Recent Developments in Aircraft Wireless Networks

Obi Orjih, oco1@cec.wustl.edu

Abstract

This report discusses some key recent developments in the area of wireless networking on aircraft. We discuss the products and services in commercial aviation that have been driven by the demand for in-flight entertainment and connectivity. We also touch on the research that has enabled this technology. Lastly, we mention the developments in military aircraft wireless networks, and the standards behind them.

See also:

Table of Contents

---

1. Introduction

In recent years, wireless networking has become more commonplace than wired networking. One application domain in which wireless networks are of far greater practical use is aviation, since planes are scattered all over the world. In this paper we discuss recent and future developments in aircraft wireless networks (AWNs). In commercial aviation, the major goals is to provide in-flight Internet connectivity to passengers. We discuss some research which has enabled this technology as well as some current and future services, such as Connexion by Boeing and OnAir, which satisfy this demand. The military uses wireless networks to improve tactical situational awareness for war-fighting aircraft. It is important to note that the AWN paradigm is different in military applications, where the intent is not to connect to the public Internet. The military domain is also where the development of AWNs is the most mature in terms of standardization and ubiquity. We discuss two of the most relevant military AWN standards, Link-16 and JTRS.

Back to Table of Contents

---

2. Research Developments

In this section, we discuss research work dealing with AWNs. Since the motivation for the work in this area is support of in-flight passenger communication, our focus is on research concerning network connectivity from within an aircraft to the outside world. A common architecture for these services found in research and industry is shown in Figure 1. It consists of three basic segments: an aircraft, a satellite link, and a ground station. On the aircraft, a wireless access point can be used to provide connectivity to passengers and crew members. The satellite link provides a connection to the ground station, which is connected to the Internet.

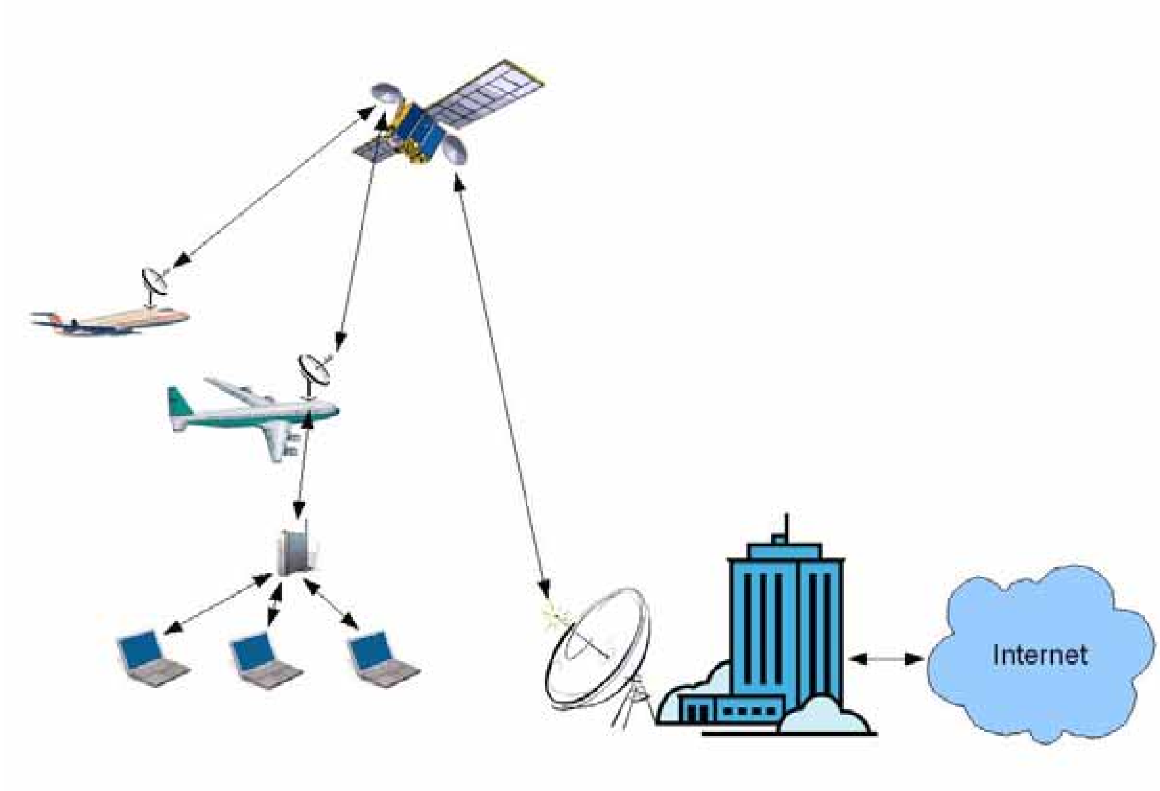

Figure 1 - Example commercial airline network topology

A common thread among the research projects examined here is that each aims find a way to enable AWNs to be more useful and efficient. In fact, some of the research and development work eventually had useful application in industry. The major issues in AWN research that we examine are interoperability, interference, mobility, and quality of service (QoS).

Interoperability is important because airlines are looking to provide different services to their passengers, which requires the use of multiple different technologies. Two of the key services considered are Internet and cellular connectivity. To provide these services, an aircraft must have access points for receiving both kinds of wireless signals and be able to transmit traffic from both systems to the ground via the satellite link. Interference comes into play because it is undesirable for these transmissions to interfere with the navigational and communications systems needed for operation of the aircraft. Case studies have shown that there have been times where passenger personal electronic devices (PEDs) have caused aircraft systems to malfunction. However, some research studies indicate that this should not be the case.

The physical movement of the aircraft makes mobility and QoS issues of concern. An aircraft and the ground stations with which it communicates must be mobility-aware, as the aircraft is essentially a moving network. As it moves, an aircraft must register with each new ground station it encounters in order to establish a path for traffic to and from the aircraft. The ground station must also handle routing to the multiple nodes which reside on each aircraft connected to it. The process of switching between satellites and/or ground stations can cause a loss or degradation of service for passengers. The architecture of the communication system should be such that the impact of handovers on QoS is minimized. We examine research dealing with these issues in the following subsections.

2.1 Integration and Interoperability

One research project developed to demonstrate interoperability in AWNs was the Terrestrial Hybrid Environment for Verification of Aeronautical Networks (THEVAN). As the name suggests, the platform was not actually an aircraft, but a modified ambulance chassis loaded with racks of wireless networking equipment. The intent was to demonstrate the integration of different technologies which could be used to provide network services in an aircraft. These technologies included a Ku-band satellite system, a medium data-rate satellite system (MDSS), a commercial Very High Frequency (VHF) radio, and IEEE 802.11b. The Ku satcom phased array antenna was used to provide a full-duplex 2 Mbps/256 kpbs (downlink/uplink) connection to a fixed ground station via satellite. The MDSS was composed of 16 L-band Globalstar-compatible satellite phones providing an aggregate data rate of 112 kbps. The VHF data radios were commercial modems which provided a 19.2 kbps full-duplex link. Cisco 802.11b (11 Mbps) access points were used with external bi-directional amplifiers and omni directional antennas. The testbed was used to evaluate IP-based (Mobile IPv4 and IPv6) connections on a mobile platform. They demonstrated that TCP and UDP connections could be maintained as the platform moved through a wide area. They also showed that the different networking technologies could be integrated to provide Internet services, such as Hyper Text Transfer Protocol (HTTP) and File Transfer Protocol (FTP), to users. THEVAN was also able to switch between the different forms of RF connectivity as they became available [Brooks04].

Unlike THEVAN, the WirelessCabin project was tested on airplanes. The goal of the project was to develop an architecture for in-flight wireless access for passengers. The technologies considered for integration in this project were GSM, UMTS, WLAN (IEEE 802.11), and Bluetooth. In their system, a 3G piconet and an 802.11 WLAN are set up for passengers to use to connect to the outside world. In addition, passengers can set up Personal Area Networks (PANs) for their personal devices using Bluetooth. This would all operate in one environment without the wireless technologies interfering with each other. Their architecture consisted of three segments: cabin, transport, and ground. Network traffic was partitioned into four QoS classes, first (highest priority) through fourth, depending on real-time requirements. However, support of this classification was an issue when integrating the different technologies. For example, UMTS provides QoS support while 802.11 did not [Jahn03b]. The culmination of this work was a demonstration flight aboard an Airbus A340 aircraft in September 2004. During the flight, GSM and VoIP voice services and IP e-mail and web services were successfully demonstrated [Jahn04].

2.2 Interference

Another area of concern is the potential interference of wireless communication equipment with aircraft navigation and communication systems. PEDs emit two kinds of radiation: intentional and spurious. Intentional emissions are those with the purpose of transmitting data in the allocated frequency bands of the PED. Only devices which communicate via wireless links have these. Spurious emissions are those which are unintentional, and contribute to the RF noise level. Although all PEDs have these, they are more significant in wireless PEDs. Intentional transmissions are normally not a concern because their frequency bands are limited and do not overlap the frequencies of airline systems, as shown in Table 1. However, if the power level of a spurious emission is high enough at a receiving frequency of an aircraft nav/comm system, it could interfere with aircraft operations [Jahn03a].

Table 1 - Frequency ranges of wireless communication equipment and aircraft nav/comm systems [Jahn03a]

Omega navigation 10 - 14 kHz	ADF 190 - 1750 kHz	HF 2 - 30 MHz	Marker beacon 74.85, 75, 75.-5 MHz	VOR/LOC 108 - 118 MHz	VHF COM 118 - 136 MHz	Glide slope 328 - 335 MHz

GSM 400 450 - 496 MHz	GSM 850 824 - 894 MHz	GSM 900 876 - 950 MHz	DME 960 - 1220 MHz	TCAS/ATC 1030, 1090 MHz	GPS 1575 MHz	SATCOM 1529, 1661 MHz
GSM 1800 1710 - 1880 MHz	European UMTS 1880 - 2025, 2110 - 2200 MHz	GSM 1900 1850 - 1900 MHz	IMS band: 802.11b, Bluetooth 2446.5 - 2483.5 MHz	Low-range altimeter 4.3 GHz	Microwave landing system 5.03, 5.09 GHz	802.11a 5.15 - 5.35 GHz
Weather radar 5.4 GHz	802.11a 5.725 - 5.825 GHz	Weather radar 9.3 GHz	Sky radio 11.7 GHz	DBS TV 12.2 - 12.7 GHz		

Studies on the interference of PEDs with aircraft systems have produced conflicting results. Some studies based on incident reporting seem to indicate that PEDs interfere with avionics systems. One study indicated that of the 40 PED related reports collected by the International Transport Association, laptop computers (40%) were the most frequent cause of the trouble and that navigation systems (68%) were the most affected. The study also pointed out that in three of those cases it was verified that the problem ceased when the PED was turned off and reappeared when the PED was turned back on [HousePED00]. Another study which examined the Aviation Safety Reporting System database reaffirmed that navigation systems (112 out of 130 system anomalies) were most affected by PEDs. Cell phones and laptop computers (25 each out of 104 incidents where the PED was identified) were the most common culprits [NASAPED01].

However, a few recent studies have shown that PEDs should not generate powerful enough spurious emissions to interfere with aircraft systems. One such study tested the spurious emissions of various cellular technologies against the operating frequencies of some common nav/comm systems. The author concluded that the technologies tested (CDMA-Cellular, TDMA-11 Hz, TDMA-50 Hz Cellular and PCS, GSM, and DCS 1800) in the lab environment should not interfere with VHF omni-directional range (VOR), localizer (LOC), VHF communication, glide slope (GS), and global positioning system (GPS) avionics systems [Kuriger03].

2.3 Mobility

The Aeronautical Telecommunications Network (ATN), developed by the International Civil Aviation Organization, was envisioned as a way to provide ground/ground and air/ground data communications services in the aviation industry. ATN is based on the seven-layer Open Systems Interconnection (OSI) model. It is a private network with its own addresses, and a scheme for providing network mobility for aircraft. Their mobility solution was based a large address space and backbone routers updating path information in the network. When an aircraft attached to a new access point, the associated backbone router would pass the routing information for that aircraft's network back through the ATN backbone. The ATN also has specifications for managing different QoS levels. Although the standard has been in development for over 15 years, ATN is used only in a limited range of applications in the industry, such as Air Traffic Services (ATS) and Airline Operation Communications (AOC) [Smith01].

As the passenger communications business began to accelerate, it was necessary to analyze which network model would be the most useful in the future. The rest of the world was using IP and its services while the airline industry was implementing ATN. In order to provide passengers with Internet connectivity, IP has to be supported. The decision is then how to provide ATN services over IP. There were four proposals for a new architecture:

- Transitional scenario using an airborne gateway
    - Mobility support using ATN
- Transitional scenario using a ground-based gateway

  - Mobility support using Mobile IPv4
- Transitional scenario using an IP Subnetwork Dependent Convergence Function (SNDCF)
  - Mobility support using ATN
- Interoperability scenario using TCP/IPv6
  - Mobility support using IPv6

The interoperability scenario using IPv6 is the preferred solution as this would provide many of the mobility and QoS services native to ATN [Netto03]. One disadvantage of Mobile IPv4 when compared to ATN is increased delay due the extensive use of tunneling, especially with the multiple expected route switches during a long flight. The route optimization schemes in IPv6 will help mitigate this issue. The current problem is that IPv6 is yet to be widely deployed. Despite this, ATN has failed to catch on, and Mobile IPv4 has become the popular solution for aircraft network mobility. For example, the research done in [Brooks04] and [Che05] use schemes based on Mobile IPv4 as their mobility solutions.

2.4 Quality of Service

QoS is an important issue for satellite links which are used to support passenger communication because efficient handover algorithms are needed as planes move from one satellite's coverage area to another's. This is compounded by the fact that these links have long propagation delays, are prone to errors, and are limited in bandwidth. These challenges were the subject of a few research projects.

The Network Architecture and Technologies for Airborne Communications of Internet High Bandwidth Applications (NATACHA) project was commissioned by the European Union to develop an architecture for aircraft passenger communication and to evaluate the performance of IP-based multimedia services in the system. Although the project officially lasted from May 2002 to July 2004, related work was still ongoing in 2005 [NATACHA]. The architecture they developed, dubbed Aeronautical Broadband Communication System (AirCom), consisted of the same three segments that are present in other research work and industry: airborne, satellite, and ground. They concluded that satellite links with Code Division Multiple Access (CDMA) bandwidth sharing would be best suited in this application domain. They also proposed a bandwidth on demand (BoD) end-to-end QoS scheme based on IP's IntServ [Dini05a]. For local link management, they divided the network traffic into three classes:

- Constant Bandwidth Allocation
  - Strict real-time requirements
- Dynamic Bandwidth Allocation
  - Based on network load - stringent delay and packet loss requirements, relaxed jitter requirements
- Best Effort Allocation
  - No QoS parameters

Their simulation results led to the conclusion that a Multi Code CDMA (MC-CDMA) resource allocation technique using a Packet-by-packet General Processor Sharing (P-GPS) algorithm for QoS buffer prioritization worked best in managing the different QoS levels [Dini05b].

Other research has also used IP-based services for managing QoS. One such study developed an inter-satellite handover framework which integrates Mobile IPv4 and RSVP signaling while taking into account the added constraints of satellite links. Handovers are divided into three phases: information collection, handover decision, and handover execution. Upon handover execution, resource re-reservation need only take place on the new satellite link between the airborne mobility router and the ground mobility server using the previous RSVP reservations. Simulation results showed significant performance improvement when RSVP was used during handover [Che05].

So far we have explored research issues dealing with AWNs. This research has been done in support of the commercial airlines' desire to provide network connectivity to passengers while in flight. In the next section, we examine some of the services which are available in industry.

Back to Table of Contents

3. Commercial Developments

Until recently, passenger aircraft were one of the last places where the public could not receive Internet connectivity and services that are offered on the ground. Recent developments have started to change this. The initial service offerings were limited in data rates and constrained to seat-back interfaces. This proved to be unprofitable as the real passenger demand was for bandwidth-demanding multimedia services on their own PEDs. An architecture to support this is being put in place, as the next generation of aircraft communication satellites is being deployed. In this section we discuss this satellite system owned by Inmarsat and the services that are, and are soon to be, offered using them. In addition, we discuss the current market leader in passenger communication services, Connexion by Boeing, whose services are not provided using Inmarsat.

3.1 Satellite Services

Although there are other satellite service providers, including Iridium and Globalstar, the biggest player in providing satellite communication for commercial aircraft is Inmarsat, an international company which operates a constellation of 11 geostationary satellites. Of these satellites, four are I-2 (second generation), five are I-3 (third generation), and two are I-4 (fourth generation). Inmarsat offers services in multiple sectors, including telephony, maritime, and aeronautic. Their satellites provide three kinds of coverage: global beam, wide spot bean, and narrow spot beam. The global beam is capable of covering about one-third of the earth's surface, but provides low data rate communication [Inmarsat2].

Of Inmarsat's Aero services which are currently widely available, the most recent is Swift64, which offers up to 64 kbps per channel, 6.67 times faster than any of their other services. This done using the wide spot beam on the I-3 and I-4 satellites. Swift64 terminals can offer up to 4 channels, increasing the data rate to 256 kbps per terminal. Channel bonding and data acceleration techniques can boost the effective data rate close to 0.5 Mbps [Swift64]. The narrow spot beam capability of I-4 satellites will be the backbone of Inmarsat's planned Broadband Global Area Network (BGAN) services. BGAN, also known as SwiftBroadband, will offer up to 492 kbps, which can be used to support Internet services and GSM. When the system is complete there will be three I-4 satellites, one positioned over each major ocean (Pacific, Atlantic, and Indian) [Inmarsat1].

Swift64 is currently being used to provide Internet connectivity to mostly business and corporate travelers. One example of a company which does this is EMS Satcom, which equips corporate jets with antennas and terminals which are compatible with Swift64. Their eNfusion product line offers travelers up to 256 kpbs using 4 Swift64 channels [EMSSATCOM]. Other companies like Satcom Direct offer similar services [SatcomDirect]. ARINC's SKYlink is another business jet solution which offers data rates of up to 3.5 Mbps upstream and 128 kbps downstream, though it does not use Inmarsat technology [SKYLink].

3.2 Airline Services

OnAir, a joint venture between Airbus and SITA INC, aims to provide Internet connectivity to all airline passengers, not just VIPs. This service is based on Inmarsat's SwiftBroadband, and is advertising shared data rates of up to 864 kbps. The service will allow Internet and GSM/GPRS (2.5G), and will be offered on both Boeing and Airbus aircraft. OnAir currently offers in-seat telephony and text messaging, but looks to roll out their full service in early 2007. Their coverage area will be complete when Inmarsat launches the third and final I-4 satellite, to be positioned over the Pacific Ocean, later in 2007 [OnAir].

The first company to market with an in-flight passenger connectivity service does not use the Inmarsat satellite constellation. Boeing rolled out its Connexion by Boeing service in 2004, using Ku-band satellite equipment leased from its satellite businesses and other business partners [Connexion2]. The service offers a high-speed two-way Internet connection and global TV. This is provided on multiple partner carriers on both Boeing and Airbus aircraft [Connexion1]. Each transponder can provide data rates of 5 Mbps downlink and up to 1 Mbps uplink. An aircraft may carry multiple transponders, and so may receive more data, up to 20 Mbps, downlink. However, the uplink traffic per aircraft is capped at 1 Mbps. In addition to in-flight passenger entertainment, the service (like other connectivity services) can be used for aircrew and airline operations [Connexion3]. Tests are ongoing to offer in-flight telephony, over CDMA-2000 and GSM, using the service. The service is also offered to executive jets [Connexion1].

Connexion by Boeing is also noteworthy for their network mobility approach. In order to avoid the increased delay due to tunneling associated with Mobile IP, they use a scheme based on Border Gateway Protocol (BGP) routing updates. This works because BGP is universally supported and is the backbone routing protocol of the Internet. In their system, ground stations only advertise network IP addresses for the aircraft that they are currently serving. They start with a /24 address block advertisement, which is normally sufficient for propagation. In the case that it is not, the size of the advertised network is increased. Testing has shown that the time to set up a two-way connection with a satellite is complementary with the time it takes BGP updates to globally converge [BGPMobility]. This means that the new route is ready for use at the same time the satellite link is.

Back to Table of Contents

4. Military Developments

As mentioned earlier, the structure of military AWNs is very different from that found in commercial aviation. The purpose of these networks is not to provide Internet services, but to increase tactical situation awareness for pilots and weapon systems operators. A generalized network topology is shown in Figure 2. An airborne command and control (C2) center, such as the Airborne Warning and Control System (AWACS), is usually the main hub of activity. In addition to the battle management tasks, AWACSs typically report status back to central command on the ground. The network is used to exchange communication, navigation, and identification (CNI) as well as tactical information over voice and data channels. Interoperability between the different aircraft platforms is enabled through rigorous standardization. In this section we discuss the latest standards in military AWNs. One should note that although the information presented here was gathered from publicly available sources, the standards themselves are not publicly available due to export restrictions.

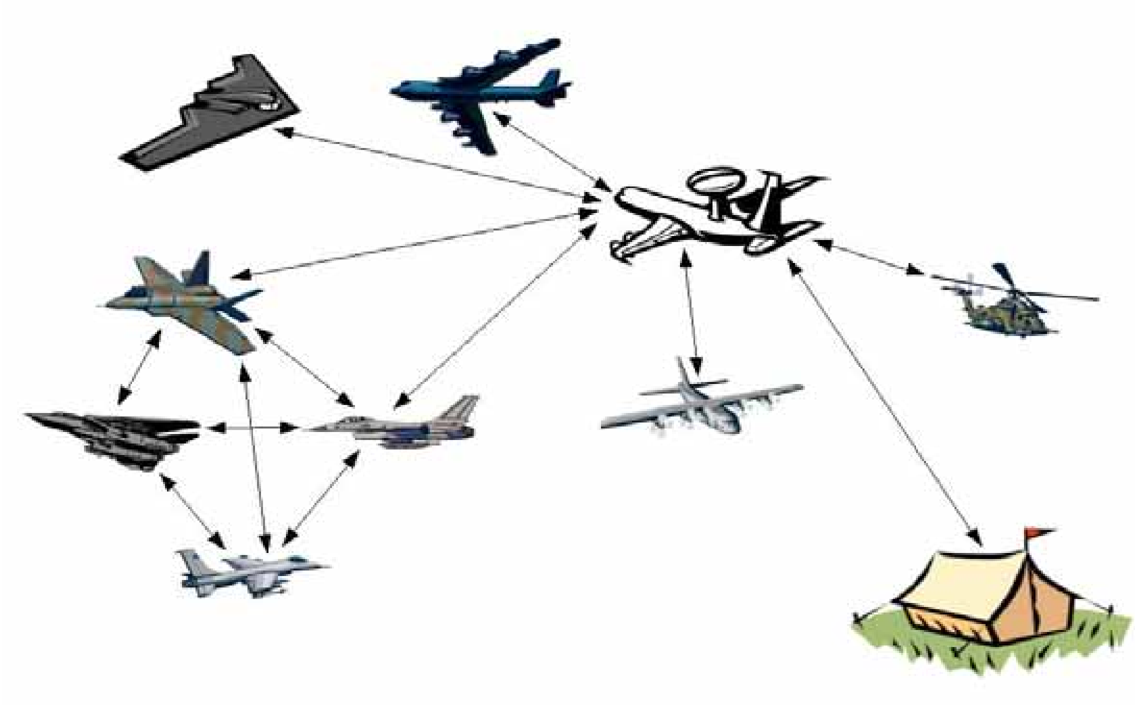

Figure 2 - Example tactical military network topology

4.1 Link-16

The latest in tactical data links is Tactical Digital Information Link J (TADIL-J), which was developed for the U.S. armed forces. TADIL-J is defined by U.S. MIL-STD-6016, and has been adopted by NATO and other nations around the world as Link-16 [Link16, TADILJ]. Link-16 improves upon the features of its predecessors, Link-11 (TADIL-A) and Link-4A (TADIL-C). There are two classes of terminals which implement Link 16: Joint Tactical Information Distribution System (JTIDS) and Multifunctional Information Distribution System (MIDS) terminals. Because MIDS terminals are required to be smaller and lighter due to platform necessities, they implement a smaller set of the standard than JTIDs terminals do. [TADIL, JTIDS].

Link-16 provides for a high-speed, jam-resistant, secure network. It improves on its predecessors in these three areas as well as information granularity and reduced terminal size. The link is shared using a TDMA protocol which calls for a 12.8 minute epoch with 64 frames of 1536 slots of length 7.8125 ms. This is illustrated in Figure 3. The standard provides for the allocation of slots in a frame as needed for throughput requirements. The network is partitioned into nets, of which there can be 132 in an area. Each net can have up to 32 participants. The possible message formats include fixed, free text, and variable. The link operates in the L band between 969 MHz and 1.206 GHz. [DataComm, JTIDSLink16]

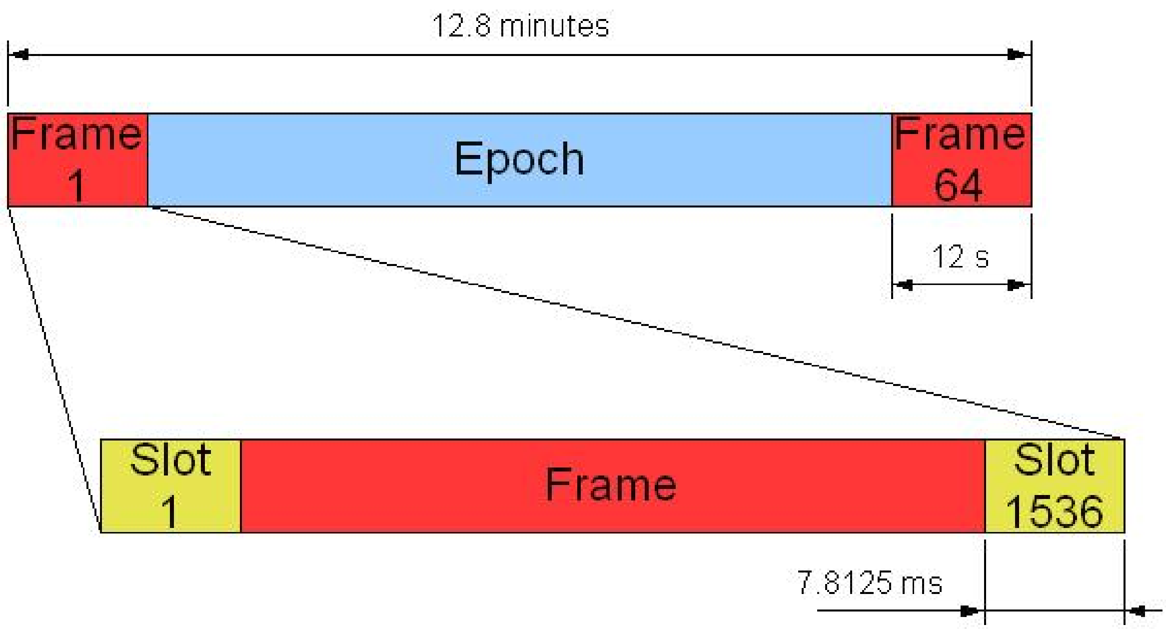

Figure 3 - Link-16 TDMA structure

Network segregation is done in two ways. First, a JTIDS Unit (JU) must have the proper configuration information to enter a net. Within a net, the time slots can be allocated to Network Participation Groups (NPGs) based on function. The groups include: Surveillance, Electronic Warfare, Mission Management, Weapons Coordination, Air Control, Fighter-to-Fighter, Secure Voice, and Precise Participant Location and Identification (PPLI). JUs need only participate in NPGs which support their mission [DataComm].

Data transmission is performed using a frequency hopping scheme which is highly resistant to jamming. Frequency hopping is performed every 13 ms to one of 51 channels. In addition to frequency hopping, security is provided using crypto variables. One crypto variable is used to encrypt the data to be transmitted, and another is used to control the transmitted waveform. In addition, pseudo-random noise and jitter can be added to the signal to increase difficulty of detection and jamming. Adding a jitter portion to the beginning of every slot halves the data rate. In addition, every other message pulse can be repeated so that Reed-Solomon Forward Error Correction can be used to salvage the message if it is being jammed. This also haves the data rate of the link. If no dynamically configurable security options are chosen, data can be transmitted at up to 107.56 kbps. [Link16, JTIDSLink16, DataComm].

4.2 JTRS

Another military wireless networking standard worth mentioning is the Joint Tactical Radio System (JTRS). JTRS is the next generation radio for US military field operations. It has a large operating bandwidth, from 2 MHz to 2+ GHz. Another unique aspect of JTRS is that it is a software-defined radio which provides both voice and data transfer. These two characteristics enable it to be backwards compatible with many military and civilian radio systems, including Link-4A, Link-11, and MIL-STD-188-181 UHF SATCOM. It includes encryption capabilities for security and Wideband Networking Software for mobile ad hoc networks. Depending on the configuration of the radio, burst rates of up to 1.2 Mbps are achievable. The program is still in development, and will be rolled out in clusters. Two of the five clusters (1 and 4) include requirements for aircraft [JTRS1, JTRS2].

Like JTIDS/Link-16, JTRS will provide a means for secure voice and data transmission, which will be used to increased situational awareness while in combat. This model is in contrast to that of commercial aviation, where the goal is to provide in-flight connectivity to the public Internet.

Back to Table of Contents

5. Summary

AWNs continue to be an area of great interest and development, particularly in commercial aviation. This is driven by passenger demand for in-flight entertainment and communication services. Connexion by Boeing was the first in the airline market to offer services with which passengers could use their own PEDs. However, they will have stiff competition from companies such as OnAir, which will offer services based on Inmarsat's SwiftBroadband. As these products and services continue to roll out, the impact of research in the field, which played a big part in making this all possible, is likely to be diminished. In the military realm, implementation is driven by standardization. Link-16 has been deployed for many years and is common on most war-fighting aircraft platforms. The highly configurable JTRS is being developed to replace many legacy military radio platforms, providing both voice and data services.

Back to Table of Contents

---

6. References

[Jahn03a] Jahn, A., Holzbock, M., Muller, J., Kebel, R., de Sanctis, M., Rogoyski, A., Trachtman, E., Franzrahe, O., Werner, M., Hu, F., "Evolution of aeronautical communications for personal and multimedia services," IEEE Communications Magazine, July 2003.
http://www.coe.montana.edu/ee/rwolff/Games%20Project/literature%20search/Aeornautical%20communications.p
Article on the evolution of aeronautical communications technologies used for passenger multimedia servies.

[Jahn03b] Jahn, A., Nicbla, C.P., "System architecture for 3G wireless networks in aircraft," IEEE 58th Vehicular Technology Conference (VTC 2003).
Describes an architecture for the convergence of technologies to support 3G communication in aircraft.

[Jahn04] "Results from the WirelessCabin Demonstration Flight,"
http://www.eurasip.org/content/Eusipco/IST05/papers/295.pdf
Technical report which discusses the results from the WirelessCabin demonstration flight.

[DataComm] "Fire Controlman Volume 06 - Digital Communications, Chapter 5 - New Technology in Data Communications," http://www.tpub.com/content/fc/14103/css/14103_73.htm
Handbook on data communication with information on military aircraft networks such as Link-4A, Link-11, and Link-16.

[Connexion1] "Connexion by Boeing," http://www.connexionbyboeing.com/
Connexion by Boeing home page.

[Connexion2] "Connexion by Boeing - Wikipedia," http://en.wikipedia.org/wiki/Connexion_by_Boeing
Wikipedia article on Connexion by Boeing.

[Connexion3] "Broadband Connectivity to Aircraft,"
http://www.itu.int/ITU-R/study-groups/seminars/rsg8-tech-innov/docs/3.4-broadband-connectivity-to-aircraft.ppt
Presentation with details on the broadband connectivity scheme used in Connexion by Boeing.

[TADIL] "Tactical Digital Information Links (TADIL)," http://www.fas.org/irp/program/disseminate/tadil.htm
Webpage with information on TADILs, including TADIL-A/B, TADIL-C, and TADIL-J.

[JTIDSLink16] "JTIDS Link 16,"
https://wrc.navair-rdte.navy.mil/warfighter_enc/weapons/SensElec/Sensors/link16.htm
Webpage with information on JTIDS/Link-16.

[Dini05a] Dini, P., Cusani, R, "End to End Quality of Service Management for Multimedia Service Provision in the Aeronautical Broadband Communication System," 14th IST Mobile & Wireless Communications Summit, 2005. http://www.eurasip.org/content/Eusipco/IST05/papers/340.pdf
Proposes an end-to-end QoS scheme for wireless aircraft networks.

[Dini05b] Dini, P., Signoretti, F.M., Cusani, R., "Resource Allocation Policies for QoS Guarantee Service Provision over a CDMA Satellite Return Link in the Aircraft Broadband Communication System," 2nd International Symposium on Wireless Communication Systems, 2005.
Proposes an resource allocation scheme for QoS in aircraft wireless networks.

[Che05] Che, H., Chan, P.M.L., Hu, Y.F., "Design and Analysis of QoS-Enabled Handover Algorithm for Aeronautical Communication Systems," 2nd International Symposium on Wireless Communication Systems, 2005.
Discusses QoS maintenance during satellite handover in aeronautical wireless networks.

[Brooks04] Brooks, D., Wilkins, R., Hoder, D., "Mobile IP communications for aeronautical applications," 23rd Digital Avionics Systems Conference (DASC 2004).
Discusses a project for demonstrating integration of technologies for wireless aircraft communications.

[Smith01] Smith, P., "IPSky: IPv6 for the Aeronautical Telecommunications Network," Digital Avionics Systems Conference, 2001.
Discusses the potential transition to IPv6 as a mobility solution for aircraft networks.

[Netto03] Netto, C., Khannna, M., "ATN Over IP Models for Evaluation," Digital Avionics Systems Conference, 2003.
Discusses the provision of ATN services over Mobile IP.

[JTRS1] "Joint Tactical Radio System (JTRS)," http://www.defense-update.com/products/j/JTRS.htm
Webpage which discusses JTRS at a high level.

[JTIDS] "Joint Tactical Information Distribution System - Wikipedia," http://en.wikipedia.org/wiki/JTIDS
Wikipedial article on JTIDS.

[Link16] "Link 16 - Wikipedia," http://en.wikipedia.org/wiki/Link_16
Wikipedial article on Link-16.

[TADILJ] "TADIL-J - Wikipedia," http://en.wikipedia.org/wiki/TADIL-J
Wikipedial article on TADIL-J.

[JTRS2] "Joint Tactical Radio System - Wikipedia," http://en.wikipedia.org/wiki/Joint_Tactical_Radio_System
Wikipedial article on JTRS.

[Inmarsat1] "About Inmarsat - Our satellites," http://about.inmarsat.com/satellites.aspx?top_level_id=3&language=EN&textonly=False
Inmarsat webpage which discusses their satellite systems.

[Inmarsat2] "Inmarsat - Wikipedia," http://en.wikipedia.org/wiki/Inmarsat
Wikipedial article on Inmarsat.

[Swift64] "Aeronautical Services Swift 64," http://aero.inmarsat.com/services/swift_64.aspx?top_level_id=3&sub_level_id=1&language=EN&textonly=False
Inmarsate webpage which discusses their Swift64 service.

[BGPMobility] "Global IP Network Mobility using Border Gateway Protocol," http://www.apnic.net/meetings/19/docs/sigs/routing/routing-pres-skeen-global-ip-netmob.pdf

Presentation with details on the BGP routing scheme used in Connexion by Boeing.

[HousePED00] "Portable Electronic Devices: Do they really pose a safety hazard on aircraft," http://www.house.gov/transportation/aviation/hearing/07-20-00/07-20-00memo.html
House of Representatives report on the potential hazard of PEDs on aircraft.

[NASAPED01] "Personal Electronic Devices and Their Interference With Aircraft Systems," http://techreports.larc.nasa.gov/ltrs/PDF/2001/cr/NASA-2001-cr210866.pdf
NASA report on cases of PED interference in aircrafts.

[Kuriger03] Kuriger, G., Grant, H., Cartwright, A., Heirman, D., "Investigation of Spurious Emissions From Cellular Phones and the Possible Effect on Aircraft Navigation Equipment," IEEE Transactions on Electromagnetic Compatibility, Vol. 45, 2003.
Article which investigates the emissions by cell phones and their potential for interference with aircraft systems.

[EMSSATCOM] "EMS SATCOM Aeronautical Solutions," http://www.emssatcom.com/solutions/s_aeronautical.asp
EMS SATCOM web page on their aeronautical communication solutions.

[SatcomDirect] "Satcom Direct," http://www.satcomdirect.com/
Satcom Direct home page.

[SKYLink] ""SKYLink by ARINC Direct," http://www.arinc.com/products/business_aviation_services/skylink.html
ARINC webpage which discusses its SKYLink products.

[OnAir] "Top 50 Questions About OnAir", http://www.tenzing.com/en/faq/faq_en.pdf
OnAir frequently asked questions brochure.

[NATACHA] "NATACHA EU Project", http://labreti.ing.uniroma1.it/natacha/index.htm
Webpage which discusses the NATACHA project.

Back to Table of Contents

---

7. List of Acronyms

Back to Table of Contents

3G - Third generation (in mobile communication)
ADF - Automatic Direction Finder
AirCom - Aeronautical Broadband Communication System
ATC - Air Traffic Control
AOC - Airline Operation Communications
ATN - Aeronautical Telecommunications Network
ATS - Air Traffic Services
AWACS - Airborne Warning and Control System
AWN - Aircraft Wireless Network
BGAN - Broadband Global Area Network
BGP - Border Gateway Protocol
BoD - Bandwidth on Demand
C2 - Command and Control
CDMA - Code Division Multiple Access
CNI - Communication, navigation, and identification

DBS - Direct Broadcast Satellite
DCS - Digital Cellular System
DME - Distance Measure Equipment
FTP - File Transfer Protocol
GPS - Global Positioning System
GS - Glide slope
GSM - Global System for Mobile Communication
HF - High Frequency
HTTP - Hyper Text Transfer Protocol
IMS - Industrial, Scientific, and Medical
IntServ - Integrated Services
IP - Internet Protocol
JTIDS - Joint Tactical Information Distribution System
JTRS - Joint Tactical Radio System
JU - JTIDS Unit
LOC - Localizer
MC-CDMA - Multi Code CDMA
MDSS - Medium Data-rate Satellite System
MIDS - Multifunctional Information Distribution System
NATACHA - Network Architecture and Technologies for Airborne Communications of Internet High Bandwidth Applications
NATO - North Atlantic Treat Organization
NPG - Network Participation Group
OSI - Open Systems Interconnection
P-GPS - Packet-by-packet General Processor Sharing
PAN - Personal Area Network
PCS - Personal Communication Service
PED - Personal electronic device
PPLI - Precise Participant Location and Identification
QoS - Quality of Service
RF - Radio frequency
RSVP - Resource ReSerVation Protocol
SNDCF - Subnetwork Dependent Convergence Function
TADIL - Tactical Digital Information Link
TCAS - Traffic alert and Collision Avoidance System
TCP - Transmission Control Protocol
TDMA - Time Division Multiple Access
THEVAN - Terrestrial Hybrid Environment for Verification of Aeronautical Networks
UDP - User Datagram Protocol
UHF - Ultra High Frequency
UMTS - Universal Mobile Telecommunications System
VHF - Very High Frequency
VoIP - Voice over IP
VOR - VHF omni-directional range
WLAN - Wireless Local Area Network

Back to Table of Contents

Last modified: April 23 2006
Note: This paper is available online at http://students.cec.wustl.edu/~oco1/CS574/Project/index.html