Summary
This paper reports on the results of interoperability testing of ATN CPDLC applications between the Federal Aviation Administration (FAA) Technical Center of the United States and the Electronic Navigation Research Institute (ENRI) of Japan.
1 Introduction

1.1 Overview

The Federal Aviation Administration (FAA) W. J. Hughes Technical Center and the Electronic Navigation Research Institute (ENRI) carried out a connection test of their prototype ATN CPDLC Version 1 air and ground applications from 29 November – 1 December 2005. The tests were aimed at verifying the interoperability of basic CPDLC services in preparation for a planned application end-to-end test over a VHF Digital Link Mode 3 (VDL3) sub-network.

All test items were successfully passed after a number of minor technical issues had been overcome. In addition, two points regarding system implementation and a minor error in the CPDLC and PM-CPDLC P/OICS were identified.

1.2 History

The FAA and ENRI have been researching ATN applications to provide air-ground data link services, and VDL3 as a candidate air-ground data link medium. It was decided to jointly carry out a series of interoperability tests and demonstrations between the ATN and VDL3 test bed systems developed independently by both sides.

In 2004, the FAA and ENRI carried out interoperability tests of their VDL3 airborne and ground equipment, and demonstrated digital communication voice and data communication between ATN BIS routers. The BIS connection test raised a number of technical issues, as reported in WGN04/IP07.

The FAA and ENRI then carried out an interoperability test of Version 1 CPDLC applications in late 2005 to confirm that the BIS router technical issues identified during the 2004 test had been resolved and to prepare for a planned end-to-end demonstration of an ATN air-ground application over VDL3. This working paper summarises the results of this test effort. Details of the router-to-router verification test are omitted, since all the outstanding issues were confirmed as resolved.

Unfortunately, given that the FAA's VDL Mode 3 programme has been placed on hold, ENRI and the FAA have suspended further work involving the VDL Mode 3 subnetwork, which would have been part of the final end-to-end testing, inclusive of the applications, the subnetwork and the ATN routing.
1.3 Referenced Documents

The following documents are referenced in this report.


2 Interoperability Test

The purpose of these tests was to verify interoperability between the ENRI and FAA airborne and ground CPDLC end systems. The test was carried out between ENRI in Chofu, Japan and the FAA Technical Center in Atlantic City, USA.

2.1 Test Configuration

The test configuration is shown in Figure 1. There were two configurations: ENRI air/FAA ground and FAA air/ENRI ground, with the each side playing the rôle of airborne or ground system in turn. Switching between configurations was carried out by software configuration changes.

The experimental teams on each side communicated by means of instant messaging (Yahoo! Instant Messenger) and electronic mail over the public Internet.

2.1.1 Network Connection

The ENRI and FAA ATN domains were connected via ground-ground Boundary Intermediate System (BIS) routers with ISO/IEC 8208 PLP packets tunnelled over the public Internet using XOT (X.25 over TCP: RFC1613) between a pair of Cisco 2600 series routers.

Although interoperability between the FAA’s BIS router (developed by BCI Inc.) and ENRI’s BIS router (developed by Oki Electric Industry Co.) had been tested in 2004, the testing had raised a number of technical issues. A preliminary ATN router connection test was therefore carried out to confirm that these issues had been resolved before proceeding with the CPDLC interoperability test.

![Figure 1 Test Configuration](image-url)
2.1.2 CPDLC Applications

Both FAA and ENRI CPDLC systems, comprising both ground and airborne ASEs, incorporated Version 1 CPDLC applications and Edition 2 Upper Layer Communication Services (ULCS), based on ICAO Doc 9705 Edition 2. The ENRI system was developed by Oki Electric Industry Co.

2.2 Pre-Test Interoperability Evaluation

Before planning the interoperability tests, interoperability was evaluated by comparing the following and evaluating mismatches to determine their impact on interoperability:

- Implementation status of relevant Proposed Defect Reports (PDRs) covering the CPDLC Version 2 application.
- Protocol/Operational Implementation Conformance Statements (P/OICS) for the ground and airborne CPDLC applications based on the proformas submitted as working papers to ATN Panel Working Group A Subgroup A2 [3, 4].
- Protocol Implementation Conformance Statements (PICS) based on ATN Profile Requirements Lists (APRLs) in Doc 9705 for the ISO Connection Oriented Transport Protocol (COTP), Session Protocol, Presentation Protocol, and Association Control Service Element (ACSE).

No major interoperability problems were found, but an error was detected in the CPDLC P/OICS proformas, and a defect report (PDR5060001) was raised.

2.3 Test Cases

The test cases tested the basic CPDLC services: CPDLC-start, CPDLC-end, CPDLC-user-abort, CPDLC-provider-abort, and uplink and downlink message transmission. Since the aim was to verify the operation of the CPDLC protocols, individual messages were not tested. The test items are shown in Table 1.

<table>
<thead>
<tr>
<th>No.</th>
<th>Test Item</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CPDLC-start from air</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>CPDLC-start from ground</td>
<td>CURRENT DATA AUTHORITY downlink, LOGICAL ACK uplink</td>
</tr>
<tr>
<td>3</td>
<td>CPDLC-start from air rejected by ground</td>
<td>Reject with uM162 (SERVICE UNAVAILABLE)</td>
</tr>
<tr>
<td>4</td>
<td>CPDLC-start from ground rejected by air</td>
<td>Reject with dM107 (NOT AUTHORIZED NEXT DATA AUTHORITY)</td>
</tr>
<tr>
<td>5</td>
<td>Uplink Message</td>
<td>uM182 FreeText</td>
</tr>
<tr>
<td>6</td>
<td>Downlink Message</td>
<td>DM98 FreeText, LOGICAL ACK</td>
</tr>
<tr>
<td>7</td>
<td>CPDLC-end</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>CPDLC-user-abort from ground</td>
<td>Reason: undefined(0)</td>
</tr>
<tr>
<td>9</td>
<td>CPDLC-user-abort from air</td>
<td>Reason: undefined(0)</td>
</tr>
<tr>
<td>10</td>
<td>CPDLC-provider-abort</td>
<td>Induced by disconnecting ATN router from CPDLC ASE on ground side. Reason: communication-service-failure(5)</td>
</tr>
</tbody>
</table>
2.4 Results and Discussion

All tests were successfully concluded, after a number of problems which were resolved by code modifications by either ENRI or the FAA.

2.4.1 Analysis of Problems Encountered

The number of problems encountered broken down by category are shown in Table 2.

<table>
<thead>
<tr>
<th>Problem Category</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Encoding/decoding</td>
<td>3</td>
</tr>
<tr>
<td>Rejection of CPDLC-start</td>
<td>3</td>
</tr>
<tr>
<td>Technical issue out of scope of SARPs</td>
<td>1</td>
</tr>
<tr>
<td>Misconfiguration</td>
<td>1</td>
</tr>
<tr>
<td>Experiment procedure error</td>
<td>1</td>
</tr>
</tbody>
</table>

Of the problems encountered due to encode/decode errors, one was due to an ambiguity in ICAO Doc 9705 Edition 2, as discussed in section 2.4.2.

The difficulties associated with rejection of CPDLC-start were related to a message parameter set in the Reject Reason of the CPDLC-start-reject. See section 2.4.3.

The “technical issue out of scope of SARPs” was due to a failure of the CPDLC-air-user terminal on the ENRI side to correctly reflect the state of the CPDLC-air-ASE.

The remaining problems were due to operator error.

2.4.2 Ambiguity in ICAO Doc 9705 Edition 2

One of the encode/decode errors encountered was due to an ambiguity in ICAO Doc 9705 Edition 2 regarding the Called/Calling Peer Identifier of the ground system, which had been interpreted differently by ENRI and the FAA.

This ambiguity is apparently (but not entirely satisfactorily) resolved in Edition 3 of ICAO Doc 9705, but had not been picked up in the preliminary examination of PDRs applied to Edition 2.

According to ICAO Doc 9705 Edition 2/3, paragraph 2.3.3.2.2:

> 2.3.3.2.2 If the service is air initiated, the Called Peer Identifier parameter value shall conform to the abstract syntax four to eight-character facility designation.

From this, it can be understood that the length of the Called Peer Identifier can be from 4–8 characters.

However, regarding the encoding of End System Identifiers and AE-Qualifiers, Note 2 to paragraph 4.3.2.4 of ICAO Doc 9705 Edition 2 reads as follows:

> For ground stations, the <end-system-id> is derived from an eight-letter facility designator, e.g., “LFPODLHX”. The syntax of the first four letters is defined in ICAO Doc 7910 “Location Indicators”; the syntax of the remaining letters is defined in ICAO Doc 8585 “Designators for Aircraft Operating Agencies, Aeronautical Authorities and Services.”
The ENRI system had been implemented to transmit and decode a fixed 8-character facility designator, based on paragraph 4.3.2.4, while the FAA system had been implemented to transmit and decode a fixed 4-character facility designator.

Note 2 to paragraph 4.3.2.4 of ICAO Doc 9705 Edition 3 has been modified to partly resolve this, but this was not detected in the investigation of PDRs before the testing commenced. In Edition 3, Note 2 reads as follows:

For ground stations, the <end-system-id> is derived from a four to eight character facility designator, e.g., “LFPODLHX”. The syntax of the first four letters is defined in ICAO Doc 7910 “Location Indicators” (the value “0000” is reserved - see 4.3.3.8.1.2.2.e)); the syntax of the remaining letters is defined in ICAO Doc 8585 “Designators for Aircraft Operating Agencies, Aeronautical Authorities and Services.”

To ensure interoperability, CPDLC ASEs therefore should be implemented to accommodate a four to eight-character facility designator, rather than expecting a fixed-length designator.

2.4.3 “Logical Ack Required” in Reject Reason to CPDLC-start

When an ATCUplinkMessage or ATCDownlinkMessage is received with the LogicalAck field in the message header set to “required”, the message receiver is expected to send the LOGICAL ACKNOWLEDGEMENT message in response.

In the case of a CPDLC-start transmitted by the ENRI ground ASE being rejected by the FAA airborne ASE, the RejectReason had the LogicalAck field set to “required”. This caused the ENRI ground system to attempt to send a LOGICAL ACKNOWLEDGEMENT, even though the dialogue was in the process of being terminated.

According to Note 2 to ICAO Doc 9705 paragraph 2.3.5.3.1.4 and Note 2 to paragraph 2.3.5.5.1.4, the state of the CPDLC-user becomes inactive when it receives a rejection to a CPDLC-start request. Therefore, the ASE should not have attempted to send the LOGICAL ACKNOWLEDGEMENT.

However, in the case of rejecting a CPDLC-start, it makes no sense to set LogicalAck required in the RejectReason, so the rejecting ASE should not do so. This does not appear to be stated under paragraph 2.3.7.4.1.2 (on the invocation of CPDLC-start Response by the CPDLC-air-user) or the corresponding paragraph 2.3.7.5.1.2 for the CPDLC-ground-user. Although obvious, perhaps it should be explicitly prohibited, although doing so would not result in an error so long as the initiating ASE correctly becomes inactive on receiving the RejectReason.
3 Conclusion

The FAA and ENRI successfully conducted tests to verify the interoperability of their ATN routers and Version 1 CPDLC applications based on ICAO Doc 9705 Edition 2.

The test effort identified an error in the CPDLC and PM-CPDLC P/OICS, and a PDR was raised.

An ambiguity was identified in ICAO Doc 9705 Edition 2 regarding the length of the ICAO facility designator. While this has been resolved in Edition 3, implementers are advised to ensure that their ASEs can correctly handle 4 to 8-character facility designators, rather than assume a fixed length, regardless of local Interface Control Documents or other interoperability standards in force.

Finally, it is noted that setting LogicalAck required in the RejectReason to a CPDLC-start request is not explicitly prohibited by Doc 9705, although logically meaningless. This should not result in an error if the start initiator correctly enters an inactive state when it receives the RejectReason.

Acknowledgements

The FAA and ENRI would like to acknowledge the cooperation and efforts of their contractors, BCI Inc. and Oki Electric Industry Co., in this test effort.