VDL3 Data Link Service (DLS) & Subnetwork Interface

VDL3 Team

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Organization: MITRE/CAASD F085 & FAATC ACT-350
Project: 0298012Q-NS
The Problem

- Conflict of Priority with HDLC sequencing
  - MAC resequencing of frames based on priority will cause excessive loss of efficiency

- Desire for simplification in solution
Current DLS based on HDLC

- HDLC assigns sequence number to all frames
- If frame out of sequence, it is discarded and retransmission begins where sequencing leaves off
- MAC needs to be able to resequence to support priority
  - Higher priority messages need to be able to move forward in sequence
The Solution: A Simplified DLS based on an A-CLDL Protocol

- Two options to deal with inefficiency:
  - Frame resequencing at MAC sublayer
    - Adds complexity
    - Adds additional failure modes
  - Adopt a DLS based on Acknowledged-Connectionless Data Link (A-CLDL) protocol
    - Simplifies protocol
    - MAC is already ensuring sequencing within each priority stream via stop-and-wait protocol
- Simulation results, presented previously, indicate that the A-CLDL proposal will provide a more efficient operation at the expected traffic loading
Message Flow for a proposed DLS based on A-CLDL

**Packets**

**Frames**

**Data Bursts**

**DLS**

**MAC**

**Message** -- 1 frame up to 15 bursts or multiple frames up to 7 bursts

**ACKs**

**M Bursts**  **V/D Bursts**
Frame Format for A-CLDL

- **4 types of frames**
  - Information
  - **Management**
    - Acknowledge
    - Control Command
    - Control Response

<table>
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<th>Description</th>
<th>Octet</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<tr>
<td>Information</td>
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</tbody>
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First bit transmitted ↓

- Bit Number
  - 1: Aircraft Station Address
  - 2: XOR
  - 3: 24-bit FCS
  - 4: Address Type
  - 5: Priority
  - 6: MF
  - 7: Frame Type
  - 8: User Data
A-CLDL Operation: Frame Grouping

- Frames may be collected into a single Media Access event to improve efficiency of the system
  - Frames that require acknowledgement must all be of the same priority and for the same destination, since only one peer can send an ACK at a time
  - Frames that don’t require acknowledgement can be grouped as the space allows
A-CLDL Operation: Acknowledgement

- DLS acknowledges correct receipt of a media access event instead of specific frames
- Any frame requiring acknowledgement in group in error requires retransmission of all frames requiring acknowledgement within group
- Frames not requiring acknowledgement are not retransmitted
- Frames not requiring acknowledgement can be processed if its CRC passes, even if other frames in group are in error
A-CLDL Implications

- Reliance on MAC sublayer
  - Provides connection-oriented service to deal with link failures
  - Enforces sequencing within each priority queue
  - MAC controls retransmission and ACK timing
    - DLS and MAC need to be tightly coupled for optimal performance
  - `Terminate_Link` M uplink burst allows MAC to completely control link status
- Reliance on Transport Protocol or Subnetwork Protocol
  - Suppresses any duplicate packets that may occur
  - Retransmission for any lost packets (*Highly unlikely*)
Advantages Relative to Current HDLC-based Approach

- Simple DLS
  - 3 states (Idle, Data_Pending, ACK_Pending)
  - Always operational
  - Removes redundant functionality from DLS
  - MAC already provides a connection-oriented service for the link layer
- Less Overhead (6 octets vs. 8/9 octets)
  - ACK 4 octets vs. 8/9 octets
- Better data integrity (24-bit vs. 16-bit CRC) ~ 10^{-10}
- Maximizes efficiency with MAC protocol and Priority processing
- Rapid recovery for Connectionless Subnetwork Interface
Subnetwork Architecture

VDL Mode 3 Subnetwork

Ground Subnetwork
Subnetwork Compression

- Provide a subnetwork layer above the DLS service that performs protocol specific compression.
- Provides flexibility to support access to different subnetwork interfaces within VDL mode 3.
  - Allow industry to decide on best subnetwork protocol for desired application(s)
Subnetwork Compression

Subnetwork Compression is defined within first Octet in DLS user data.
- defines subnetwork payload type
- defines compression performed (if any)
Subnetwork Compression

- Currently examining 2 different ATN approaches:
  - CLNP Header Compression (Connectionless Service)
  - ISO 8208 Compression (Connection Oriented Service)

- Ground system supports all options to provide aircraft with maximum flexibility

- Aircraft only needs to have to support one option for minimizing complexity in the avionics, although the use of multiple is also possible
Previous VDL3-ATN Protocol Structure

Functions resident in Ground Radio

LEGEND:
- Connectionless Network Protocol (CLNP)
- Routing Information Exchange Protocol (RP)
- Subnetwork Dependent Convergence Function (SNDCF)
- Subnetwork Access Protocol (SNAcP)
- Data Terminating Equipment (DTE)
- Data Circuit Terminating Equipment (DCE)
- High Level Data Link Control (HDLC)
Proposed VDL3-ATN Protocol Stack with Connectionless Subnetwork Interface

LEGEND:
- Connectionless Network Protocol (CLNP)
- Subnetwork Dependent Convergence Function (SNDCF)
- Interworking (IW)
- Acknowledged Connectionless Datalink (A-CLDL)
Proposed VDL3-ATN Protocol Stack with Connection-Oriented Subnetwork Interface

**GROUND**

- Ground ATN Router(s)
- Relaying/Routeing
- CLNP/RP
- CLNP/RP
- Ground SNDCF
- ISO8208
- Ground SNACP
- ISO8208
- Data Link
- Data Link
- Physical
- Physical

**AVIONICS BUS**

- Aircraft ATN Router(s)
- Relaying/Routeing
- CLNP/RP
- CLNP/RP
- Avionics SNDCF
- ISO8208
- Avionics SNACP
- ISO8208
- Data Link
- Data Link
- Physical
- Physical

**VHF SUBNETWORK**

- VHF PLP
- A-CLDL
- D8PSK
- TDMA
- ISO8208
- ISO8208
- Data Link
- Data Link
- MAC
- MAC
- Physical
- Physical

**AVIONICS BUS**

- Aircraft ATN Router(s)
- Relaying/Routeing
- CLNP/RP
- CLNP/RP
- Avionics SNDCF
- ISO8208
- Avionics SNACP
- ISO8208
- Data Link
- Data Link
- Physical
- Physical

**LEGEND:**

- Connectionless Network Protocol (CLNP)
- Subnetwork Dependent Convergence Function (SNDCF)
- Interworking (IW)
- Packet Layer Protocol (PLP)
- Acknowledged Connectionless Datalink (A-CLDL)
VDL Mode 3 Access Protocols

ATN Compression

ES - IS

IDRP

CLNP

Mobile SNDCF

SNDCF

8208

SUBNETWORK COMPRESSOR

CLDL

8208 Compressor

CLNP (Simplex or Duplex) Compressor

TDMA
CLNP Interface (Connectionless)

- Provide a direct CLNP Interface to ATN Router.
- Compression is performed on CLNP header within VDL 3 subnetwork.

- Broadcast compression supported.
8208 Interface (Connection-Oriented)

- Follows traditionally defined ATN interface
  - CLNP Header Compression (LREF) performed prior to entering the Mode 3 Subnetwork.
- Additional Compression performed on ISO 8208 headers and management packets within the subnetwork.
- Priority based SVC’s mapped into DLS
8208 Interface

- Provides subnetwork flow control on a per-connection basis
- Employs full DCE state machine in airborne station.
- Subnetwork compressor will incorporate
  - ISO 8208 Header compression
  - Packet re-sequencing
  - Duplicate Suppression
- Based on Mode S Packet Layer Protocol for reusability
Summary of Recent VDL3 SARPs Protocol Changes

- Provide a data link layer that supports priority processing and sequencing within each priority
- Provide a subnetwork layer that allows protocol specific compression techniques.
- Supports other network protocols.
- Provides industry with options to develop avionics based on application types.
- Supports different classes of users
Supplementary Material
VDLT System - Logical Ground Hierarchy

- Large number of control facilities need access to local voice switch and one of a limited number of Routers -> Primary/Secondary GNI Hierarchy
  - Primary GNI has direct connection to Router
  - Secondary GNI has connection to Router via Primary GNI
- Primary/Secondary GNI optimizes subnetwork traffic and reduces disconnect time between GNIs

Legend:
- ARTCC  Air route Traffic Control Center
- ATN    Aeronautical Telecommunications Network
- AFSS   Automated Flight Service Station
- GNI    Ground Network Interface
- TRACON Terminal Radar Approach Control
- ATCT   Airport Traffic Control Tower
VDL3 Radio Ground Network System

- Present transparent interface to voice switch
- Provide voice compression
- Interface with data subnetwork
- Manage connections and map addresses for DL
- Provide circuit failure detection

- Provide signaling and control for radios
- Main/standby switching for separate TX and RX units
- Support UHF Simulcasting with vocoder function
- Support Remote Maintenance and Monitoring functions

Control Site

Host Computer

Data Link Applications Processor (DLAP)

Voice Switch

ATN Router

Ground Network Interface (GNI)

Remote Site 1

Timing

Radio Interface Unit (RIU)

UHF Radio(s)

Remote Site 2

Timing

Radio Interface Unit (RIU)

UHF Radio(s)

Voice Switch

Switch Backup

NAS Infrastructure Management System

Optional Signaling (?)
A-CLDL Operation:
Make-before-Break Support

- DLS header contains Ground Subnetwork Address to indicate previous GNI to use to access existing Mobility protocol (e.g. IDRP) connection until new connection can be established
- Priority field included to assist in maintaining QoS while routing in the ground subnetwork
A-CLDL Operation: Handoff Continuity

- DLS needs to be tightly integrated with MAC for efficient performance
- This raises an issue during handoffs if data is in the DLS queues to prevent loss of data
- Option 1
  - DLS located in GNI at control site maintains data queues even if radio switched
  - If connection changed across router/GNI boundaries, new GNI can request forwarding of previous DLS queued frames
- Option 2
  - If simplicity is desired, can allow transport or connection-oriented subnetwork layer to recover
  - Transport layer recovery may have efficiency implications due to large retransmission timer values
ATN ISO Stack

LEGEND:
- Connectionless Network Protocol (CLNP)
- Routeing Information Exchange Protocol (RP)
- Subnetwork Dependent Convergence Function (SNDCF)
- Subnetwork Access Protocol (SNAcP)