AeroMACS: A common platform for air traffic management applications

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1. Introduction.

Widening the scope of ground communications with wireless applications

The communications infrastructure in airports is bursting at the seams. It is a collection of legacy technologies not designed to cope with today's traffic volumes and connectivity needs of aircraft, mobile and fixed assets, sensors, and staff throughout the airport and on the aircraft. Some airports try to cope with the limitations of these old narrowband technologies by complementing them with more advanced cellular and Wi-Fi technologies. These technologies have wider bandwidth, but they do not meet the stringent requirements of air traffic management and control, so they can take on only a complementary role. Airlines, airports, air traffic agencies, and airport authorities use them when and where they are available and have sufficient capacity, but cannot rely exclusively on them for mission-critical applications.

This fragmented and inefficient coexistence of multiple wireless technologies leaves all stakeholders dissatisfied. A complete overhaul of airports' ground wireless communications infrastructure is necessary to support the air traffic control and management envisioned by the FAA's Next Generation Air Transportation System (NextGen) in the United States, the Single European Sky ATM Research (SESAR) in Europe, and traffic control authorities in Asia-Pacific countries such as China and Japan.

AeroMACS, the Aeronautical Mobile Airport Communications System, is a technology that enables ground traffic management to move beyond the frustrating hodgepodge that exists now. AeroMACS has the capacity, performance, security and reliability to support a wide range of air traffic applications connecting staff and fixed and mobile assets across the airport area, whether within a single network or multiple ones. It supports a multitude of coexisting applications over a single platform shared by air traffic control agencies, airlines and airports, using the Aeronautical Mobile (Route) Service (AM(R)S) band (5091–5150 MHz) for airport ground applications allocated for safety and traffic control worldwide, by the ITU at the World Radiocommunication Conference 2007 (WRC-07).

In our previous paper, "Enabling the next generation in air traffic management with AeroMACS," we outlined the role of AeroMACS within the ground air-traffic environment, the drivers to adoption, and how AeroMACS meets the industry's requirements. In this paper, we move a step forward to focus on the applications that AeroMACS enables and that benefit three stakeholder groups: airlines, airports and air traffic agencies. AeroMACS supports each

Methodology

This paper identifies a set of applications that are necessary to air traffic management and that AeroMACS can support in terms of performance and cost efficiency. Some of these applications are fully or partially supported in today's networks, others are not yet deployed because existing networks cannot support them.

We worked with the WiMAX Forum and AeroMACS vendors to understand AeroMACS costs and performance, and how they compare to other technologies.

To identify the applications that the air traffic ecosystem needs and AeroMACS supports, we conducted interviews with airlines, airport authorities, air traffic control agencies, and service providers. In addition to understanding the requirements for a ground wireless broadband network, this exercise allowed us to explore how the applications used by different ecosystem players can coexist within the same network or within the same airport, and what business models can support this coexistence.

individual application, but its main strength is the flexibility to support multiple applications, with different requirements, concurrently, and in a scalable and cost-effective way. This flexibility is crucial to justifying the concerted investment in AeroMACS that all three stakeholders will have to make and to achieve the economies of scale that the wide adoption of AeroMACS creates.

We first look at how the AeroMACS platform supports the coexistence of multiple applications – to connect to the aircraft, mobile staff, and mobile and fixed assets. We then explore the application set – existing applications that can be moved to AeroMACS, and new ones that the legacy deployed infrastructure cannot support – for each of the three stakeholders: airlines, airports and air traffic agencies. Finally, we discuss the business models that may support a thriving ecosystem for air traffic control.

2. A new technology for the next generation of fixed and mobile applications.

The need for robust, reliable and secure wireless connectivity

In airports, ground wireless communications are inevitably moving toward a major architectural transition that enables the air industry to introduce next-generation applications – applications that will improve the safety and reliability of air transportation and reduce costs and congestion. Wireless technologies now in use create an uneasy and unsatisfactory environment in which all the players face strict limitations on what they can do, preventing them from taking advantage of technological innovation and the new functionality it allows.

The most commonly used technology worldwide is ACARS, which uses VHF/VDL Mode 2, or HF links. As a solution that uses dedicated spectrum and is optimized for the aviation industry, it provides very robust, reliable and secure connections, but is limited to 31.5 kbps, strictly limiting the type and number of applications it can support and imposing a high per-bit cost.

To address ACARS's limitations, airports and airlines use cellular networks, Wi-Fi and Gatelink (based on Wi-Fi, but with the potential to combine with cellular networks). These technologies have the capacity that ACARS lacks, and a lower per-bit cost. However, control over performance, security and reliability is lower, making these technologies unsuitable for many applications. In cellular networks, airport authorities do not control the infrastructure, and access is contended (i.e., airports and airlines compete with passengers and visitors for network access). In Wi-Fi networks, the airport authority may own the infrastructure, but it does not have exclusive control of the spectrum (i.e., competing networks may contend for spectrum access).

	ACARS	Wi-Fi Gatelink	Cellular	AeroMACS
Control	↑	↓	↓	↑
Reliability	↑	↓	↓	↑
Performance	↓	↔ ↑	↔ ↑	↑
Capacity	↓	↔ ↑	↔	↑
Global availability	↑	↑	↔	↑ *
Security	↑	↔ ↑	↔ ↑	↑
Per-bit cost efficiency	↓	↑	↑ **	↑
Coverage radius	↑	↔	↔	↔

↑ High ↓ Low ↔ Medium

* Potential ** With the exception of roaming traffic

The coexistence of ACARS with cellular and Wi-Fi creates an apparent dichotomy between cost and performance, and between reliability and capacity. AeroMACS bridges these gaps as it supports high-speed, low-latency links, within a network infrastructure that is under the control of the airport authority, other aviation players, or service providers, depending on location-specific arrangements. The ability to control the AeroMACS infrastructure provides the reliability and security that most applications require.

Perhaps even more important than high speed and low latency, however, is the capacity that AeroMACS brings to ground air-traffic environments. While a fast, low-latency connection is required to support single applications, high capacity is required to support a large number of applications, and to connect many terminals and terminal types.

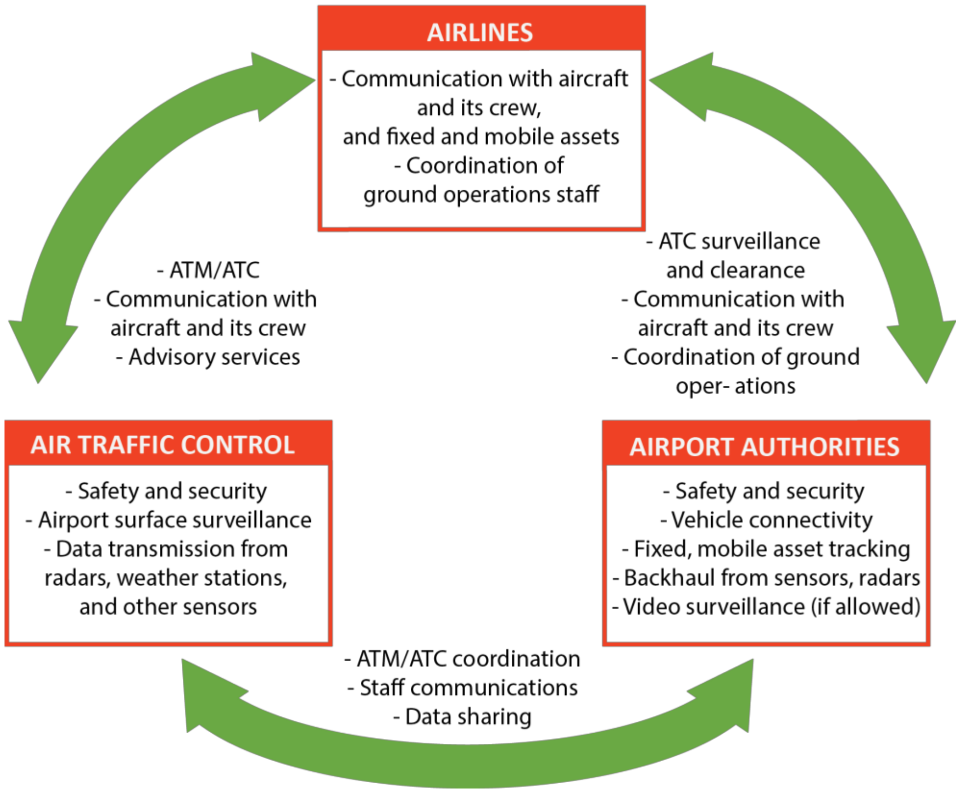
To a large extent, the challenge of the next generation of air traffic control applications is not that each is bandwidth-intensive, but that a large number of them, with varying requirements have to coexist, and that they must connect to both fixed and mobile assets.

Multiple technologies can – and will – be recruited to serve the needs of ground communications in airports. ACARS will continue to be in use for a long time. Wi-Fi and cellular networks have an ancillary role to play and can support applications that are not mission-critical, but are, nevertheless, valuable.

At the same time, however, it is crucial to deploy a single technology on a global scale that meets the air-traffic ground communications interoperability requirements. The ITU allocation of the AM(R)S band, AeroMACS standardization efforts, and the support base among major stakeholders, make AeroMACS the best candidate for global reach. Because of its capacity, AeroMACS provides a platform that multiple stakeholders can use, to support a large number of applications that run concurrently. The costs of the AeroMACS infrastructure – and the benefits – can be shared, strengthening the business case for all users.

In the next sections, we identify applications AeroMACS supports for the main stakeholders – airlines, air traffic agencies, and airport authorities – in three domains: ground-to-aircraft, mobile (staff and assets), and fixed (i.e., backhaul for fixed assets). More applications can and will be supported in AeroMACS networks, but those presented here illustrate the foundational role that AeroMACS has in managing the ground segment of air traffic and its capabilities.

Expansion of communication capabilities for aviation shareholders with AeroMACS applications



3. Airlines.

Enabling rich communications from ground to aircraft

AeroMACS enables ground-to-aircraft rich communications to support both the current applications hosted by ACARS, and new ones that require more bandwidth than ACARS can provide. The list of aircraft-based applications in the table on the right is a long one, but it is only a subset of the applications that can and will be deployed.

Airlines are a key beneficiary of aircraft applications, as they facilitate the communications between ground and aircraft teams. In fact, many applications are likely to be specific to the airline. New data-rich applications will be developed and deployed as AeroMACS networks become widespread, and new functionality is required when new aircraft models enter the market.

Many applications used by the aircraft, however, will involve the air traffic agencies and airport authorities, which – in their effort to provide safety, security and efficiency of flight – collect and manage information from the ground (see next sections) that they need to deliver to the aircraft.

Airlines can also use AeroMACS to support mobile applications to manage ground-based tasks such as de-icing, communicating with staff, and tracking mobile assets. In addition, airlines may use fixed AeroMACS links to exchange data across fixed locations and assets on the ground. Some of these applications may be shared with the airport authority, which may provide some of the ground-based services or which may need to be informed about them.

	Airlines: applications supported by AeroMACS

Aircraft	▪ SWIM applications:
	  ▪ Weather maps and forecast, weather advisory, turbulence guidance maps
	  ▪ Routing and traffic information: real-time and predictive
	  ▪ Static and dynamic airport/runway configuration information and maps
	▪ AIS synchronization: FMS and GPS navigational databases, aerodrome charts (database updates for electronic flight bag [EFB])
	▪ Air improvement program (AIP)
	▪ Aeronautical information management (AIM)
	▪ Airline operational control (AOC), area control center (AAC)
	▪ Data download – e.g., quality assurance and flight recorder
	▪ Data upload – e.g., updates to flight operation manuals
	▪ Remote control troubleshooting of aircraft
	▪ Information for pilot takeoff setting (weighting and balance)

Mobile	▪ Coordination of fueling, de-icing operations, maintenance, luggage management ▪ Communication with ground staff ▪ Tracking of vehicles and other mobile assets
Fixed	▪ Data uploads/downloads with fixed connected terminals for operations

4. Air traffic control.
Increasing the safety and efficiency of air transportation

Air traffic control agencies have been the strongest proponents of AeroMACS adoption. The technology plays a crucial role in maintaining security and safety standards as air traffic congestion grows, and in improving the tools to manage air traffic, decrease the cost of air traffic control, and improve energy efficiency.

In many countries, air traffic control agencies have played a proactive role in the harmonization and standardization of AeroMACS and have driven many proof-of-concept (POC) trials. These agencies expect to actively participate in AeroMACS rollouts in collaboration with airport authorities.

In other countries, air traffic control agencies oversee air traffic but are less directly involved in ATC and ATM applications. In these environments, the airport authorities often have a wider mandate to provide air security and safety and, as a result, are the entities at the forefront of AeroMACS adoption on the ground – in terms of both POC trials and commercial deployments.

Depending on the country, the applications listed in the table at right will be implemented and managed by either air traffic control agencies, or airport authorities. In both cases, AeroMACS has a dual role:

- Collect and aggregate data from fixed and mobile assets, sensors and other terminals, as well as ground staff, to provide the inputs to ATC and ATM applications.
- Share the data and provide advisory services to airlines – both on the ground and to aircraft.

	Air traffic control: Applications supported by AeroMACS
Aircraft	▪ Air/ground voice and data communications (from aircraft to airport, flight operations center [FOC] and central flow management unit [CFMU]) ▪ Advisory services
Mobile	▪ ATC/ATM applications ▪ Advisory services
Fixed	▪ Ground communications, navigation and surveillance ▪ Support for airport surface surveillance capability (ASSC), including airport surface detection equipment – model X (ASDE-X) communications with multilateration sensors and radars ▪ Connectivity to airport surveillance radars (ASR), navigation aids (i.e., instrument landing systems), and VHF omnidirectional radio (VOR) ▪ Ground connectivity to Flexible Terminal Sensor Network (FTSN), including weather stations (ASOS, AWOS), runway visual range (RVR) sensors, and low-level wind shear alert system (LLWAS) sensors

5. Airport authorities.
A single platform for a new approach to air traffic management

AeroMACS will play a paramount role for airport authorities, because it provides efficient, reliable and secure broadband connectivity across the entire airport footprint and, hence, it has a wide scope to support the security and safety of the environment, collect data from fixed and mobile terminals, and maintain communications with staff and aircraft.

As noted in the previous section, airport authorities in some countries are also responsible for air traffic control, and this expands their use of AeroMACS.

In most countries, airport authorities are responsible for deploying and operating the AeroMACS infrastructure as well (see next section), and this allows them to ensure they have the coverage they need across the footprint. This is important, because AeroMACS enables airport authorities to collect data from ground terminals connected to radars, sensors, cameras (where allowed), and other devices that may be located in remote zones. Today, airport authorities may not be able to collect data from these locations, because there is no wireline connectivity and installing wireline infrastructure may be prohibitively expensive. Alternatively, airport authorities may deploy Wi-Fi or other wireless technologies to reach areas that lack wireline connectivity, but this is likely to be an expensive proposition, because the wireless network usage will be limited to a restricted set of devices and applications.

	Airport authorities: Applications supported by AeroMACS
Aircraft	▪ Communications with pilots and crew to coordinate takeoff, landing, maintenance, ground operations, emergencies ▪ ATC surveillance and clearance
Mobile	▪ Communication with ground staff ▪ Communication with airport vehicles ▪ Tracking of mobile assets ▪ Safety and security ▪ Coordination of de-icing, snow removal operations, luggage management
Fixed	▪ Data backhaul from sensors, radars and other connected devices that do not have a wireline connection ▪ Data uploads/downloads with fixed connected terminals ▪ Ground safety and security, including radar, perimeter surveillance, runway incursion prevention, airfield lighting, and detection of intruders, foreign object damage (FOD), and wildlife ▪ Video surveillance (where allowed)

6. Deployment scenarios.
Adapting business models to provide the right deployment incentives

AeroMACS supports multiple business models in which different players own, deploy, operate and use the wireless infrastructure. The adoption of specific business models depends on multiple factors, such as the size of the airport, the role of air traffic control agencies and the airport authority, the presence of airline hubs, and regulation. For instance, a small airport may have a single network that serves all stakeholders, while a large airport may have multiple AeroMACS networks, some of which may serve one player exclusively.

The figure at right shows examples of possible business models. The network operator in each case may be a third-party services player, the airport authority, or the air traffic control agency. We expect that a varied mix of business models will emerge as AeroMACS is deployed, because the local requirements and regulations vary.

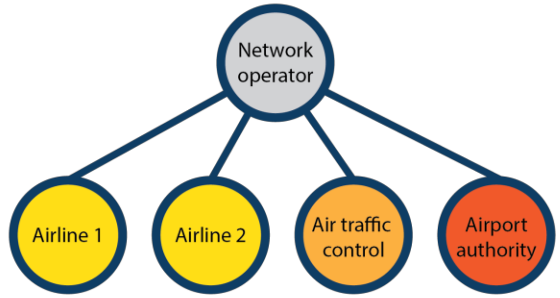
In the first scenario, a single network operator serves airlines, the airport authority, and the air traffic control agency. This simple network model may be attractive to regional airports.

The second scenario shows two networks – one reserved for airlines and the other for air traffic control and the airport authority. The first network may be managed by an external operator that ensures that airlines have equal access to network resources.

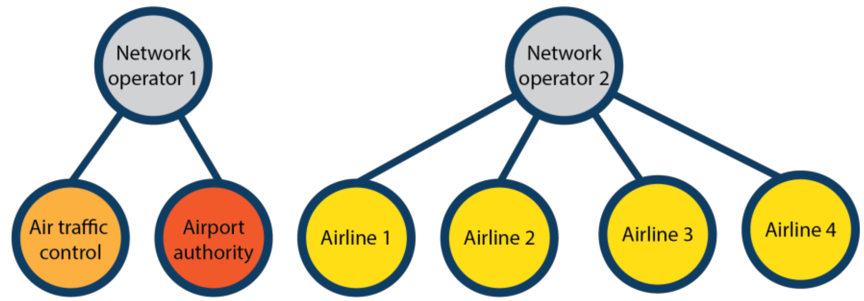
In the third scenario, there are three operators – one for air traffic control only, a second one for a single airline (e.g., an airline that uses the airport as a hub), and a third one with multiple tenants.

Business models to support AeroMACS infrastucture

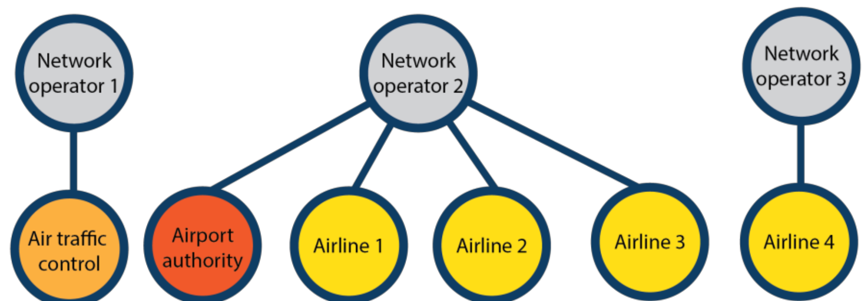
Scenario 1. One network operator, serving all shareholders



Scenario 2. Two network operators, one serving only airlines



Scenario 3. Three network operators, one for air traffic control, one for single airline



7. The network reference model.
A proof-of-concept for AeroMACS in the Dallas–Fort Worth airport

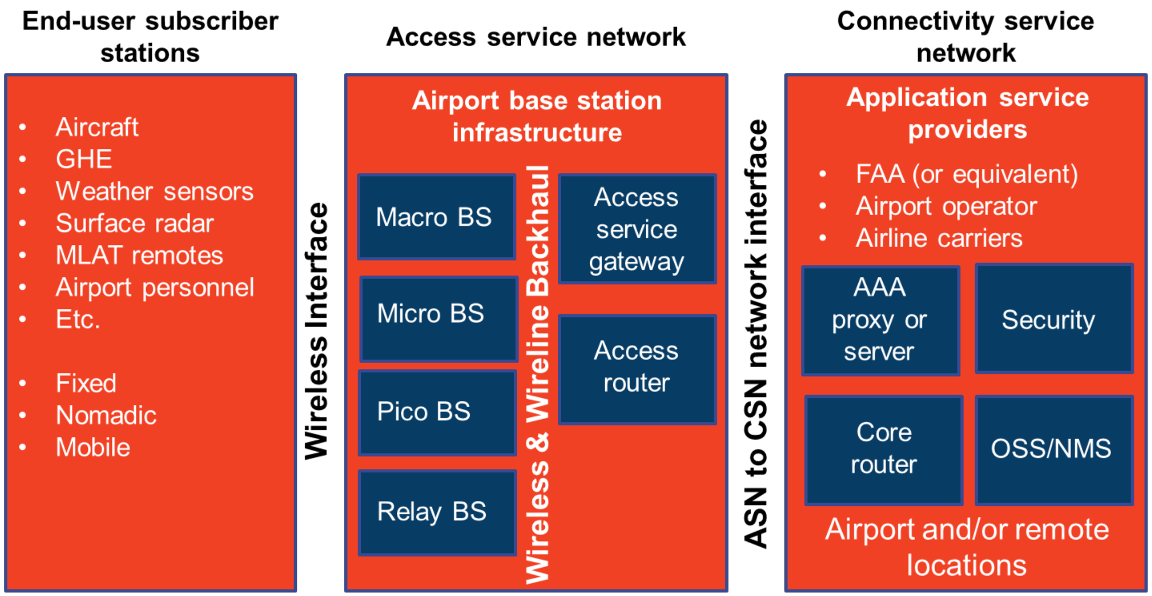
The WiMAX Forum has developed a network reference model as a proof of concept, which it is testing at the Dallas–Fort Worth airport.

In the model, the end-user stations (aircraft, and ground-based fixed and mobile devices or sensors) are linked to the connectivity service networks of the key ecosystem players – traffic control agencies, airports and airlines – through the access service network deployed on the airport grounds. The access service network transports all traffic, while each connectivity service network hosts a selected group of applications.

The POC includes a plan for a phased AeroMACS deployment, in which the coverage and capacity of the access service network grows as the number of applications and amount of traffic increase.

Assuming that the AeroMACS network has a capacity of 70 mbps in the uplink or downlink, it can deliver 31,500 MB per hour. Based on an estimated 650,000 takeoff and landings per year, and each aircraft is connected for about one hour, mostly in the gate area, AeroMACS could deliver over 300 MB per aircraft. (For reference, a high-resolution weather map is 1 to 2 MB.)

AeroMACS network reference model



Source: WiMAX Forum

8. Implications.
AeroMACS benefits increase as the application pool widens

AeroMACS is not a technology whose adoption depends on one or a few killer apps. It is a technology that enables sharing the network infrastructure among ecosystem players, each running multiple applications with a diverse set of requirements.

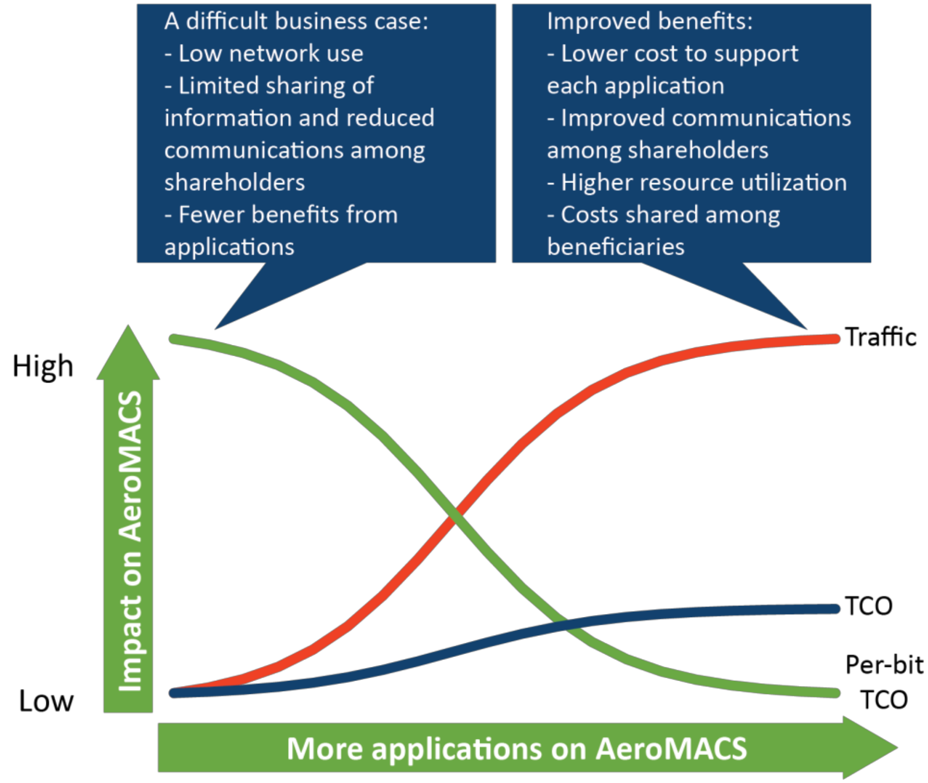
The benefits of AeroMACS networks expand as the number of applications and, hence, the traffic increases. Because the TCO for the network remains largely constant or grows slowly, the per-bit TCO – a more useful measure of the value of the network to the operator – decreases, lowering the cost of running an application.

The worldwide adoption of AeroMACS will necessarily proceed gradually, with the initial deployments occurring in developed countries and large airports. Applications for air traffic management and airport operations will be the first to be adopted, because they are local to the airport and require only coordination between the air traffic control agencies and the airport authorities. With the subsequent adoption by airlines, the role of aircraft-based applications will grow rapidly, along with the overall benefits and cost savings from AeroMACS networks.

As a result, the business case for AeroMACS can be challenging in the initial stage, during which the network operators face high deployment costs but get limited revenues from tenants. The appropriate TCO for AeroMACS requires a mid- to long-term assessment, to include a second phase during which airlines will install AeroMACS.

The success of AeroMACS is predicated on global adoption supported by airlines, which will open the way to full utilization of the network infrastructure. At the same time, however, the application set for different countries, airports and

The benefits of widening the application set in AeroMACS networks

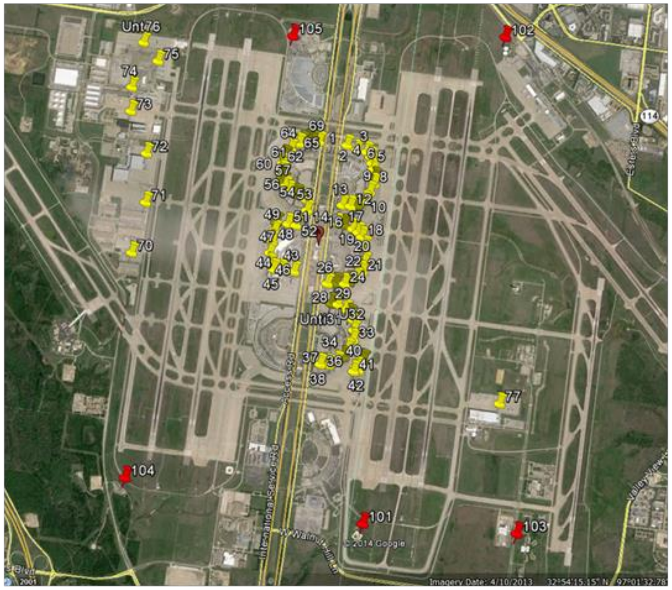


Source: Senza Fili

airlines will vary to fit the specific requirements and preferences of the players, encouraging the ecosystem to continue to innovate and to improve air traffic management.

With AeroMACS, wireless connectivity is no longer the bottleneck, but a shared platform that gives airlines, air traffic control agencies, and airport authorities the flexibility they need to move to the next generation of air traffic management.

AeroMACS proof-of-concept at Dallas-Fort Worth



Source: WiMAX Forum, CelPlan

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Glossary

AAA	Authentication, authorization and accounting
AAC	Area control center
ACARS	Aircraft Communications Addressing and Reporting System
AeroMACS	Aeronautical Mobile Aircraft Communication System
AIP	Air improvement program
AM(R)S	Aeronautical Mobile (Route) Service
AOC	Airline operational control
ASDE-X	Airport surface detection equipment – model X
ASN	Access service network
ASR	Airport surveillance radars
ASSC	Airport surface surveillance capability
ASOS	Automated surface observing system
ATC	Air traffic control
ATM	Air traffic management
AWOS	Automated weather observing system
BS	Base station
CFMU	Central flow management unit
CSN	Connectivity service network
EFB	Electronic flight bag
FAA	Federal Aviation Administration
FMS	Flight management system
FOC	Flight operations center
FOD	Foreign object damage
FTSN	Flexible Terminal Sensor Network
GHE	Ground handling equipment
GPS	Global positioning system
HF	High frequency
IEEE	Institute of Electrical and Electronics Engineers
ITU	International Telecommunication Union
LLWAS	Low-level wind shear alert system
MLAT	Multilateration
NextGen	Next Generation [Air Transportation System]
OSS	Operations support system
POC	Proof of concept
RVR	Runway visual range
SESAR	Single European Sky ATM Research
SWIM	System Wide Information Management
TCO	Total cost of ownership
VDL	VHF Digital Link
VHF	Very high frequency
VOR	VHF omnidirectional radio
WiMAX	Wireless Worldwide Interoperability for Microwave Access
WRC	World Radiocommunication Conference

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