100.8	121.0	129.1
100	86.7	108.4	130.0	138.7
200	92.7	115.9	139.1	148.3
500	100.7	125.8	151.0	161.1
1000	106.7	133.4	160.0	170.7
2000	112.7	140.9	169.1	180.3
5000	120.7	150.8	181.0	193.1
10000	126.7	158.4	190.0	202.7

Table 6. Link Budget Assumptions

TX power (dBm)	20
Tx antenna gain (dB)	6
Rx antenna gain (dB)	6
Noise figure (dB)	8
Fading margin (dB)	5

Table 7. Effective Throughput and maximum Path Loss for different modulations

Modulations	RX Sensitivity	Effective Mbit/s	Maximum Path Loss (dB)
64QAM 3/4	-74.3	7.2	93.3
64QAM 2/3	-76.3	6.4	95.3
16QAM 3/4	-80.3	4.8	99.3
16QAM 1/2	-83.8	3.2	102.8
QPSK 3/4	-86.3	2.4	105.3
QPSK 1/2	-89.3	1.6	108.3
QPSK 1/2 rep2	-92.3	0.8	111.3

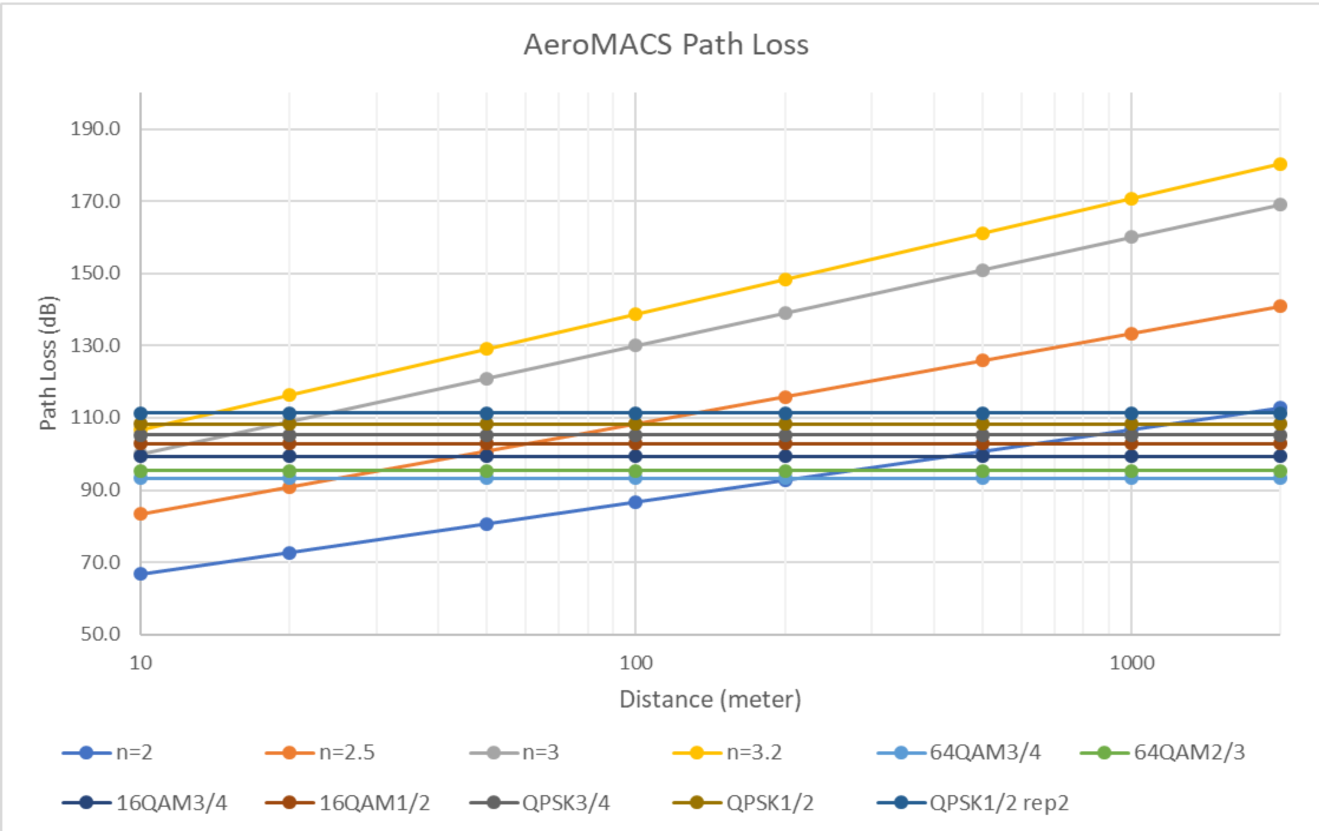

Figure 2. AeroMACS Path Loss

Table 8. Maximum cell radius (meter) and Expected Video Throughput (Down + Up)

n	64QAM 3/4	64QAM 2/3	16QAM 3/4	16QAM 1/2	QPSK 3/4	QPSK 1/2	QPSK 1/2 rep2
2	200	250	450	650	830	1050	1100
2.5	25	20	32	60	75	100	120
3	0	0	0	11	12	20	22
3.2	0	0	0	0	0	12	15
Throughput (Mbps)	7.2	6.4	4.8	3.2	2.4	1.6	0.8

The Spectrum Selection

Before doing a design, it is important to survey the apron for the availability of the above bands and eventual interference present. This requires a spectrum analyzer with a spectrogram that can record the I/Q signals. An observation of one week should be done to assure that a band is available and free of interference.

The next step is to verify the availability of base station equipment and user terminals at the desired bands.

Next, the site locations should be defined, based on the following criteria:

- Height, access and obstructions
- Availability of power
- Availability of optical fiber

The Technology

The technology used in the above bands is 802.11 or a proprietary microwave one. Most of the applications are local and the only one that will impact international roaming is the AeroMACS which is based on 802.11e (WiMAX).

WiMAX has been replaced by Long Term Evolution (LTE) in most of the commercial market, so the natural question is should be it replaced in AeroMACS also?

The reason for the replacement was of commercial nature and the allegation was based on some technical issues that were later proven as not real and were abandoned in the 5G version of LTE. LTE must accommodate many industries and is encumbered by many features not required by the aeronautical community. WiMAX technology has a diversity advantage in relation to LTE, which did not adopt this WiMAX feature.

It took the aeronautical industry 10 years to define AeroMACS and the aviation industry requires a stable technology that is under its full control. The aeronautical community can benefit from a noncommercial technology, due to security reasons. This will also allow the community to tailor the technology to its requirements. The IEEE standard used in AeroMACS should continue to evolve, with the aeronautical requirements in perspective and with the participation of the aeronautical community.

The Apron Design

Boston's General Edward Lawrence Logan International (BOS) Airport was used for this exercise. It is located at 42°21′N and 071°00′23″W, with an elevation of 6 m AMSL. Table 9 gives the main characteristics of the airport.

Table 9. Logan Airport Parameters

Logan airport	2019	per day
Aircraft Operations	427,176	1,170
Passengers	42,522,411	116,500
Cargo (lb.)	688,939,147	1,887,505

Table 10 lists Logan airport runways.

Table 10. Logan Runways

Runways	Length (m)
4L/22R	2,396
4R/22L	3,050
9/27	2,134
14/32	1,524
15L/33R	779
15R/33L	3,073

Table 11 lists Logan's terminals with the number of gates.

Table 11. Logan Terminals and Gates

Terminal	Gates
A (Main)	11
A (Satellite)	10
B (North)	9
B (South)	29
C	39
E	12
Total	110

Figure 3 shows a top view of Logan airport, followed by a diagram depicting the terminals and runways (Figure 4 and Figure 5) and a more detailed view of the terminals. Figure 6 shows a view of typical gates. There is a total of 110 gates in the airport. Table 12 lists the minimum and maximum gate dimensions.

Table 12. Typical Gates

Gate	Min (m)	Max (m)
Width	20	45
Depth	30	40
Reach	50	100

Figure 3. Logan Airport Overall View

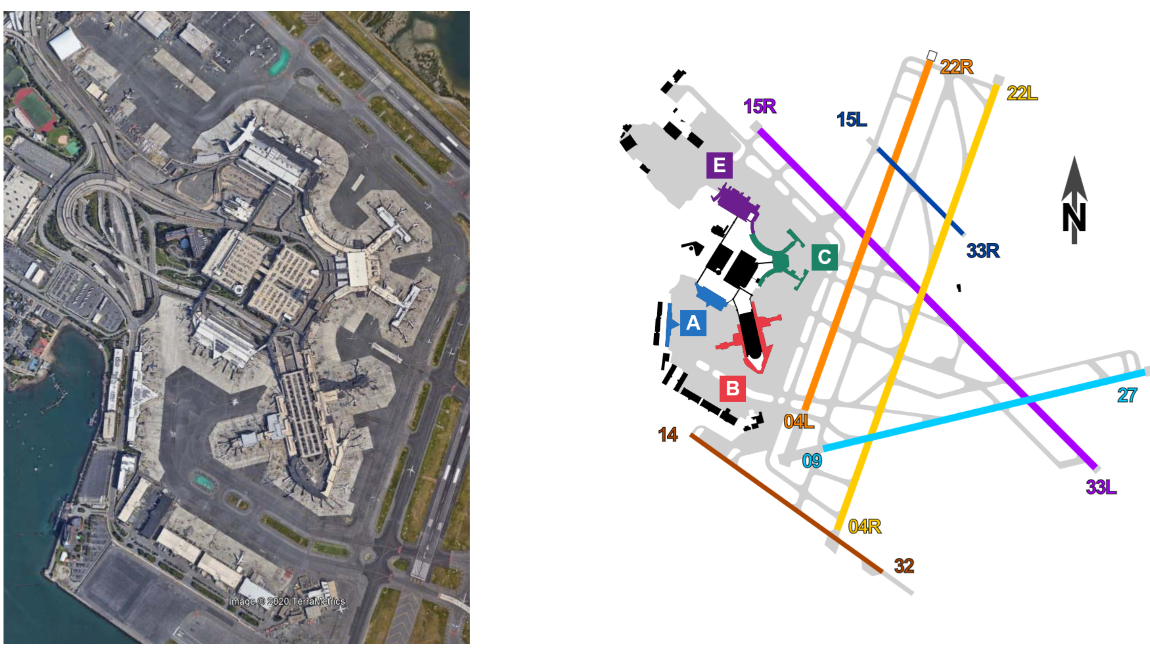

Figure 4. Logan Terminal View and Terminal Diagram

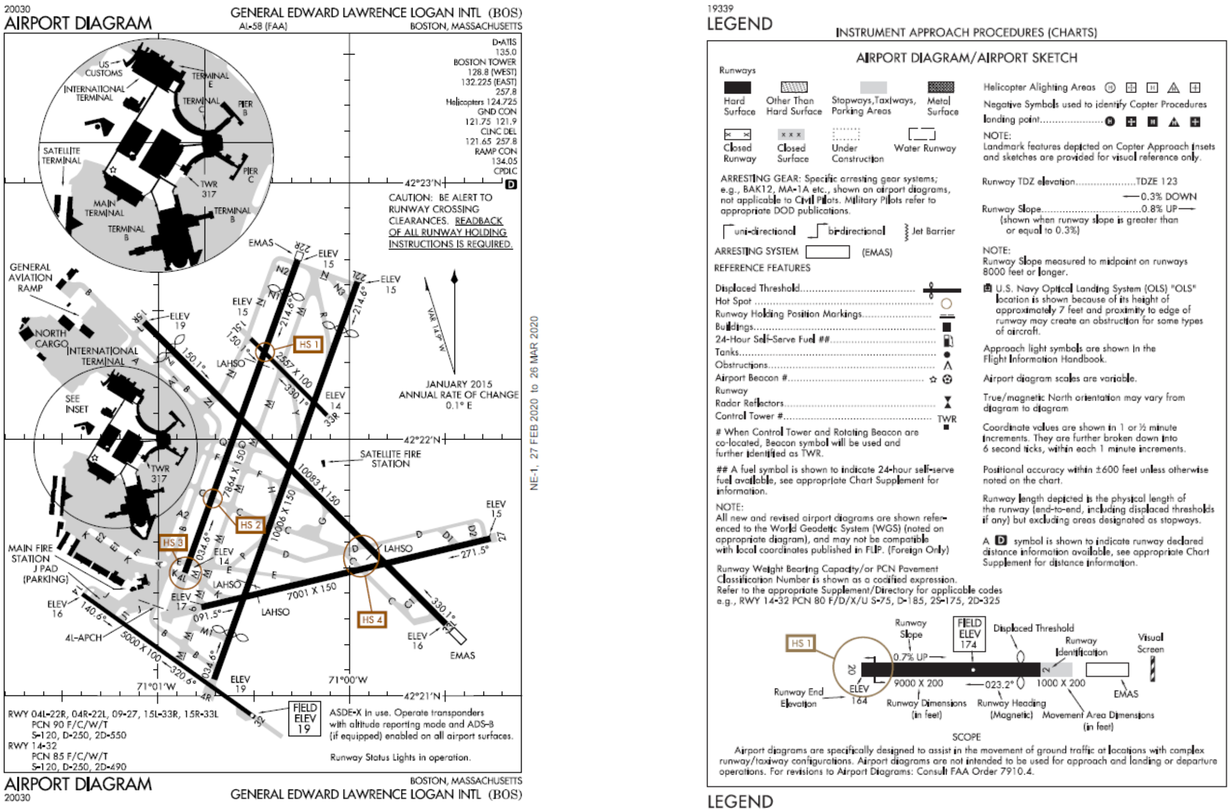

Figure 5. Logan Airport Diagram

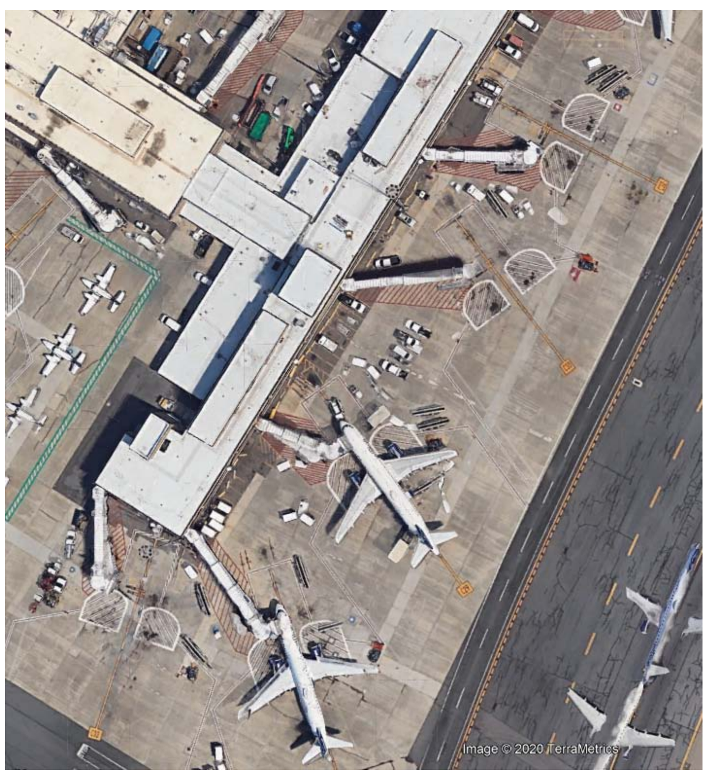

Figure 6. Logan Gate Detail

Video Design

The video design should provide a full coverage of the entire apron area. This does not mean that all cameras must be installed, but the design should accommodate all of them, so they can be deployed as needed in an optimized manner.

The cameras can be divided in 4 groups, as shown in the next table, each one with a different visualization type (zone). A maximum video feed resolution of 5 MPixel was used considering the limitation given by the AeroMACS channel. It is possible to deploy higher resolution video feeds, as the Video management system can reduce the video data stream to the capabilities of the viewing terminal.

Based on these assumptions it was estimated that 750 video feeds should be required to provide full view of all apron areas with an adequate visualization resolution (Table 13). A single camera can have multiple lenses (video feeds), so it covers 360°, 180° or any view angle. The total number of cameras will be around 350.

These cameras may have some local storage and have analytical capabilities embedded.

The cameras should be connected always when possible by optical fiber to a server, where the video feeds will be stored, processed and given access to. When a fiber connection is not feasible the secondary and tertiary AeroMACS channels can be used or the microwave backhaul frequencies.

A Video Management System (VMS) will manage the feeds and provide access as requested by the applications.

Wireless Design

The eleven Primary AeroMACS channels should be dedicated to airplane access to video and data over the entire apron area. The eleven channels should be divided in 4 groups according to the cell size.

The eleven Primary AeroMACS channels should be dedicated to airplane access to video and data over the entire apron area. The eleven channels should be divided in 4 groups according to the cell size. The estimated number of Base Stations is 320, as shown in Table 14.

The other WLAN (Wireless Local Area Networks) will follow a similar pattern and the estimated number of Base stations is listed in Table 15

The Wi-Fi units support multiple frequencies, so they are only counted once. The backhaul connections are not included, as they will be deployed only when fiber is not available.

Table 13. Estimated Number of Video Feeds

Video Cells	View Angle	Focal Length (mm)	Visualization Zone Type	Resolution (MP)	Radius (m)	Number of video feeds
Micro Cells	45°	16	Recognition	5	52	50
Small Cells	90°	8	Observation	5	55	100
Average Cells	180°	4	Detection	5	72	200
Large Cells	360°	1.6	Monitoring	5	90	400
Total						750

Table 14. Estimated Number of AeroMACS Base Stations

Primary AeroMACS channels	Channels	n (path loss)	Radius (m)	Throughput (Mbps)	Base Stations
Micro Cells	2	3	11	3.2	60
Small Cells	3	3	32	4.8	120
Average Cells	3	2.5	60	3.2	120
Large Cells	3	2	450	4.8	20
Total	11				320

Table 15. Estimated Number of Base Stations/ Wireless Routers

IEEE WLAN	Range (MHz)		Bandwidth (MHz)	Channels	Base Stations
802.11ah (Sensors)	902	928	2	13	10
802.11b/g/n/ax (Wi-Fi)	2,401	2,495	20	11	120
802.15.1 (Bluetooth 5.2)	2,400	2,485	1	1	120
802.11j (Public Safety)	4,940	4,990	20	2	120
802.11e (AeroMACS S)	5,000	5,030	5	6	
802.11e (AeroMACS T)	5,030	5,091	5	12	
802.11e (AeroMACS P)	5,091	5,150	5	11	120
802.11a/h/n/ac/ax (Wi-Fi)	5,250	5,350	20	5	
802.11a/h/n/ac/ax (Wi-Fi)	5,470	5,725	20	12	
802.11p (ITS)	5,850	5,925	10	7	120
Total					610

Design Reliability

The design should have high reliability, so the server should be duplicated and all the connections to sensors, cameras and base stations should be done through two independent routes.

The camera and Base stations should be connected by two optical fibers. Cameras may be duplicated for critical applications.

Deployment, Management and Maintenance

The extent of the equipment to be deployed to provide the required functionality, is quite large and requires expertise in several areas, from video, wireless, data management, software development and so on. Several vendors and service providers will be involved.

It requires also the coordination between the requirements of:

- Airport Authority (AA)
- Airlines (A)
- Air Traffic Management (ATM)

The system must be managed on a day to day basis.

The maintenance of such a complex network requires a 24/7 availability.

These tasks require a separate team, that can constitute a new airport entity or be contracted to outside companies.

Additionally, coordination at national level between airports is required to uniform the procedures and assign spectrum usage.

Conclusion

A long-term airport apron design is being proposed that should support operations for the next 20 years. The calculations were done to provide reference numbers as each airport will require a specific design. The validation of the assumptions made can be done on a pilot project, sponsored by FAA.

Bibliography

[1] ICAO (International Civil Aviation Organization), 2017, Doc 10044- Manual on the Aeronautical Mobile Airport Communications System (AeroMACS), ICAO, Canada.

[2] Allen, David, Aero, July 2003, Electronic Flight Bag (EFB)

[3] Korowajczuk, Leonhard (CelPlan Technologies, Inc.), 2018, AeroMACS Airport Network Design-Logan Airport, Reston, VA, USA

[4] Korowajczuk, Leonhard (CelPlan Technologies, Inc.), 2014, AeroMACS Airport Network Design-DFW Airport, Reston, VA, USA

[5] Korowajczuk, Leonhard (CelPlan Technologies, Inc.), 2016, Ground to Ground Communications DFW, ORD, Bos Airports, Reston, VA, USA

[6] ARINC, July 2017, Aeronautical Mobile Airport Communication System (AeroMACS) Transceiver and Aircraft Installation Standards, Maryland, USA, SAE ITC

[7] FAA, February 2016, Engineering Brief n97 (Guidance for AeroMACS installation by the airport operator), DC, USA

[8] ICAO (International Civil Aviation Organization), 2007, SARP (Standard and Recommendation Practices) Aeronautical Telecommunications, Volume III- Communication Systems, DC, USA

[9] Byrne, Declan, July 2018, AeroMACS at Glance… Moving Towards the Airport 3.0, WiMAX Forum

[10] Plass, Simon, 2011, Future Aeronautical Communications, In Tech, Croatia

[11] Apaza, Rafael (NASA Glenn Research Center), October 2016, Aeronautical Mobile Airport Communication System (AeroMACS) Technical Development Briefing

[12] Rodrigues, Antonio Vivaldi (CelPlan Brazil), August 2018, Challenge and Advantages of AeroMACS Implementation in Brazilian Airports

[13] Budinger, James, NASA, October 2011, AeroMACS

[14] Budinger, James, FAA, November 2010, AeroMACS for Access to SWIM

[15] US DoT, FAA, December 96, Surface Movement Guidance and Control System.

[16] FAA, Next Gen Implementation Plan, 2018-2019.

[17] Byrne, Declan, WiMAX Forum, AeroMACS- A Global Standard for Airport Surface Communications

[18] Gray, Doug, WiMAX Forum, AeroMACS Network Reference Model, 2014

[19] Byrne, Declan, WiMAX Forum, November 2019, AeroMACS Enabling Safe and Secure Connectivity Worldwide

[20] DO-346 - Minimum Operational Performance Standards (MOPS) for the Aeronautical Mobile Airport Communication System (AeroMACS)

[21] IEEE 802.16e- 2005

[22] IEEE 802.16m- 2011

[23] FAA/EUROCONTROL, TSO-C207a-AeroMACS Airborne Mobile Station (AMS) Equipment

[24] RTCA, DO-345: AeroMACS Profile

[25] RTCA, DO-346: AeroMACS MOPS (Minimum Operational Performance Standards)

[26] EUROCAE, ED-227: AeroMACS MASPS (Minimum Aviation System Performance Standards)

[27] Apron Planning and Design Guidebook, 2013, Transportation Research Board, National Academy of Science.

2020 Integrated Communications, Navigation, and Surveillance (ICNS) Conference
September 8-10, 2020