Options for Reliable Wireless On-Board Communications in Aerospace

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Trends in Aerospace

Demand for air transportation continuously growing
→ Europe in 2023: 14% more flights than in 2016*

Reduction of fuel consumption and CO₂ emission
→ Ongoing task supported by innovations

Digitalization as a game-changer
→ Advancing products, services, and ways of working

*http://www.eurocontrol.int/statfor
Trends in Aerospace

**Novel aviation and space options**
- Unmanned Aerial Vehicles (UAV)
- Flying taxis
- High Altitude Pseudo Satellites (HAPS)
- Massive satellite constellations
- ...

→ Enabling also open innovation and new services

*Wireless communications integral part of all platforms*
Passenger Aircraft: Wireless Communication

Non safety-related

- Passenger communication
- Inflight entertainment

Safety-related

- Machine-Type Communications (MTC)
- Crew communications

(Source: Airbus)
Wireless in Aerospace Environment

Certification need including safety and security
→ Highly deterministic and reliable networks

Partially in harsh and inaccessible locations
→ Ruggedized and autonomous wireless nodes

Cost reduction – “COST→COTS”
→ Extended use of standard components and protocols
Wireless vs. Wired Communications

Sparing of cables and harnesses
→ Weight reduction

Marginal (re-)configuration and customization efforts
→ Enhanced productivity

Wireless radio interfaces
→ Replacement of mechanically realized interfaces

Redundancy over wireless and optionally wired media
→ Enhanced reliability

Wired! Weird… ;)

See also: “Lighten up – Towards wireless aircraft,” Airbus Group’s magazine FORUM #87
Aircraft Wireless Network Architectures

Different areas:

- Air-to-ground (mainly via satellites): commander-pilot communications, Internet access, …
- At ground: gatelink, maintenance access, …
- On-board: crew / passenger WiFi, wireless backbones, wireless sensor networks, e.g.:

Design Assurance Level (DAL) Consideration:

- A - Catastrophic / B - Hazardous / C - Major / D - Minor / E - No effect
Wireless Avionics Intra-Communications (WAIC)

WAIC vision:
• Support applications related to “Safety and Regularity of Flight”
• Provide communications between electrical systems on board the same aircraft
• Constitute an exclusive wireless network required for operation of the aircraft

Application areas:
• Sensors: temperature, tire pressure, structure health monitoring, …
• Controls: cabin functions, active vibration control, …
• Communications: flight deck and cabin crew audio/video/data, …

Globally harmonized allocation of protected spectrum: 4.2-4.4 GHz

Starting standardization and industrialization

http://waic.avsi.aero/
Wireless Sensor Networks – Aerospace Application Areas

**Space and Launch Systems**
- Wireless sensors/actuators
- ...

**Fixed Wing**
- Cabin network
- Health monitoring
- Flight test
- Landing gear
- ...

**Rotorcraft**
- Flight test
- Health monitoring
TDMA-Based WSN with AP-Redundancy

Goals addressed by approach:
• Reliability
• Guaranteed latency
• Robust against hacking and jamming
TDMA-Based WSN with AP-Redundancy

Empty Aircraft Cabin
400,000 packets = 78 hours

Measured 1-AP $\text{RSSI} > -60 \text{ dBm}$

J. Blackenstein et al., “Error characterization of multi-Access Point WSNs in an Aircraft Cabin,” IEEE Int. Conf. on Communication Workshop (ICC) 2015
TDMA-Based WSN with AP-Redundancy

Ariane 5
Upper Stage

TDMA: Time Division Multiple Access
WSN: Wireless Sensor Network
AP: Access Point
RSSI: Received Signal Strength Indication
PER: Packet Error Ratio
TDMA-Based WSN with AP-Redundancy

Aircraft Cabin with Passengers
7,000 packets = 1:36 h

RSSI: Received Signal Strength Indication
PER: Packet Error Ratio

TDMA: Time Division Multiple Access
WSN: Wireless Sensor Network
AP: Access Point

→ Redundancy is key!
Redundant Fixed Hopping (RedFixHop) WSN

Approach: Constructive interference based flooding

EWSN 2016 - Dependability Competition – 1st place

IEEE SECON 2016 – Best Demo Award
http://secon2016.ieee-secon.org/content/demos-session

EWSN 2017 - Dependability Competition – 2nd place

High reliability: 100% message delivery despite heavy interference → facilitating certification
Low latency: down to 5 ms → meeting requirements of a large set of aerospace applications
Energy-efficiency:<10 mW → enabling green powering solutions by energy harvesting
Potential 5G Areas for Aerospace

A2A: Air to Air
(D)A2G: (Direct) Air to Ground
Note: WiFi, Gatelink, and safety-related excluded
Enabling of Multi-Path Dimension (Aircraft Case)
Enabling of Multi-Path Dimension (Aircraft Case)

Combination varies over time:
- Throughput
- Delay
- Availability
- …

GEO + Direct A2G
LEO only
Air-to-Air Multihop + Direct A2G

(Qualitative Example)
5G Demonstration Toward Full Virtualization

(Video: [http://eitdigital.eu/icaro-video](http://eitdigital.eu/icaro-video))

Ericsson Aachen ICT Center Eurolab

- vEPC MNO_A
- vEPC MNO_B
- Cloud 5G core lab
- Multiple connections (one per eNB)
- S1-U_A, S1-MME_A, S1-U_B, S1-MME_B

MOCN: Multi-Operator Core Network

Airbus Group Munich (Ottobrunn) A340 Mockup

- Sistelbanda 4G+ small cell with MOCN functionality
- 5G “Radio Flight Rack” (ground)
- Indoor macro RBS6202
- DA2GC (functional Representation)

2.6 GHz band selected (all German operators)

Ericsson 5G “Flight Rack” (ground)

Transport Gateway

- 

~500 km

Munich (Ottobrunn)

Ericsson

Sistelbanda
(Pseudo) Satellites for 5G

Application areas:
- Aircraft
- Underserved areas
- IoT coverage
- Local hotspots
- Rescue missions
- Disaster recovery
- …

Advantages:
- Instant service introduction
- Global coverage
- Marginal ground infrastructure

See also: “Resiliente Netze mit Funkzugang,” VDE-Positionspapier, 03/2017
Conclusions

• Various novel directions for wireless networks in aerospace with high potential

• Challenges:
  – Reliability / energy / latency triangle
  – Integration
  – Certification

• Wireless emerging for reliable on-board communications

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