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AERONAUTICAL TELECOMMUNICATIONS NETWORK PANEL

WORKING GROUP 2

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ATN Time Performance Measurements Over Mode S

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SUMMARY

A snapshot of end to end ATN time performance measurements using the Mode S subnetwork was collected during flight testing. Two applications, OSI Ping and Controller - Pilot Data Link Communications (CPDLC) were used to generate the data samples.

ATN time measures over the Mode S Subnetwork

1. Introduction

The FAA Technical Center has developed an ATN test facility for the purpose of experimentation, validation and verification of ATN topics. Included as part of this test facility is a Boeing 727 project aircraft which is equipped for ATN communications capability. A number of test flights have been completed utilizing the Mode S subnetwork as the air ground communications mechanization. This paper describes the timing results of recently completed flight tests.

2. Facilities Description

2.1 Ground Facilities. The components of the ground facility consist of an ATN router, ground data link processor (GDLP), enroute and terminal Mode S interrogators (sensors) and a wide area network (WAN) connection to external facilities such as remote routers and a high fidelity ATC simulation facility.

a. ATN router - This is an Intel '486 PC running the Unix operating system (OS) (Berkeley Software Distribution, BSD). Significant kernel changes were made to allow ATN basic features such as a subnetwork dependent convergence functions (SNDCF), X.25 interface and routing join and leave events.

b. GDLP - This is also an Intel '486 based unit running an unmodified commercial version of the BSD Unix OS. Included is the ability to communicate with two Mode S sensors using X.25 LAPB protocols.

c. Mode S sensors - Two production sensors are included in the test facility. The terminal radar is located on the grounds of the Technical Center and the long range enroute radar is located approximately 18 Km from the test facility. The terminal radar, with a 4.8 second scan rate was used for the tests described in this paper.

d. Satcom - A connection to the Southbury, Connecticut satellite ground earth station (GES) is part of the facility.

e. External connections - Connections are available to remote ATN routers and a local ATC test facility. A gateway to non-ATN protocol equipment is being built to enable controllers to evaluate proposed data link procedures.

2.2 Aircraft facilities. For increased test flexibility, the aircraft equipment is mounted on removable racks. This allows transferring the equipment between aircraft in one is unavailable. The racks are self contained, needing only power, antenna and, altitude information from the airframe.

a. Air router - This is a laptop '486 running the same modified BSD OS as the ground router. A docking station permits various configurations for X.25 and Arinc 429 accessory cards and hard disk expansion.

b. Aircraft data link processor (ADLP) - There are currently two different configurations of ADLP in the test facility. A PC DOS based ADLP, developed as a SARPs compliant prototype by the FAA, is used for data collection and code modifications. A unit provided by an avionics vendor, based on information supplied by FAA, is also used for testing, but lacks data recording capabilities.

c. Transponder - A 4MCU transponder tray is available which interchangeably accommodates a Level 3 to Level 5 transponder.

d. Global positioning system (GPS) - A GPS unit provides the input used to create ADS messages. In future flights, this unit will also provide position information to a long squitter transponder.

2.3 Software Applications and Tools. All applications utilized an ISO 'stack' consisting of the ISO transport class 4 connection oriented service (COTP), connectionless network service (CLNS), an SNDCF and connection oriented network subnetwork (CONS). Applications to be tested over the ATN included:

a. A one way echo application which permits messages to be generated at the ground router console and echoed back to the ground by the aircraft application.

b. A controller - pilot data link communication application which enables emulation of air terminal to ground terminal air traffic messaging services.

c. A RTCA compliant ADS application which accepts input from a GPS receiver, accepts contracts from the peer ADS ground application and generates ADS position reports through a switched virtual circuit (SVC). NOTE: This should not be confused with the real time long squitter GPS reporting capability of certain Mode S transponders, or ADS-B.

d. Various network debugging utilities are available for logging and time stamping of collected data. Both routers, the ADLP and GDLP and the sensors have recording capabilities.

3. Test Results

Appendix A highlights round trip message times and sizes for the ATN router to router connectivity over the Mode S link, utilizing these components described above:

- ATN Ground Router
- Mode S Ground Data Link Processor (GDLP)
- Mode S Terminal Secondary Surveillance Radar
- Mode S Transponder (Level 3, No Extended Length Message (ELM) downlink capability)
- Mode S Aircraft Data Link Processor (ADLP)
- ATN Aircraft Router

3.1 Time measures and packet sizes are compiled based on the following events:

Initiation and subnetwork acquisition.
End System (ES) to Intermediate System (IS) protocol exchange.
Inter Domain Routing Protocol (IDRP) Startup.
Transport to Transport connection.
Controller - Pilot Data Link Communication application..
Open Systems Interconnect (OSI) Ping application.

Figure A.1 in Appendix A shows results of a sample of 50 OSI Ping message exchanges.

3.2 The times indicated in Appendix A are for a single sample only, not an average or mean time. Note that the total time for each event could vary by as much as +/- 4.8 seconds, the terminal sensor scan rate. This variance depends upon the time that the data is delivered to the sensor for uplink, and the current position of the rotating antenna relative to the target aircraft.

3.3 All data located in Appendix A and in Figure A-1 was collected with a Level 3 non ELM downlink transponder. Due to this significant limitation, and the fact that in OSI Ping there was more downlink data than uplink data, the roundtrip times were non-optimal. For example, the downlink consisted of 126 bytes of user data sent at a maximum of 28 bytes in each sensor rotation. Out of the 28 bytes, 24 were from the original user data and 4 were Mode S header data. Thus, when limited to a Level 3 transponder, at least six rotations were required to deliver the downlink data. Roughly 28.8 seconds (6 rotations X 4.8 seconds per rotation) were needed to deliver the downlink reply, compared with a single 4.8 second (or one rotation) for the uplink ELM data.

3.4 The timing results for all events will be substantially improved by the use of a Level 4 or Level 5 transponder. For example, using OSI Ping events, the predicted roundtrip time will be reduced from the measured 34.4 second average, to approximately 10 seconds; assuming a single scan for each uplink and downlink.

3.5 The FAA will be conducting experiments with the Level 4 transponder during March and April of 1996. The results will be made available at the conclusion of the tests.

APPENDIX A

Initiation over the Mode S Subnetwork

a) GDLP sends a Subnetwork Management Event (SNME) "join" to the Ground Router with known aircraft Data Terminal Equipment (DTE) address.

Packet Size: N/A (Does not go over Mode S RF link)

b) Ground Router sends ISO 8208 Call Request packet to the Aircraft Router.

Ground Router to GDLP: 28 bytes.
GDLP reformats to: 13 bytes of actual transmission over RF link.
ADLP reformats back to: 28 bytes for Air Router.

c) Air Router responds with an ISO 8208 Call Accept packet to the Ground Router.

Aircraft Router to ADLP: 22 bytes.
ADLP reformats to: 13 bytes of actual transmission over the RF link.
GDLP reformats back to: 22 bytes for Ground Router.

TOTAL INITIATION TIME: 6 seconds
TOTAL BYTES OVER RF LINK: 26
TOTAL BYTES END TO END: 56

End System (ES) to Intermediate System (IS) protocol

a) Ground Router sends a ISO 9542 Intermediate System Hello (ISH) packet to the Aircraft Router.

Ground Router to GDLP: 33 bytes.
GDLP reformats to: 33 bytes of actual transmission over RF link.
ADLP reformats back to: 33 bytes for Air Router.

b) Air Router responds with an ISO 9542 ISH packet to the Ground Router.

Aircraft Router to ADLP: 33 bytes.
ADLP reformats to: 34 bytes of actual transmission over the RF link.
GDLP reformats back to: 33 bytes for Ground Router.

TOTAL ES-IS TIME: 14 seconds
TOTAL BYTES OVER RF LINK: 67
TOTAL BYTES END TO END: 66

IDRP Startup Session

a) Ground Router sends an ISO 10747 IDRP OPEN Boundary Intermediate System Protocol Data Unit (BISPDU) to the Aircraft Router (uncompressed by Subnetwork Dependent Convergence Facility (SNDCF)).

Ground Router to GDLP: 110 bytes.
GDLP reformats to: 110 bytes of actual transmission over RF link.
ADLP reformats back to: 110 bytes for Air Router.

b) Air Router responds with an ISO 10747 IDRP OPEN BISPDU to the Ground Router (uncompressed by SNDCF).

Aircraft Router to ADLP: 110 bytes.
ADLP reformats to: 111 bytes of actual transmission over the RF link.
GDLP reformats back to: 110 bytes for Ground Router.

c) Ground Router sends another ISO 10747 IDRP OPEN BISPDU to the Aircraft Router (compressed by SNDCF).

Ground Router to GDLP: 56 bytes.
GDLP reformats to: 56 bytes of actual transmission over RF link.
ADLP reformats back to: 56 bytes for Air Router.

d) Air Router responds with another ISO 10747 IDRP OPEN BISPDU to the Ground Router (compressed by SNDCF).

Aircraft Router to ADLP: 56 bytes.
ADLP reformats to: 57 bytes of actual transmission over the RF link.
GDLP reformats back to: 56 bytes for Ground Router.

e) Ground Router sends an ISO 10747 IDRP UPDATE BISPDU to the Aircraft Router (compressed by SNDCF).

Ground Router to GDLP: 83 bytes.
GDLP reformats to: 83 bytes of actual transmission over RF link.
ADLP reformats back to: 83 bytes for Air Router.

f) Air Router responds with an ISO 10747 IDRP UPDATE BISPDU to the Ground Router (compressed by SNDCF).

Aircraft Router to ADLP: 96 bytes.
ADLP reformats to: 97 bytes of actual transmission over the RF link.
GDLP reformats back to: 96 bytes for Ground Router.

g) Ground Router sends an ISO 10747 IDRP KEEPALIVE BISPDU to the Aircraft Router (compressed by SNDCF).

Ground Router to GDLP: 39 bytes.
GDLP reformats to: 39 bytes of actual transmission over RF link.
ADLP reformats back to: 39 bytes for Air Router.

h) Air Router responds with an ISO 10747 IDRP KEEPALIVE BISPDU to the Ground Router (compressed by SNDCF).

Aircraft Router to ADLP: 39 bytes.
ADLP reformats to: 40 bytes of actual transmission over the RF link.
GDLP reformats back to: 39 bytes for Ground Router.

TOTAL IDRP STARTUP SESSION TIME: 41 seconds
TOTAL BYTES OVER RF LINK: 593
TOTAL BYTES END TO END: 589

Transport to Transport connection

NOTE: The following values were used for the TP4 timers: DR,CC,DT,CR timers 250 seconds
Keepalive 960 seconds

Send_Ack 300 seconds

a) Upon receipt of a Transmission Control Protocol (TCP) / Internet Protocol (IP) connection request by the ground Air Traffic Control (ATC) application, the ground router sends an ISO 8073 Transport Connect Request Transport Protocol Data Unit (TPDU) to the Aircraft Router.

Ground Router to GDLP: 98 bytes.
GDLP reformats to: 98 bytes of actual transmission over RF link.
ADLP reformats back to: 98 bytes for Air Router.

b) Air Router responds with an ISO 8073 Transport Connect Confirm TPDU to the Ground Router.

Aircraft Router to ADLP: 87 bytes.
ADLP reformats to: 88 bytes of actual transmission over the RF link.
GDLP reformats back to: 87 bytes for Ground Router.

TOTAL TRANSPORT CONNECTION TIME: 19 seconds
TOTAL BYTES OVER RF LINK: 186
TOTAL BYTES END TO END: 185

Controller - Pilot Data Link Communication application

In this scenario a total of 10 CPDLC messages have been selected (5 in the uplink direction and 5 in the downlink direction), and measured uplinks separate from the downlinks as shown:

a) Uplink Message # 1 DESCEND TO AND MAINTAIN 8000FT. CONTACT ATLANTIC CITY APPROACH AT 123.25

Message Size: 91 bytes (Includes ISO headers)
Uplink Time: 6 seconds

Downlink Message # 1 WILCO

Message Size: 23 bytes (Includes ISO headers)
Downlink Time: 3 seconds

b) Uplink Message # 2 DESCEND TO AND MAINTAIN 5000FT.

Message Size: 49 bytes (Includes ISO headers)
Uplink Time: 5 seconds

Downlink Message # 2 WILCO
Downlink Time: 4 seconds
Message Size: 23 bytes (Includes ISO headers)

c) Uplink Message # 3 PROCEED DIRECT TO SEA ISLE

Message Size: 44 bytes (Includes ISO headers)
Uplink Time: 6 seconds

Downlink Message # 3 ROGER
Downlink Time: 4 seconds
Message Size: 23 bytes (Includes ISO headers)

d) Uplink Message # 4 AFFIRM

Message Size:		24 bytes (Includes ISO headers)
Uplink Time:		4 seconds
Downlink Message # 4	WILCO	
Downlink Time:		3 seconds
Message Size:		23 bytes (Includes ISO headers)

e) Uplink Message # 5 — DEPART SEA ISLE HEADING 360 RADAR VECTOR ILS RW 13

Message Size:		68 bytes (Includes ISO headers)
Uplink Time:		6 seconds
Downlink Message # 5	WILCO	
Downlink Time:		5 seconds
Message Size:		23 bytes (Includes ISO headers)

ISO/OSI Ping.

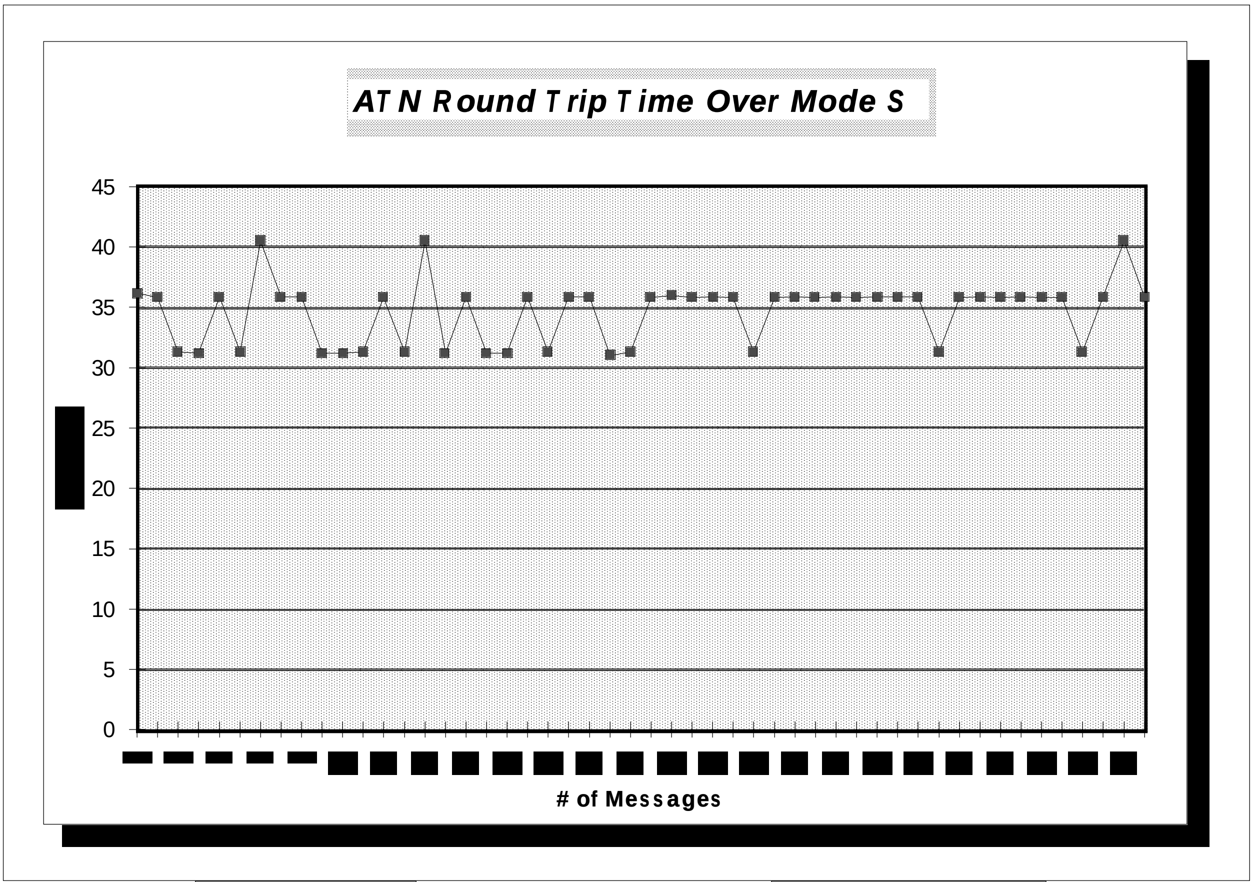
This last category measures the round trip time for a total of 10 messages between the Ground Router and the Aircraft Router, using the OSI ping mechanism over the Mode S Subnetwork.

Note 1: OSI Ping does not get compressed by SNDCF.
Note 2: OSI Ping reaches the Network layer at the ISO 8208 only and then echoes back.
Note 3: Each uplink Ping is 72 bytes and each Downlink echo is 129 bytes, for a total of 201 bytes.

Ping # 1	Round Trip Time:	42.5 seconds
Ping # 2	Round Trip Time:	31.4 seconds
Ping # 3	Round Trip Time:	31.5 seconds
Ping # 4	Round Trip Time:	36.2 seconds
Ping # 5	Round Trip Time:	36.1 seconds
Ping # 6	Round Trip Time:	36.1 seconds
Ping # 7	Round Trip Time:	36.1 seconds
Ping # 8	Round Trip Time:	31.4 seconds
Ping # 9	Round Trip Time:	31.5 seconds
Ping # 10	Round Trip Time:	31.5 seconds

AVERAGE ROUND TRIP TIME: 34.4 seconds*

* estimated to drop to approximately 10 seconds when a level 4 or 5 transponder is used.



Each Message in Size:
Uplink-> 72
Downlink->129
Total: 201 Bytes

MEAN: 34.67sec
MEDIAN: 35.8sec
MODE: 35.9 sec
STD DEV: 2.61sec

Figure A.1