Communications Basics

853 ELSG/NT
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Ann Heinke
853 ELSG/NT (contr)
(970)663-4529
Agenda

- Communications Basics
- Vocabulary
- Aeronautical Voice Communications
  - VHF radios
- Aeronautical Data Communications
  - OSI Model
  - Applications
  - Protocol Stacks (ACARS & ATN)
  - FANS 1/A Defined
  - Media (VHF, SATCOM, HFDL)

ESC/PA clearance number is ESC 07-0358
Communications Requisites

- Users needing to communicate
- Something to talk about
- Language
- Medium to carry comms
- Conversation Rules

- Pilots & a/c, controllers
- Air Traffic Control procedures & surveillance
- DO-258 syntax and semantics (ASN.1/PER, phraseology, etc.)
- SATCOM, VHF, HF, etc.
- DO-212, DO-219, ARINC 622 protocols
FANS1/A Network

Aircraft & Flight Crew

ATC Controller

ARINC 618+622

DSP Network

ARINC 620+622

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Vocabulary

- ATN – Aeronautical Telecommunications Network
- FANS – Future Air Navigation System
- ADS – Automatic Dependent Surveillance
- CPDLC – Controller Pilot Data Link Communication
- ATS – Air Traffic Services
- AFN – ATS Facilities Notification
- OSI – Open Systems Interconnect
- ISO – International Organization for Standardization
Vocabulary

• **End System** – host computer responsible for generating and decoding application messages

• **Router** – relays and forwards packets across multiple subnetworks, which may belong to different administrations

• **Subnetwork** – relays and forwards packets across a single protocol-based network, belonging to a single administration

• **Data Link** – relays and forwards frames point-to-point
Vocabulary

• Transceiver: a radio receiver and transmitter housed in one device. Also known as walkie-talkies or 2-Way Radios, transceivers are bi-directional radios, first developed for military use. Major characteristics include a half-duplex (only one handset unit can receive and transmit at a time) channel and a push-to-talk switch that starts transmission.
Aeronautical Voice Comms

- VHF radios have been in use for ATC communications worldwide since the beginning of ATC
- Invented by Marconi in 1895, the amplitude modulation radio has basically remained unchanged for decades
- VHF radios provide LOS 2-way voice capability on a per-channel basis
- Most regions require airborne radios to support 25kHz channel spacing
Aeronautical Voice Comms

• Spectrum congestion in Europe has led to various methods to increase # of channels, with same spectrum & equipment
  – CLIMAX (offset carrier)
  – 8.33 kHz channel spacing
• Frequency range is the same (118 MHz to 137 MHz)
• Tighter channel spacing yields more comm channels
  – From 760 channels at 25kHz,
  – To 2280 channels at 8.33 kHz
Aeronautical Voice Comms

- To the operator, basic difference is in number of digits called out in the VHF channel:
  - 6 digits vs. 4 digits
  - i.e. 132.050 vs 132.0
- 8.33kHz VHF radio capability is required in most of Europe & Scandinavia
Aeronautical Voice Comms

- Military aircraft space limitations lead to integrated equipment
- 8.33 kHz capability is often an upgrade to the existing UHF/VHF radio
- Several ARC-210 type radios exist, only some have been upgraded to support 8.33kHz capability
Network Components

Subnetwork A

End System

Router

Subnetwork

Subnetwork B

End System
Open Systems Interconnect (OSI) reference model

- **Application**: Access to comm system services (FTP, email)
- **Presentation**: Negotiate data representation
- **Session**: Synchronizes interactions between applications
- **Transport**: End-to-end data integrity, QOS, and sequential data
- **Network**: Relays & routes across subnetworks
- **Data Link**: Transforms raw bits into error-free channel (point-point)
- **Physical**: Transmits raw bits over comm media
OSI Reference Model
Open Systems Interconnect (OSI) reference model

- Application
- Presentation
- Session
- Transport
- Network
- Data Link
- Physical

DATA
Aeronautical Applications & the OSI Reference Model

Open Systems Interconnect (OSI) reference model

- Physical
- Data Link
- Network
- Transport
- Session
- Presentation
- ADS

Per_Report
- DATA
- DATA
- DATA
- DATA

101101000110010101001110
ATS Applications

• **Automatic Dependent Surveillance (ADS)**
  - An automatic means to report aircraft position to Air Traffic Control (using data communications)
    • *No pilot action*
  - Defined by ARINC 745 and RTCA DO-212 MOPS
  - Interoperability requirements in RTCA DO-258/ED-100
  - Fully Two-way, Bit-Oriented, Digital Communications
  - Three Main Types Of Service
    • Periodic Reporting
    • Demand Reporting
    • Event Reporting
ATS Applications

- **Controller/Pilot Data Link Communications (CPDLC)**
  - A set of pre-formatted messages used to exchange clearances and information between pilots and controllers
  - Known as “ATC Comm” or “ATC Data Link” in FANS1
  - Defined by RTCA DO-219 MOPS
  - Interoperability requirements in RTCA DO-258/ED-100
  - Fully Two-Way, Bit-Oriented, Digital Communications
  - One Type of Service:
    - Pilot/Controller Dialogue
ATS Applications

• ATS Facilities Notification (AFN)
  – A helper application, used to enable ATS applications
  – Defined by ARINC 622
  – Interoperability requirements in RTCA DO-258/ED-100
  – Fully Two-Way, Character-Oriented, ACARS Communications
  – Two Main Types of Communication:
    • Contact
    • Contact Advisory
  – AFN Intended to Support All ATS Applications
ADS Architecture

ADSF

Contracts

ADSP

API

Connections

Transport

Network

Link

Physical

Transport

Network

Link

Physical
Protocol Stacks

ACARS is not an OSI protocol stack, but we can show functions as similar

<table>
<thead>
<tr>
<th>Protocol Stack</th>
<th>Function Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AOC &amp; AAC</td>
<td>Character oriented ACARS applications</td>
</tr>
<tr>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>ARINC 618</td>
<td>N/A, except for end to end CRC</td>
</tr>
<tr>
<td>ARINC 429</td>
<td>Relays &amp; routes across subnetworks</td>
</tr>
<tr>
<td>Physical</td>
<td>Transforms raw bits into error-free channel (point-point)</td>
</tr>
<tr>
<td></td>
<td>Transmits raw bits over comm media</td>
</tr>
</tbody>
</table>
Protocol Stacks

AFN and ARINC 622 Processing Reside on top of ACARS stack

<table>
<thead>
<tr>
<th>AFN</th>
<th>622</th>
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<tr>
<td>N/A</td>
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<td>N/A</td>
</tr>
</tbody>
</table>

- AFN: Character oriented AFN, ARINC 622 process
- ARINC 618: Relays & routes across subnetworks
- ARINC 429: Transforms raw bits into error-free channel (point-point)
- Physical: Transmits raw bits over comm media
ADS FANS Architecture

Contracts

Connections

ADSF

API

ADSP

A-622

ACARS

Link

Physical

A-622

ACARS

Link

Physical
The ICAO ATN is defined as a 7-layer, OSI model

- **Application**: Access to comm system services (FTP, email)
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ATN Model

- ATN requires bit-oriented subnetworks
- FANS 1/A can operate over bit or character-oriented subnetworks
  - Because of ARINC 622 processing
- ATN requires new Router protocol, for global understanding and mobile routing
- FANS 1/A uses static tables created by DSPs to route
- In both environments, applications will be certified to DO-178B Level C or equivalent
- In the ATN, all routers must also be certified to DO-178B Level C
FANS 1/A What is it?

- **Future Air Navigation System**
  - “FANS 1/A” = ADS + CPDLC + AFN all over ARINC 622
- **What does the pilot see?**
  - AFN
  - CPDLC
  - ADS status (maybe)
- **How does the ATC facility alter what the pilot sees?**
  - Different ATC facilities will be different in terms of services, messages, timing, procedures, ....
• **What else?**
  - Pilots must file ICAO-PANS ATM doc
  - Pilots do not determine media selection
  - FAA is not leading this deployment – the South Pacific stakeholders are leading the way (read SPOM)
What benefits are provided?

- **FANS implementation on the aircraft, ground and data link service provider network allows new routes that may never have been established without the FANS technology components**
- FANS requires new procedures in the flight deck and the ground facility
- UAL estimates savings of over 1 million annually per plane on SOPAC FANS routes
- Operators who are not trained in FANS procedures are excluded from FANS routes
Media

- SATCOM
- VHF
- HFDL?
SATCOM – Classic Aero

- Inmarsat SATCOM used to provide ATS and AOC communications
  - Also airline passenger communications
- Aero-H, Aero-H+ and Aero-I all provide ATS communication capability
- Inmarsat provides global coverage via Inmarsat-3 and Inmarsat-4 satellites from latitudes -78 south to +78 north (or greater)
- Multiple Inmarsat signatories provide ground earth station operations
- Inmarsat continues to improve network & capabilities
SATCOM – Swift64 & SBB

• Inmarsat’s new capabilities:
  – Swift64: circuit-mode ISDN at 64kbps
  – SwiftBroadband(SBB): 432kbps TCP/IP data

• Swift64 & SBB not intended for ATS use,
  – Being used by AF aircraft for “back-end” communications
  – Mission planning, Secure voice, etc

• Vendors are developing combined SBB + Aero terminals as the next generation for aviation equipment
VHF Data Comm

Flavors:

• VHF ACARS (classic)
• VDL Mode 2
• VDL Mode 3
• VDL Mode 4
VHF ACARS

- 25kHz Analog channel, using MODEMs for data comm
- 2400bps maximum channel rate
- Character-oriented data (Airlines Communication and Reporting System)
- RTP switches from voice to data modes
- Wide-spread Commercial Airline Use
  - N. America, Europe, Australian coast, Pacific Rim coverage
- Used in FANS 1/A System, in conjunction with ARINC 622
- Can not be used for ATN
VDL Mode 2

- Digital data channel
  - 20 times more efficient than ACARS
- 31,500 bps channel rate
- Bit-oriented data (ATN-compliant)
- RTP switches from analog voice to digital data modes
- In limited operations
- Some U.S. & European coverage
- Supports FANS 1/A and ATN
VDL Mode 2 Coverage
VDL Mode 3

- 4 Digital Voice and/or Digital Data Channels
  - Subchannels correspond to primary frequency
- 31,500 bps channel rate
- Bit-oriented data (ATN-compliant)
- Simultaneous Digital Voice and Digital Data
- Program cancelled
- Supports FANS 1/A and ATN * (with mods to ATN)
VDL Mode 3

Current VHF Voice
and Analog Data
1 Voice Channel 25KHz Channel

VDL Mode 3
Up to 4 Times Current Voice Capacity
Provides 4 Voice and/or Data Channels
25KHz Channel

NEXCOM

120.10

120.10

120.101

120.102

120.103

120.104
VDL Mode 4

- GNSS-time synchronized, Self-organizing Time Division Multiple Access (STDMA)
- Single Digital Channel, Uses Multiple Frequencies
- 9600 bps – 31.5 kbps Channel Rate (dependent on modulation)
- Two Service Modes
  - VDL Mode 4 Specific Services
    - Broadcast, Point-to-Point
  - ATN-compliant Services
VDL Mode 4

- Operates with or without Ground Stations
- Trials Completed in North European ADS-B Network “NEAN”
  - Germany, Denmark and Sweden
  - Lufthansa, SAS, OLT, Maersk Helicopters and Golden Air
- Can Support FANS 1/A and ATN
  - Used now for ADS-B
- Boeing and Airbus on the record against VDLM4 due to antenna interference into VHF voice
HFDL Ops Status

- Not yet approved for Air Traffic Services messages (ex. CPDLC and ADS)
- Coverage is not uniform globally, and not designed to be used over continental airspace
  - Problematic for testing
- Commercial OEMs equipping wide-body jets
  - Commercial operators would like to use HFDL for ATS messaging over the north pole
- Pacific ATSUs opposed to use of HFDL
- HFDL is fine for non-time sensitive AOC
Future Media

- Commercial telecom providers are working to bring novel broadband solutions to aviation.
- While the future for ATC comms is not clear, there should be a vast improvement in data rates, call intelligibility, features, and reduced cost in the future.
Questions?

Ann Heinke
853dELSG/NT (consultant)
970-663-4529
Heinke@overlookci.com
### Acronyms

- **AAC** - Airline Administrative Communications
- **ACARS** - Aircraft Communications Addressing and Reporting System
- **ACF** - ACARS Compatible Function
- **ADS** - Automatic Dependent Surveillance
- **AEEC** – Airlines Electronic Engineering Committee
- **AFN** - ATS Facilities Notification
- **AIDC** - ATS Interfacility Data Communications
- **AOC** - Airline Operational Control
- **API** - Application Program Interface
- **ATN** - Aeronautical Telecommunication Network
- **ATS** - Air Traffic Services
- **CM** – Context Management
- **CMU** - Communications Management Unit
- **CPDLC** - Controller/Pilot Data Link Communications
- **DLIC** – Data Link Initiation Communications
- **DSP** – Data Link Service Provider
- **EICAS** - Engine Indicating and Crew Alerting System
- **FANS** - Future Air Navigation System
- **FATBOB** – FANS Action Team Bay of Bengal
- **FIR** – Flight Information Region
- **FIT** - FANS Interoperability Team
- **FMC** - Flight Management Computer
- **FMS** - Flight Management System
- **GPS** - Global Positioning System
- **HFDL** - High Frequency Data Link
- **ICAO** - International Civil Aviation Organization
- **LOS** – Line of Sight
- **MCDU** - Multifunction Control and Display Unit
- **MFI** - Message Format Identifier
- **MOPS** - Minimum Operational Performance Standards
- **NAS** – (US) National AirSpace
- **OSI** – Open Systems Interconnect
- **RTCA** – Requirements and Technical Concepts for Aviation
- **SARPs** - Standards And Recommended Practices
- **SATCOM** - Satellite Communications System
- **SBB** – SwiftBroadBahn
- **SNDCF** - Subnetwork Dependent Convergence Function
- **SOPAC** – SOuth PACific
- **SR&O** - System Requirements and Objectives
- **TACC** - Tanker Airlift Control Center
- **VDL** - VHF Digital Link