TABLE OF CONTENTS

# 1.0 INTRODUCTION

*NOTE: This file contains* ****DRAFT**** *material proposed for a new Part 3 to ARINC 858. The Part 3 introduction and boilerplate material will be added in a subsequent version. The current material focuses on the proposed protocol specification detail.*

## 1.1 Purpose

TBD

## 1.2 Scope

TBD

**Figure 1-1 – TBD**

## 1.3 Document Overview

### 1.3.1 Multi-Part Specification Organization

ARINC 858 is published as a multi-part document specification that includes the following documents:

- Part 1 – Airborne IPS System Technical Requirements
- Part 2 – IPS Gateway Air-Ground Interoperability
- Part 3 (*this document*) – Common IPS Radio Interface (CIRI)

### 1.3.2 Part 1 Document Organization

This document is organized as follows:

- Section 1.0 – Introduction
  This section introduces the purpose and scope of this document, identifies related reference documents, and provides guidance for regulatory compliance.
- Section 2.0 – Common IPS Radio Interface Overview
  TBD.
- Section 3.0 – CIRI Protocol Description
  TBD.
- Section 4.0 – CIRI Protocol Message Structure
  TBD.
- Section 5.0 – CIRI Protocol Operation
  TBD.
- Attachment 1 – List of Acronyms
  This attachment provides a list of acronyms used in this document.
- Attachment 2 – Glossary
  This attachment explains the precise meaning of terms used in this document to avoid ambiguity and confusion.

- Appendix A – CIRI Protocol Background

  TBD.

To assist readers with navigating this document, the following figure is an illustrative guide to the document sections and the relationships among the sections.

**TBD**

**Figure 1-2 – Guide to ARINC Specification 858 Part 3**

## 1.4 Related Documents

When avionics systems and subsystems are designed to use the capabilities provided by this specification, they should incorporate the provisions of this specification by reference. References to this specification should assume the application of the latest applicable version.

### 1.4.1 Relationship of this Document to Other ARINC Standards

ARINC Standards related to this specification are listed below, and the reader should ascertain the latest applicable version.

**ARINC Specification 429:** *Digital Information Transfer System (DITS)*

**ARINC Specification 664**: *Aircraft Data Network*

**ARINC Characteristic 750:** *VHF Data Radio*

**ARINC Characteristic 766:** *Aeronautical Mobile Airport Communication System (AeroMACS) Transceiver and Aircraft Installation Standards*

**ARINC Characteristic 771:** *Low-Earth orbiting Aviation Satellite Communication System*

**ARINC Characteristic 781:** *Mark 3 Aviation Satellite Communication System*

**ARINC Characteristic 791:** *Mark I Aviation Ku-band and Ka-band Satellite Communication System*

**ARINC Characteristic 792:** *Second-Generation Ku-band and Ka-band Satellite Communication System*

**ARINC Specification 822A:** *On-ground Aircraft Wireless Communication*

**ARINC Specification 839:** *Function Definition of Airborne Manager of Air-Ground Interface Communications (MAGIC)*

**ARINC Specification 858:** *Internet Protocol Suite (IPS) for Aeronautical Safety Services, Part 1, IPS Gateway Air-Ground Interoperability*

### 1.4.2 Relationship to Other Industry Standards

The following list identifies related industry documentation referenced in this document. The version cited was available at the time of this writing, and the reader should ascertain the latest applicable version.

**EUROCAE**

- **ED-262:** *Technical Standard of Aviation Profiles for Internet Protocol Suite.* Also published as RTCA DO-379.

**International Civil Aviation Organization (ICAO)**

- **[AGMI]**: Air-Ground Mobility Interface, Version 0.9
- **ICAO Doc. 9896 Ed. 3:** *Manual for the Aeronautical Telecommunication Network (ATN) using Internet Protocol Suite (IPS) Standards and Protocols*

**Institute of Electrical and Electronics Engineers (IEEE)**

- **IEEE 802.21-2008:** *IEEE Standard for Local and Metropolitan Area Networks - Part21: Media Independent Handover Services*

**Internet Engineering Task Force (IETF)**

Note: Rather than referencing all IETF Request For Comments (RFCs) directly, this document refers to EUROCAE ED-262 and RTCA DO-379, Internet Protocol Suite Profiles, which reference IETF RFCs relevant to specification of the IPS network stack. This approach minimizes changes to this document as IETF RFCs evolve over time.

- **RFC 1982:** *Serial Number Arithmetic*
- **RFC 8175:** *Dynamic Link Exchange Protocol (DLEP)*.
- **RFC 8651:** *Dynamic Link Exchange Protocol (DLEP) Control-Plane-Based Pause Extension*
- **RFC 8703:** *Dynamic Link Exchange Protocol (DLEP) Link Identifier Extension*

**RTCA**

- **DO-379:** *Technical Standard of Aviation Profiles for Internet Protocol Suite*. Also published as EUROCAE ED-262.

**Single European Sky Air Traffic Management Research Joint Undertaking (SESAR JU)**

- **[FCI-FRD]:** *Future Communications Infrastructure (FCI) Functional Requirements Document (FRD)*, SESAR2020 PJ14-02-04 deliverable D5.2.010, Edition 00.00.07, 2018.

## 1.5 Regulatory Approval

This standard, in and of itself, will not ensure regulatory approval. Implementers are urged to obtain all information necessary for regulatory approval and work in close coordination with the appropriate regulatory authorities to gain certification as applicable.

# 2.0 COMMON IPS RADIO INTERFACE OVERVIEW

## 2.1 Functional Overview

Airborne Radios that support IPS feature a variety of radio-specific interface definitions with little-to-no commonality. For an Airborne IPS System that interfaces with a heterogeneous set of IPS-enabled Airborne Radios, this creates a diverse environment where the Airborne IPS System must adapt to the various radio interfaces, each of which do not provide the same information or capabilities.

The Common IPS Radio Interface protocol specified in this document provides a unified and extensible way of interfacing the Airborne IPS System with IPS-enabled Airborne Radios to support the needs of IPS, particularly in terms of multilink and Quality of Service (QoS). As illustrated in Figure 2-1, the Common IPS Radio Interface targets IPS-enabled Airborne Radios; throughout this document, instances of Airborne Radio should be interpreted as meaning IPS-enabled Airborne Radio.

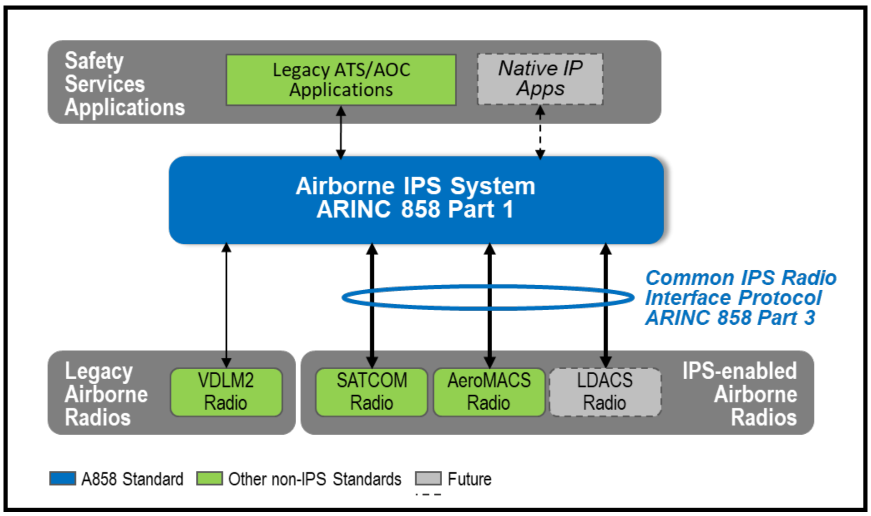


**Figure 2-1 – Common IPS Radio Interface**

The Common IPS Radio Interface protocol is specified for use with ethernet-based and ARINC 664-based aircraft networks, which are envisioned to be the future onboard network solution when IPS is deployed. The protocol may be tailored for use with other aviation onboard networks (e.g., ARINC 429-based); however, such use cases are out of scope of this specification.

The proposed Common IPS Radio Interface protocol addresses three main areas – Control Plane, Data Plane and Flow Control – summarized in the following bullets:

- Control Plane – Provides the Airborne IPS System with up-to-date information about the status of datalink services provided by onboard Airborne Radios. While this status information must include at least an indication of whether the datalink is operational (i.e., able to deliver data-plane packets to the ground), additional detail allows the Airborne IPS System to make more informed link decisions and ensure QoS of the communication.
- Data Plane – Allow for the exchange of air-to-ground and ground-to-air IPv6 packets between the Airborne IPS System and the Airborne Radio. The air-to-ground, and possibly the ground-to-air, packets must be associated with some metadata, for example to differentiate among packets with different

QoS needs or indicate whether the packet is subject to Required Communication Performance (RCP) requirements.

- Flow Control – Enable throttling of the flow of the air-to-ground packets between the Airborne IPS System and the Airborne Radio. This ensures that at any given time, only a bounded amount of air-to-ground data is queued for transmission in the Airborne Radio and the remaining data can be queued in the Airborne IPS System.

## 2.2 Applicability

Although it is well understood that existing radio-specific interface specifications are well-established in the respective radio standards, it is envisioned that some of these standards will be updated to accommodate the addition of IPS services. As these updates occur, the Common IPS Radio Interface protocol may be referenced by the updated standards. In the absence of the Common IPS Radio Interface, the Airborne IPS System provides a datalink adaptation function, as defined in ARINC 858 Part 1. The following table summarizes the radios envisioned to support IPS and expected applicability of the Common IPS Radio Interface protocol.

**Table 2-1 – Common IPS Radio Interface Applicability**

| | | | Airborne IPS System – Radio Management Interface | |
|---|---|---|---|---|
| **Airborne Radio** | | | **Radio-specific Adaptation** | **Common IPS Radio Interface** |
| **Legacy (non-IP) Radio** | VDR | A750 | Yes [1] | No |
| **IPS-enabled Radio** | AeroMACS | A766 | Yes [1] | Optional [2] |
| | *LDACS* | *Future* | *TBD [3]* | *TBD [3]* |
| | Certus | A771 | Yes [1] | Optional [2] |
| | SB-Safety | A781 | Yes [1] | Optional [2] |
| **IP-enabled Radio** | Gatelink Wi-Fi | A822A | Out of scope of ARINC 858 [4] | |
| | Gatelink Cellular | A822A | | |
| | Air-to-Ground Cellular | N/A | | |
| | Ku / Ka SATCOM | A791 / A792 | | |

Notes:

1. For existing radios that do not implement the Common IPS Radio Interface Protocol, the Airborne IPS System provides adaptation of radio-specific interfaces.
2. The standards for IPS-enabled radios may be updated to specify the Common IPS Radio Interface Protocol in lieu of or in addition to existing radio-specific management interfaces.
3. When a future LDACS standard is developed, the radio management interface may be specified as the Common IPS Radio Interface Protocol, in which case radio-specific adaptation would not be required.
4. The Airborne IPS System is not expected to interface directly with IP-enabled radios in the Aircraft Information Services Domain (AISD) but rather with an intermediary device (e.g., an AISD router or an Aircraft Interface Device (AID)) that interfaces with the IP-enabled radios. As noted in ARINC 858 Part 1, Section 2, implementation of a cross-domain interface is aircraft architecture-dependent and out of scope of A858.

# 3.0 CIRI PROTOCOL DESCRIPTION

## 3.1 Introduction

This protocol represents a technical solution for addressing the needs of the Common IPS Radio Interface introduced in Section 2.0 of this document. It is designed for exchanging information between Airborne IPS System and IPS-enabled Airborne Radio, and it address both the control plane and the data plane.

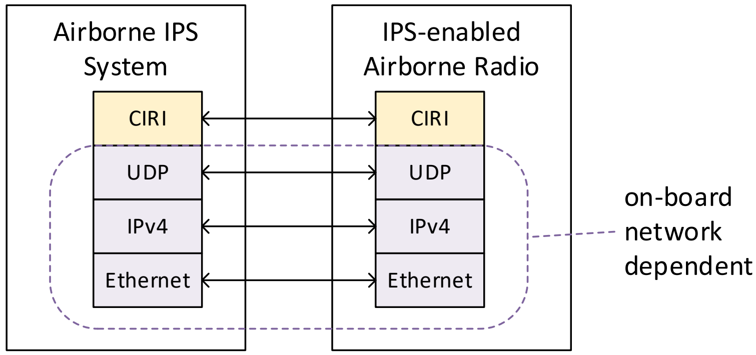


**Figure 3-1 – CIRI Context**

### 3.1.1 Control Plane

The primary purpose of the CIRI protocol is for Airborne Radio to provide various status information to the Airborne IPS System. In the simplest variant, the radio endpoint provides only discrete datalink service status (see Section 4.3.4), but the CIRI protocol provides structures to convey other information as well.

**COMMENTARY**

The Common IPS Radio Interface is not intended to provide the Airborne IPS System the capabilities to control the Airborne Radios (e.g., enabling/disabling the radio, frequency tunning, etc.).

The basic control plane communication pattern is illustrated in Figure 3-2.

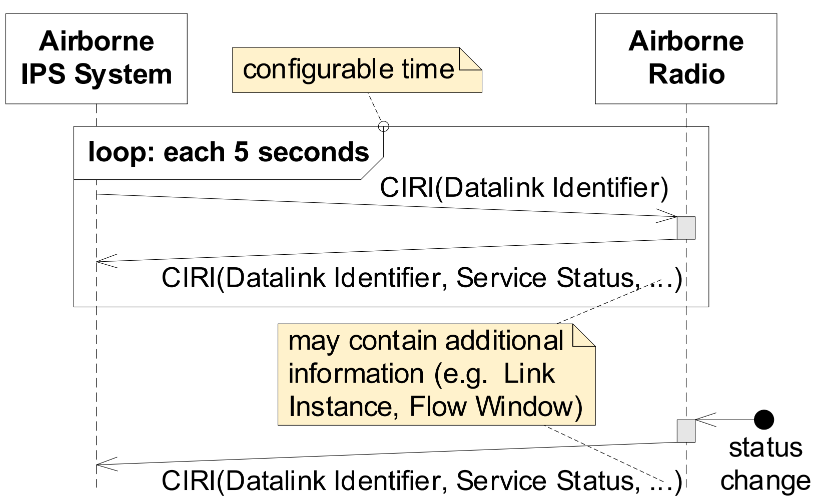


**Figure 3-2 – Basic Control Plane Communication Pattern**

The Airborne IPS System periodically sends a control-plane CIRI message, and the Airborne Radio replies with control-plane CIRI message that includes Datalink

Status, and optionally other information. These messages also serve as a health monitoring of the Airborne Radio. Additionally, the radio sends an unsolicited control-plane CIRI message whenever the datalink service status changes. See Section 5.0 for details.

This protocol does not provide any means for the Airborne IPS System to dynamically “request” or to “subscribe to” any particular information from the Airborne Radio. It is assumed that the Airborne Radio is statically configured to provide the expected information.

It is also expected that different radios in an aircraft will be able to provide different types of information. The Airborne IPS System should be able to cope with this, for example by static configuration of what information is expected from which radio. This document does not describe how is this information processed in the Airborne IPS System in much detail, as this is deemed to be a local implementation detail with little impact on interoperability.

### 3.1.2 Data Plane

Optionally, the CIRI protocol may also be used to carry the data-plane communication between Airborne IPS System and the Airborne Radio, in one or both directions. If enabled, the data-plane packets (e.g., IPv6 packets) are carried by “data-plane CIRI messages”, which are distinguished from “control-plane CIRI messages” by a flag in the CIRI header. The basic data plane communication pattern is illustrated in Figure 3-3.

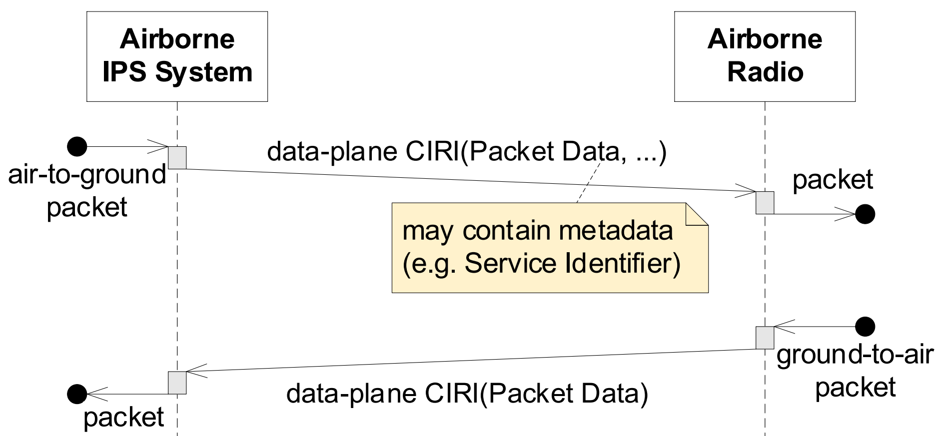


**Figure 3-3 – Data Plane Communication Pattern**

The CIRI protocol data plane communication is provided primarily to facilitate attaching metadata, such as Service ID, to air-to-ground packets, but it is not required for the control-plane CIRI operation. The Airborne Radio may gather all necessary information by other means, for example, datalink providing two services might use two independent plain data channels to discriminate packets of these services.

### 3.1.3 Flow Control

Using combination of control plane and data plane, the CIRI can be also used to throttle flow of packets from the Airborne IPS System to the Airborne Radio.

An example flow control sequence is illustrated in Figure 3-4.

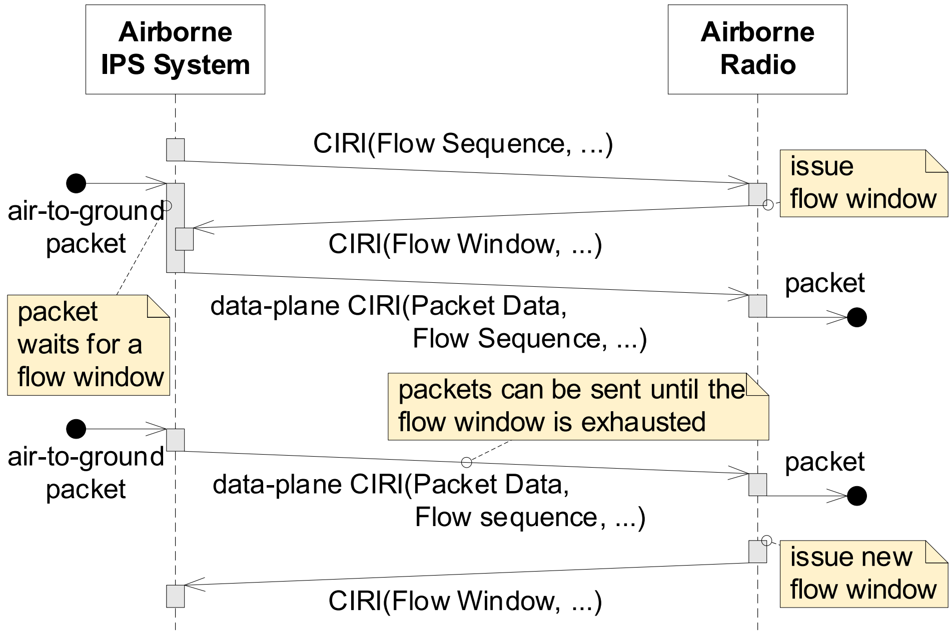


**Figure 3-4 – Flow Control Example Sequence**

For a configured flow, the flow control mechanism can be summarized as follows:

- The Airborne IPS System announces an arbitrary initial *Flow Sequence* value. The *Flow Sequence* is used as a counter of bytes sent within the flow.
- The Airborne Radio can then issue a *Flow Window*, specifying a number of bytes that can be accepted by the radio in the flow. The *Flow Window* is expressed as the highest *Flow Sequence*, that can be sent by the Airborne IPS System.
- For each air-to-ground packet within the flow, the Airborne IPS System increments the *Flow Sequence* by the size of the packet (in bytes). It keeps in its queues any air-to-ground packets that would exceed the window, until the window is extended or until the packet expires.

Keeping the Airborne Radio queues low enables prioritization (non-absolute) within the Airborne IPS System and helps to reduce the amount of lost data during a failover. Generally, the amount of data waiting in the Airborne Radio must be above a radio-specific threshold to achieve the optimal performance. For example, a SATCOM radio requests resources (e.g., timeslots) from the access network based on amount of queued data. If the flow control would keep SATCOM queues too low, the SATCOM radio would request less than the maximum number of timeslots from the access network despite additional SATCOM data queued in the Airborne IPS System; this would degrade the overall system performance.

# 4.0 CIRI PROTOCOL MESSAGE STRUCTURE

## 4.1 Message Format

CIRI message consists of a CIRI header and a sequence of CIRI options. All integers are encoded in network byte order (i.e., big endian).

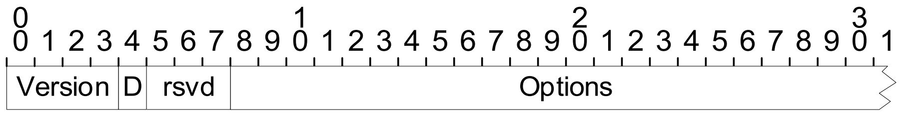


**Figure 4-1 – CIRI Message Format**

**Table 4-1 – CIRI Message Fields**

| Field | Description | Value |
|---|---|---|
| *Version* | 4-bit identifier | 0x0: Invalid<br>0x1: Current version<br>0x2 to 0xF: Reserved for future use |
| *Data Plane ("D")* | 1-bit flag, identifying whether the message is a control-plane message or a data plane message | 0: Control-plane CIRI message. Packet Data option must not be present.<br>1: Data-plane CIRI message. There must be exactly one Packet Data option present (see Section 3.1.2). |
| *rsvd* | 3-bit unused field. Initialized to zero by the sender and must be ignored by the receiver | b000 |
| *Options* | Variable-length field spanning to the end of this CIRI message. It consists of a sequence of one or more CIRI options. Order of options is not significant | |

## 4.2 Option Format

The following figure illustrates the CIRI option format.

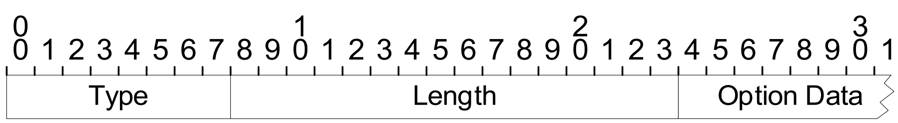


**Figure 4-2 – CIRI Option Format**

**Table 4-2 – CIRI Option Fields**

| Field | Description | Value |
|---|---|---|
| *Type* | 8-bit unsigned integer identifier | Refer to Table 4-3 |
| *Length* | 16-bit unsigned integer | 0 to $2^{16}$-1 |
| *Option Data* | Variable length field dependent on the specific option | |

If an option with unrecognized *Type* is received, or if an option is received in a context with no defined semantics (e.g., expiration time option in control-plane CIRI message), then this option must be ignored silently, and the rest of the CIRI message must be processed as if the option was not present.

If an option is received with *Length* greater than expected, the recognized beginning of the option must be processed as usual, and the surplus bytes must be ignored.

The summary of options defined in the CIRI protocol is in Table 1. It also indicates in which situations the option is mandatory (M) and in which other situations the option is optional (O). Options that can be included multiple times in a CIRI message are marked as “multiple.”

**Table 4-3 – Common IPS Radio Interface Option Applicability**

| Option *Type* | Option Name | Section in this document | Control Plane | | Data Plane | |
|---|---|---|---|---|---|---|
| | | | Airborne Radio to IPS System | IPS System to Airborne Radio | Airborne Radio to IPS System | IPS System to Airborne Radio |
| 0 | Reserved | | | | | |
| 1 | Datalink Identifier | 4.3.1 | M | M | M | M |
| 2 | Reserved | | | | | |
| 3 | Link Instance | 4.3.2 | O | | | |
| 4 | Datalink Context | 4.3.3 | O | | | |
| 5 | Service Status | 4.3.4 | M, multiple | | | |
| 6 | Flow Window | 4.3.6 | O, multiple | | | |
| 7 – 127 | Reserved for future extensions | | | | | |
| 128 | Packet Data | 4.3.7 | | | M | M |
| 129 | Service Identifier | 4.3.8 | | | | O |
| 130 | Expiration Time | 4.3.9 | | | | O |
| 131 – 133 | Reserved for future extensions | | | | | |
| 134 | Flow Sequence | 4.3.5 | | O, multiple | | O |
| 135 – 252 | Reserved for future extensions | | | | | |
| 253 | Reserved for experimental use | | | | | |
| 254 | | | | | | |
| 255 | Reserved | | | | | |

## 4.3 Message Option Specification

### 4.3.1 Datalink Identifier Option

This option identifies a datalink. It must be present once in every CIRI message. Any CIRI message without Datalink Identifier option, or with an unexpected *ID* value should be ignored.

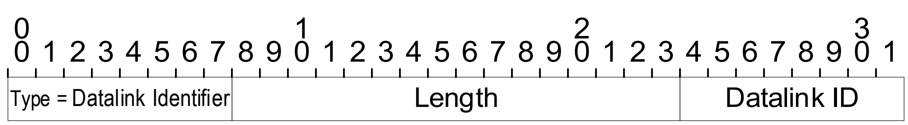


**Figure 4-3 – Datalink Identifier Option**

**Table 4-4 – Datalink Identifier Option Fields**

| Field | Description | Value |
|---|---|---|
| *Type* | Datalink Identifier | 1 |
| *Length* | Option length | 1 |
| *Datalink ID* | 8-bit unsigned integer<br>Represents a configured datalink ID | 0 to 255 |

### 4.3.2 Link Instance Option

The radio endpoint should use values of *Link instance ID* from a global repository, that will be specified by a future IPS standard document. This enables using this value directly in AGMI protocol when it is required for global mobility solution (see [AGMI]).

```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---------------+-------------------------------+---------------+
|Type = Link Instance|          Length          |Link Instance ID...|
+---------------+-------------------------------+---------------+
|...Link Instance ID|
+---------------+
```

**Figure 4-4 – Link Instance Option**

**Table 4-5 – Link Instance Option Fields**

| Field | Description | Value |
|---|---|---|
| *Type* | Link Instance | 3 |
| *Length* | Option length | 2 |
| *Link Instance ID* | 16-bit unsigned integer Represents a combination of the datalink technology and a particular access network, which therefore includes identification of a Communication Service Provider (CSP). | 0 to $2^{16}$-1 |

**COMMENTARY**

The *Link Instance ID* might be also used by the Airborne IPS System as a hint to the multilink decision. Note that the *Link Instance ID* applies to all services provided by the datalink.

### 4.3.3 Datalink Context Option

The *Context* field provides an abstract identifier of the current connection environment. Change in this value indicates that the datalink infrastructure requests the Airborne IPS System to send/re-send a mobility and multilink signaling message over this datalink.

**COMMENTARY**

The “mobility and multilink signaling message” is assumed to be an AGMI request, Router Solicitation with an OMNI option or similar, depending on deployed multilink signaling interface.
For example, if the ground infrastructure of a VHF datalink needs to receive a mobility and multilink signaling message from the aircraft after any handover to another ground station (e.g., to keep its routing configuration up to date), the Airborne Radio might use some “Ground Station ID” as value of the Datalink Context.

**4.0 CIRI PROTOCOL MESSAGE STRUCTURE**

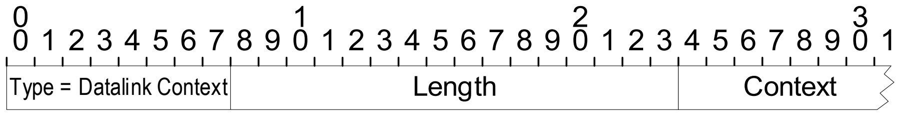


**Figure 4-5 – Datalink Context Option**

**Table 4-6 – Datalink Context Option Fields**

| Field | Description | Value |
|---|---|---|
| *Type* | Datalink Context | 4 |
| *Length* | Option length | 1 to 8 |
| *Context* | Variable length byte string | |

### 4.3.4 Service Status Option

This option specifies current status of one datalink service managed by the Airborne Radio endpoint.

Every Airborne Radio endpoint must report status for *Service ID* = 0 ("primary service") and may report statuses for other service. A CIRI message should not contain multiple Service Status options with the same *Service ID*.

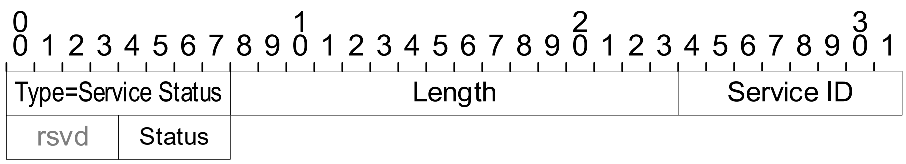


**Figure 4-6 – Service Status Option**

**Table 4-7 – Service Status Option Fields**

| Field | Description | Value |
|---|---|---|
| *Type* | Service Status | 5 |
| *Length* | Option length | 2 |
| *Service ID* | 8-bit unsigned integer<br>Identifies a datalink service as defined in Section 5.2 | 0 to 254: Datalink service identifier<br>255: Reserved for future use |
| *rsvd* | 4-bit unused field<br>This field must be initialized to zero by the sender and must be ignored by the receiver | 0x0 |
| *Status* | 4-bit unsigned integer<br>Indicates the status of the datalink service | 0: Datalink service is not operational ("link_down")<br>1 to 7: Datalink service is operational. Meaning of individual operational values is datalink-specific, where the following values are recommended:<br>• 1: Degraded with an unknown performance and impact on the user traffic ("best_effort")<br>• 4: Degraded with a known performance degradation and impact on user traffic ("link_degraded")<br>• 7: Datalink service is operational with nominal performance ("link_up") |

| Field | Description | Value |
|---|---|---|
| | | 8 to 14: reserved for future extensions. Unless configured otherwise, the receiver should treat these values as “unknown”.<br>15: Status of the service is unknown. This value is intended for internal usage in Airborne IPS System endpoint and should not be used in Service Status Option. |

**COMMENTARY**

The status values 0 to 7 are chosen to correspond to the 3-bit *Status* field from the Datalink Option in the AGMI protocol. See section 4.4.5 of [AGMI].

### 4.3.5 Flow Sequence Option

This option is used for the purpose of flow control (see Section 5.5). It signals the current *Flow Sequence* number for the given flow, which is a counter of bytes of air-to-ground packets sent within the flow, used by the Airborne IPS System endpoint. It might be included in both control-plane and data-plane CIRI messages.

When the Flow Sequence option is included in a data-plane CIRI message, it indicates value of the *Flow Sequence* counter after including the size of the data-plane packet in this CIRI message.

Note that the *Flow Sequence* counter uses a serial number arithmetic (modulo $2^{32}$) as defined in RFC 1982.

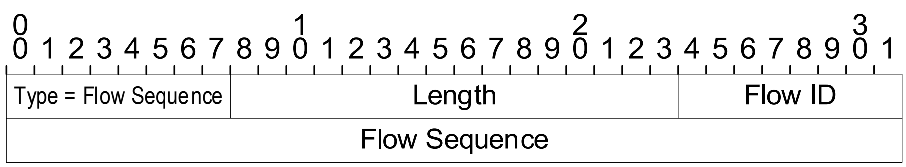


**Figure 4-7 – Flow Sequence Option**

**Table 4-8 – Flow Sequence Option Fields**

| Field | Description | Value |
|---|---|---|
| *Type* | Flow Sequence | 134 |
| *Length* | Option length | 5 |
| *Flow ID* | 8-bit unsigned integer<br>Identifies a subset of ground-to-air traffic | 0 to 255 |
| *Flow Sequence* | 32-bit unsigned integer<br>Indicates the current *Flow Sequence* used by the Airborne IPS System endpoint | 0 to $2^{32}$-1 |

### 4.3.6 Flow Window Option

This option is used for the purpose of flow control (see Section 5.5). In each control-plane CIRI message sent by the Airborne Radio endpoint, there is one Flow Window option for each configured flow.

A Flow Window option without the *Flow Window* field signals a request for Flow Sequence and does not establish an actual flow window.

**4.0 CIRI PROTOCOL MESSAGE STRUCTURE**

When a Flow Window option contains the *Flow Window* field, then it establishes a “flow window.” The flow window is expressed as the highest sequence number that can be transmitted by the Airborne IPS System in the given flow based on previously received Flow Sequence option.

The *Flow Window* uses serial number arithmetic (modulo $2^{32}$), as defined in RFC 1982. The Airborne Radio should use smallest possible *Flow Window*, that does not impair datalink performance.

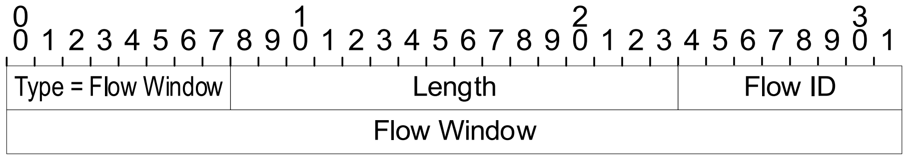


**Figure 4-8 – Flow Window Option**

**Table 4-9 – Flow Window Option Fields**

| Field | Description | Value |
|---|---|---|
| *Type* | Flow Window | 6 |
| *Length* | Option length | 1 or 5 |
| *Flow ID* | 8-bit unsigned integer<br>Identifies a subset of ground-to-air traffic | 0 to 255 |
| *Flow Window* | Optional 32-bit unsigned integer<br>Indicates the highest flow sequence number that can be accepted by the Airborne Radio endpoint. | 0 to $2^{32}$-1 |

### 4.3.7 Packet Data Option

This option must be present in any data-plane CIRI message.

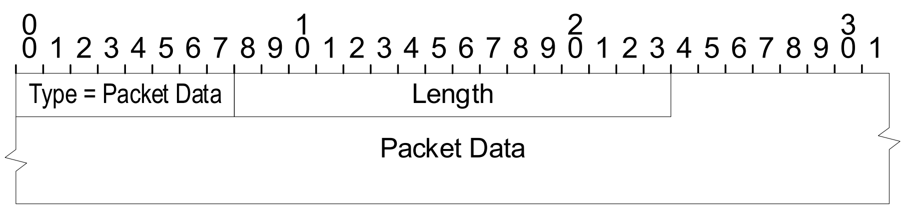


**Figure 4-9 – Packet Data Option**

**Table 4-10 – Packet Data Option Fields**

| Field | Description | Value |
|---|---|---|
| *Type* | Packet Data | 128 |
| *Length* | Option length | 0: No packet data<br>1 to $2^{16}$-1: length of packet data |
| *Packet Data* | Variable-length octet string packet containing the data-plane packet bytes | |

### 4.3.8 Service Identifier Option

This option may be present in any data-plane CIRI message. It indicates that the accompanied air-to-ground packet belongs to the identified datalink service (see Section 5.2).

The Airborne Radio is requested to use the identified datalink service to deliver the packet. The chosen service may be reflected by flow control (see Section 5.5) and treatment within the radio (e.g., prioritization).

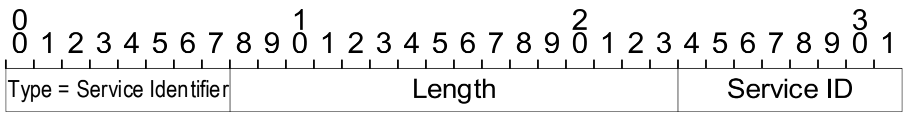


**Figure 4-10 – Service Identifier Option**

**Table 4-11 – Service Identifier Option Fields**

| Field | Description | Value |
|---|---|---|
| *Type* | Service Identifier | 129 |
| *Length* | Option length | 1 |
| *Service ID* | 8-bit unsigned integer<br>Identifies a service as defined in Section 5.2. | 0 to 254: Datalink service identifier<br>255: reserved for future use. Receiver must ignore a Service Identifier option that contains *Service ID* 255. |

### 4.3.9 Expiration Time Option

This option may be present in a data-plane CIRI message from Airborne IPS System to the Airborne Radio. It indicates that after the expiration time, the conveyed packed is expired and may be discarded by the radio.

If the radio is capable of tracking expiration time for individual packets, it should discard any packet not delivered within the expiration time, to preserve bandwidth for other traffic.

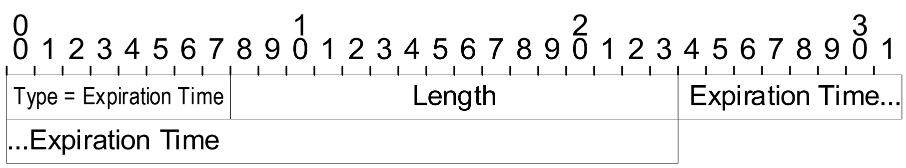


**Figure 4-11 – Expiration Time Option**

**Table 4-12 – Expiration Time Option Fields**

| Field | Description | Value |
|---|---|---|
| *Type* | Expiration Time Option | 130 |
| *Length* | Option length | 4 |
| *Expiration Time* | 32-bit unsigned integer.<br>Indicates expiration time ~~in milliseconds~~. | 0: No expiration time specified<br>1 to $2^{32}$-1: expiration time in milliseconds |

# 5.0 CIRI PROTOCOL OPERATION

CIRI operates between a pair of endpoints. Each pair consists of one Airborne IPS System endpoint and one Airborne Radio endpoint. Both endpoints must be configured with a *Datalink ID*, uniquely identifying the pair within the aircraft. Every CIRI message exchanged between those endpoints must contain a Datalink Identifier option with this *Datalink ID*.

## 5.1 Transport Layer

CIRI operation relies on a datagram-oriented transport service between the Airborne IPS System endpoint and Airborne Radio endpoint. This might be UDP/IP or any aviation-specific protocol.

Because the communication might be initiated by both peers, it is recommended that addressing should be statically configured on both endpoints and that all control-plane CIRI messages from one endpoint use the same addressing.

If the data-plane CIRI is used, it may use the same transport channel addressing as the control-plane CIRI, or it might use one or more separate transport channels, e.g., use of different UDP port numbers. This is a deployment option.

**COMMENTARY**

For example, if the CIRI operates on top of UDP/IP, then both endpoints should be configured with the same four-tuple of:

(IPS IP address, IPS UDP port number,
Radio IP address, Radio UDP port number).

and all outgoing control-plane CIRI messages use this addressing. If the CIRI is also used for data plane, then there may be another four-tuple for data-plane CIRI.

Single transport channel might be shared by multiple logical CIRI endpoints. In that case, these are distinguished by *Datalink ID*.

## 5.2 Services

An Airborne Radio provides one or more datalink services. The radio must provide the primary service (*Service ID* = 0) and may announce other services. It is assumed that the set of services provided by a radio is fixed and configured in the connected Airborne IPS System.

A datalink service is a “transport channel” for sending air-to-ground packets. Each air-to-ground packet given to the radio shall be associated with one service. If the radio gets the packet from a data-plane CIRI message, then the service is identified by the Service Identifier option (see Section 5.4.3).

If the data-plane CIRI is used, then the service of air-to-ground packets is indicated by the Service Identifier option. Other data plane protocols may define other means to specify service for the air-to-ground traffic.

A datalink service is identified by *Service ID*, which is an integer between 0 and 254:

- *Service ID* 0 is the primary service; all datalinks must provide this service.
- *Service ID* 1 to 254 are deployment specific datalink services. Not defined in this document.
- *Service ID* 255 is reserved.

This protocol uses *Service ID* in the Service Status option, Service Identifier option, and also in Flow ID option (see Section 5.5).

It is recommended that mobility and multilink signaling messages (e.g., AGMI messages) are sent over the primary service.

## 5.3 Airborne IPS System Endpoint Operation

### 5.3.1 Configuration

Airborne IPS System CIRI endpoint is configured with:

- Datalink ID – an 8-bit unsigned integer matching the *Datalink ID* of the peer Airborne Radio CIRI endpoint.
- ResponseTime – a time interval that Airborne IPS System endpoint waits for a response to a control-plane CIRI message sent to an Airborne Radio endpoint.
  - Default value: 3000ms
- HelloTime – a maximal time between two consecutive control-plane CIRI messages outgoing from Airborne IPS System endpoint
  - Default value: 5000ms
- MaxUnanswered – if number of messages unanswered by the radio exceeds this number, the radio is considered broken, and the datalink service status for all applicable services is set to UNKNOWN.
  - Default value: 2
- Configuration of transport layer (see Section 5.1). There may be a separate configuration for control plane and for the data plane.

The Airborne IPS System may need other configuration information not specified in this document regarding inclusion of metadata in data plane messages (e.g., Service ID, Expiration Time) and processing of status information received from the Airborne Radio (see Section 5.3.2.1).

### 5.3.2 Control Plane Operation

Airborne IPS System endpoint sends a control-plane CIRI message containing appropriate Datalink Identifier option to Airborne Radio endpoint immediately after initialization and then periodically (with HelloTime period).

If the IPS does not receive a response within ResponseTime for a control-plane CIRI message, then another control-plane CIRI message is sent. If the IPS does not receive a response for more than MaxUnanswered control-plane CIRI messages in a row, then the datalink is considered to be broken and status is set to “unknown” for all applicable services.

Upon receiving a control-plane CIRI message with a valid Datalink Identifier option, the Airborne IPS System endpoint updates its status information according to Service Status options included in that message and possibly from other inputs. It may also note information from other included options. This operation is summarized in Figure 5-1, and the Section 5.3.2.1 contains recommendations for processing of the information from the radio.

If a received control-plane CIRI message contains a Datalink Context option and the *Context* value is not the same as last *Context* value received from the radio, then the Airborne IPS System is requested to send a mobility and multilink signaling message over this datalink (see Section 4.3.3).

If the Airborne IPS System endpoint is configured to use the Flow control mechanism, then Section 5.5.1 also applies.

**COMMENTARY**

In order to achieve optimal datalink performance, the Airborne IPS System should use the provided *Flow Window* as much as possible, i.e., keep the air-to-ground packet in its queues, only if the packet cannot “fit” into the currently active *Flow Window*.

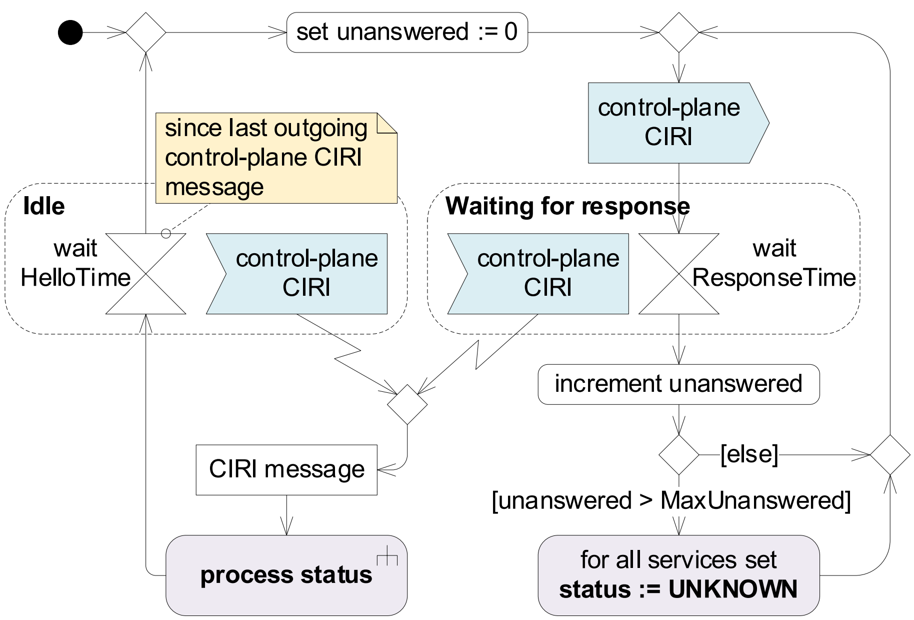


**Figure 5-1 – Airborne IPS System Endpoint Control Plane Operation**

### 5.3.2.1 CIRI Control Plane Message

Control plane CIRI message sent by the Airborne IPS System endpoint has the *Data-plane* flag set to 0 in the CIRI header and contains exactly one Datalink Identifier option. For each configured flow (see Section 5.5, there is zero or one corresponding Flow Sequence option.

### 5.3.3 Status Processing

The protocol specification does not require the Airborne IPS System to process the status information received from the Airborne Radio in any particular way, but the following bullets summarize a representative approach:

- Service Status options indicate the current status of datalink services.
  - This is the primary indication whether the datalink can be used to convey data-plane traffic to and from the ground.
  - The Airborne IPS System might use any other appropriate knowledge to supplement (or override) *Status* announced by the radio.
  - The *Status* of the primary service might directly map to datalink status used in the AGMI protocol (see section 4.4.5 of [AGMI]).

- Link Instance option may be used to identify datalink's current Communication service provider.
  - This information might be necessary for the mobility and multilink signaling protocol. In case of AGMI, the value of *Link Instance ID* is intended to be directly used in AGMI Datalink option and preferences [AGMI].
- Datalink Context option should be monitored to detect a need to send another mobility and multilink signaling message (see Section 4.3.3).

### 5.3.4 Data Plane Operation

Optionally, the CIRI may be used for data-plane traffic.

When the Airborne IPS System endpoint receives a valid data-plane CIRI message from the peer radio endpoint, then the carried ground-to-air packet is processed either locally or forwarded towards the destination in the aircraft.

When the Airborne IPS System wishes to send an air-to-ground packet via this datalink, a data-plane CIRI messages with this packet is sent to the peer radio. This CIRI message may contain metadata describing the packet.

If the Airborne IPS System endpoint is configured to use the flow control mechanism, then Section 5.5.1 also applies.

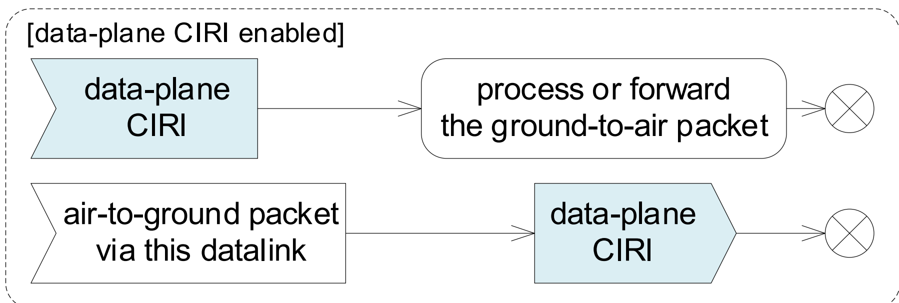


**Figure 5-2 – Airborne IPS System Endpoint Data Plane Operation**

#### 5.3.4.1 CIRI Data Plane Message

Data-plane CIRI message sent from Airborne IPS System has the *Data-plane* flag set to 1 in the CIRI header and contains exactly one Packet Data option and exactly one Datalink Identifier option. It may also contain:

- zero or one Service Identifier option
- zero or one Expiration Time option
- zero or one Flow Sequence option.
  If present, the *Flow ID* should be set either to value 255, when flow control is configured for the aggregated flow, or to the *Service ID* specified in the Service Identifier option, when flow control is configured for the given non-aggregated flow.

These options describe properties of the packet carried by the Packet Data option.

## 5.4 Airborne Radio Endpoint Operation

### 5.4.1 Configuration

- Datalink ID – an 8-bit unsigned integer matching the *Datalink ID* of the peer Airborne IPS System CIRI endpoint.
- Configuration of transport layer (see Section 5.1). There might be an individual configuration for control plane and data plane, if the CIRI data plane is used.

The Airborne Radio may need other configuration information not specified in this document regarding processing of data of different services (see Section 5.2) and the use of flow control.

### 5.4.2 Control Plane Operation

The Airborne Radio endpoint reacts to events, as summarized in Figure 5-3. Whenever:

- A valid control-plane CIRI message is received from the peer Airborne IPS System endpoint, or
- Datalink status changes, or
- Optionally, whenever any other new information is available, e.g., Flow Window or Datalink Context update.

then the radio endpoint sends a control-plane CIRI message (see Section 5.4.2.1).

If the Airborne Radio endpoint is configured to use the flow control mechanism, then Section 5.5.2 also applies.

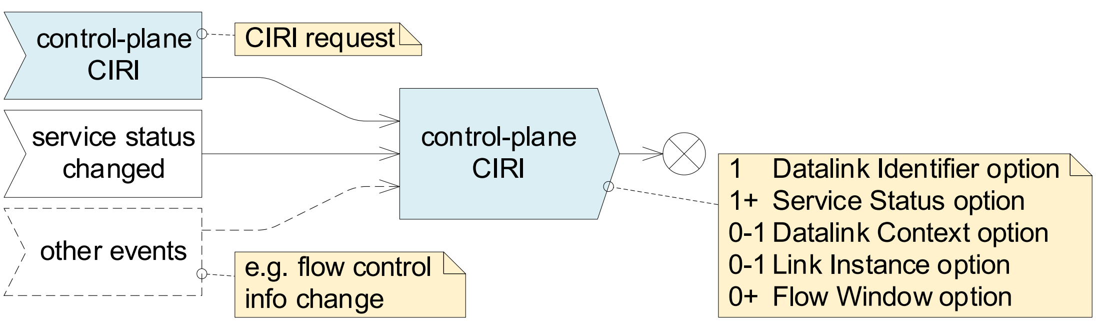


**Figure 5-3 – Airborne Radio CIRI Endpoint Control Plane Operation**

#### 5.4.2.1 CIRI Control Plane Message

The control-plane CIRI message sent by the Airborne Radio contains:

- one Datalink Identifier option
- one or more Service Status options with the current status of all configured services.
- zero or one Link Instance option
- zero or one Datalink Context option
- zero or more Flow Window options (see Section 5.5.2)
  - For each configured flow there is one Flow Window option.

### 5.4.3 Data Plane Operation

Optionally, the CIRI may be used for data-plane traffic.

When the radio endpoint receives a valid data-plane CIRI message from the peer Airborne IPS System endpoint, then the carried air-to-ground packet is queued for transmission to ground over the datalink service specified in the Service Identifier option. If the CIRI message does not contain Service Identifier option, *Service ID* = 0 (the primary service) is implied. If the CIRI message indicates an invalid *Service ID* in a Service Identifier option, then the Airborne Radio should discard the packet.

If the CIRI message contains any other metadata (e.g., Expiration Time option), then this information should be associated with the packet.

Whenever a ground-to-air packet is received from ground, a data-plane CIRI messages with this packet is sent to the peer Airborne IPS System (see Section 3.1.2).

If the Airborne Radio endpoint is configured to use the flow control mechanism, then Section 5.5.2 also applies.

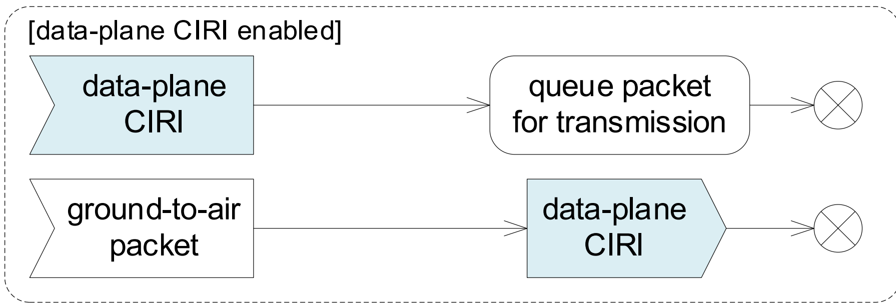


**Figure 5-4 – Airborne Radio CIRI Endpoint Data Plane Operation**

#### 5.4.3.1 CIRI Data Plane Message

The data-plane CIRI message sent by the Airborne Radio endpoint has the *Data-plane* flag set to 1 in the CIRI header and contains exactly one Datalink Identifier option and exactly one Packet Data option.

### 5.5 Flow Control

The flow control mechanism is an optional feature of the CIRI protocol. When the data-plane CIRI is employed, then the CIRI flow control mechanism provides a means for the Airborne Radio to govern the amount of data sent by the Airborne IPS System.

A **flow** is a subset of the air-to-ground traffic that is subject to the flow control mechanism. The flow is identified by a *Flow ID*:

- *Flow ID* 0 to 254 identifies traffic consisting of packets of the corresponding service (see Section 5.2)
- *Flow ID* 255 is "aggregated" flow, containing all traffic regardless of its service.

The Airborne Radio may be configured to provide a flow control mechanism for the aggregated flow, or for one or more non-aggregated flows. In the latter case, each flow is controlled independently.

A **flow sequence** is a counter of the bytes of air-to-ground packets. It is assigned by the Airborne IPS System and for each air-to-ground packet in the flow incremented by size of the packet. It is advertised in a Flow Sequence option.

A **flow window** is a license for some amount of air-to-ground data, that the Airborne IPS System can safely pass to the Airborne Radio. The Flow Window is issued by the Airborne Radio and it is expressed as the highest flow sequence number that can be transmitted by the Airborne IPS System in the given flow based on previously received Flow Sequence option. The Airborne Radio should issue smallest possible Flow window, that does not impair datalink performance.

All mathematical operations (including comparison) on Flow Window and Flow Sequence follow sequence number arithmetic (modulo $2^{32}$), as defined in RFC 1982. This is emphasized in the following text as "sn" subscript ($+_{sn}$, $\leq_{sn}$).

For the overview, see Section 3.1.3. The operation is described in detail in the following sections.

**COMMENTARY**

The main purpose of the flow control mechanism is to limit cumulation of packets in the Airborne Radio, and to instead queue these packets in the Airborne IPS System, without sacrificing the datalink performance.

**COMMENTARY**

The presented flow control mechanism assumes use of the CIRI data-plane functionality. It might be possible to define a similar flow control mechanism working with other data-plane protocols, but this option is not specified in this document.

### 5.5.1 Airborne IPS System Flow Control Operation

For all configured flows, the Airborne IPS System keeps track of the current *Flow Sequence* and *Current Flow Window*. The *Flow Sequence* should be initialized to zero and the *Current Flow Window* is initialized to "invalid".

Each control-plane CIRI message sent to the Airborne Radio endpoint must contain a Flow Sequence option for each configured flow that has an "invalid" *Current Flow Window*.

When the Airborne IPS System receives a Flow Window option for a configured flow without the *Flow Window* field (i.e., having *Length* = 1), then it should set the *Current Flow Window* to "invalid" and return a control-plane CIRI message that contains a Flow Sequence option for each flow which has the *Current Flow Window* "invalid".

When the Airborne IPS System receives a Flow Window option for a configured flow that includes the *Flow Window* field (i.e., having *Length* ≥ 5), then the *Current Flow Window* for the given flow is updated to the received value. The *Current Flow Window* remains valid until another Flow Window option is received for that flow or until the corresponding datalink service (or all services, in case of the aggregated flow) becomes non-operational (e.g., by receiving *Status* = link_down in a Service Status option).

When the Airborne IPS System wants to send an air-to-ground packet that belongs to a configured flow, then it must not exceed the issued *Flow Window*:

If there is a valid *Current Flow Window* for that flow, and if

$$\textit{Flow Sequence} +_{sn} \text{(packet size in bytes)} \leq_{sn} \textit{Current Flow Window},$$

then the *Flow Sequence* for this flow is incremented by the packet size (in bytes) and the packet is sent to the Airborne Radio. The corresponding data-plane CIRI message must include a Flow Sequence option with the updated information.

If there is no valid *Current Flow Window*, or if the updated *Flow Sequence* would exceed the window, then the packet must not be sent to the Radio. It should be instead kept in an "outbox" queue in the Airborne IPS System, until the window is extended, or until the Airborne IPS System chooses to discard the packet, e.g., because it became too old.

Example operation of the data plane in the air-to-ground direction is summarized in Figure 5-5.

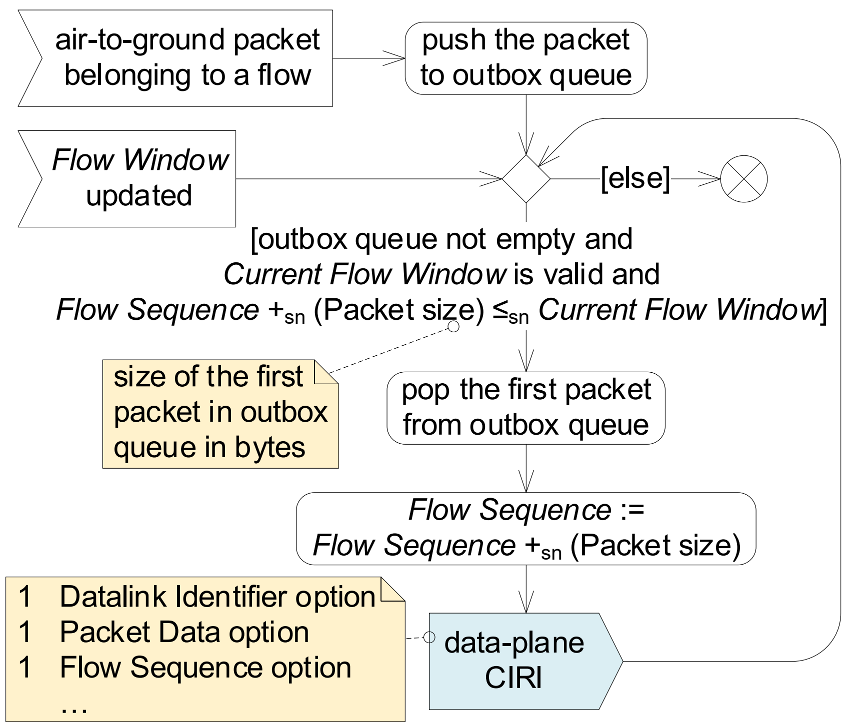


**Figure 5-5 – Example Operation of the Airborne IPS System CIRI Endpoint Data Plane in the Air-Ground Direction with Flow Control**

### 5.5.2 Airborne Radio Flow Control Operation

For each configured flow, the Airborne Radio keeps track of the *Highest Flow Sequence* and the *Current Flow Window*. These variables are initialized to "invalid". If these variables are not invalid, then the following invariant (INV) must hold:

$$\textit{Highest Flow Sequence} \leq_{sn} \textit{Current Flow Window} \qquad \text{(INV)}$$

All control-plane CIRI messages sent by the Airborne Radio contain for each configured flow one Flow Window option with the *Flow Window* field set to value of the *Current Flow Window* for that flow. If the *Current Flow Window* for that flow is invalid, then the *Flow Window* field is omitted (i.e., the Flow Window option has *Length* = 1).

After initialization, the Airborne Radio endpoint sends a control-plane CIRI message having a Flow Window option without the *Flow Window* field for each configured flow.

When the Airborne Radio:

- receives a Flow Sequence option in a control-plane CIRI message, or
- receives a Flow Sequence option in a data-plane CIRI message and the *Current Flow Window* for the flow is invalid,

then the *Highest Flow Sequence* is set to the received *Flow Sequence* and the *Current Flow Window* variable is updated to a valid value, such that

*Highest Flow Sequence* $+_{sn}$ (size of the flow window) = *Current Flow Window*.

The size of the flow window should use the lowest possible value, that does not impair datalink service performance.

When the Airborne Radio receives a Flow Sequence option for a configured flow in a data-plane CIRI message and the *Current Flow Window* for the flow has a valid value, and if:

*Highest Flow Sequence* $\leq_{sn}$ (*Flow Sequence* in the CIRI message)

Then the *Highest Flow Sequence* is set to the received *Flow Sequence*. At this point, if the invariant (INV) does not hold, then the *Current Flow Window* is set to the *Highest Flow Sequence*.

At any time, the Airborne Radio may decide to extend (or shrink) the issued *Flow Window* for a flow, by changing the *Current Flow Window* variable for the flow. When it does, it must send an unsolicited control-plane CIRI message with the updated information.

The Airborne Radio should extend the flow window and send the corresponding unsolicited CIRI message whenever it has resources available to handle additional air-to-ground traffic, e.g., because it has already transmitted some of the air-to-ground packets to the ground and released resources.

### 5.5.3 Flow Control Example

Air-to-ground throughput of a SATCOM datalink depends on "time slots" assigned by the access network infrastructure, and assignment of the time slots is driven by amount of data queued in the SATCOM Airborne Radio. So, the Airborne Radio can try to keep its queues at some "watermark" level. This ensure, with some level of confidence, that the SATCOM datalink uses available resources optimally if there are any air-to-ground data, but also that the data are not queued in the radio unnecessarily.

In the example above, the *Flow Window* indicated by the Airborne Radio might be for example computed as

*Flow Window* := *Highest Flow Sequence* $+_{sn}$ max(0,
watermark$_0$ + (nominal_throughput × period) – queued_data_size
)

where:

- *Highest Flow Sequence* is the highest *Flow Sequence* recently received from the Airborne IPS System for the given flow
- watermark$_0$ is amount of data, that should be queued at any point of time to achieve optimal performance, e.g., to request all time slots available
- nominal_throughput is best-case throughput of the datalink

- period is time between two consecution CIRI messages with the Flow control options and
- queued_data_size is amount of data already waiting for transmission in the Airborne Radio queues.

# ATTACHMENT 1 LIST OF ACRONYMS

| | |
|---|---|
| A-G or A/G | Air-to-Ground |
| AEEC | Airlines Electronic Engineering Committee |
| AeroMACS | Aeronautical Mobile Airport Communications System |
| AGMI | Air-Ground Mobility Interface |
| AID | Aircraft Interface Device |
| AISD | Aircraft Information Services Domain |
| AOC | Airline or Aeronautical Operational Control |
| ATC | Air Traffic Control |
| ATS | Air Traffic Services |
| CIRI | Common IPS Radio Interface Protocol |
| COTS | Commercial Off The Shelf |
| CSP | Communication Service Provider |
| DLEP | Dynamic Link Exchange Protocol |
| FCI | Future Communications Infrastructure |
| FRD | Functional Requirements Document |
| G-G or G/G | Ground-to-Ground |
| ICAO | International Civil Aviation Organization |
| ID | Identifier |
| IEEE | Institute of Electrical and Electronics Engineers |
| IETF | Internet Engineering Task Force |
| IF | Interface |
| INV | Invariant |
| IP | Internet Protocol |
| IPS | Internet Protocol Suite |
| IPv4 / IPv6 | Internet Protocol Version 4 or Version 6 |
| L2 | Layer 2 |
| LDACS | L Band Digital Aeronautical Communication System |
| lsb/LSB | Least Significant Bit |
| MAGIC | Manager of Air-Ground Interface Communications |
| MIB | Management Information Base |
| MIH | Media Independent Handover |
| msb/MSB | Most Significant Bit |
| OMNI | Overlay Multilink Network Interface |
| QoS | Quality of Service |
| RCP | Required Communication Performance |
| RCTP | Required Communication Technical Performance |
| RF | Radio Frequency |
| RFC | Request for Comment |
| RSP | Required Surveillance Performance |

**ATTACHMENT 1**
**LIST OF ACRONYMS**

| | |
|---|---|
| SAP | Service Access Point |
| Satcom | Satellite Communications |
| SB-Safety | Swift Broadband-Safety |
| SDO | Standards Development Organization |
| SESAR | Single European Sky Air Traffic Management (ATM) Research |
| SESAR JU | SESAR Joint Undertaking |
| Sn | Sequence Number |
| SNMP | Simple Network Management Protocol |
| TBC | To Be Confirmed |
| TBD | To Be Determined |
| TCP | Transmission Control Protocol |
| TLV | Type-Length-Value |
| UDP | User Datagram Protocol |

# ATTACHMENT 2 GLOSSARY

**Access Network**
A network that is characterized by a specific access technology. [Source: ICAO Doc. 9896]

**Air-Ground Access Network**
Access network that provides air-ground communication services.

**Air-Ground Datalink**
Refer to the definition for Air-Ground Access Network.

**Airborne IPS Host**
Airborne instantiation of an IPS Host.

**Airborne IPS Router**
An airborne device that is used to support ATN/IPS packet forwarding between one or more Airborne IPS Hosts and Airborne Radios.

**Airborne IPS System**
The collection of airborne components and functions that provide IPS services.

**Airborne Radio**
Physical airborne radio that provides the communication over-the-air using the specific air-ground access network specification and the Layer 2 interface to the Airborne IPS System.

**AMS(R)S – Aeronautical Mobile-Satellite Route Service**
An aeronautical mobile-satellite service reserved for communications related to safety and regularity of flights, primarily along national or international civil air routes. [Source: ICAO Annex 10, Volume II]

**AOC – Aeronautical Operational Control**
Communication required for the exercise of authority over the initiation, continuation, diversion or termination of flight for safety, regularity and efficiency reasons. [Source: ICAO Annex 10, Part III]

**AOC – Airline Operational Control**
Operational messages used between aircraft and airline dispatch centers or, by extension, the DoD to support flight operations. This includes, but is not limited to, flight planning, flight following, and the distribution of information to flights and affected personnel.

**ATN/IPS**
The set of technical provisions and standards that define the architecture and operation of Internet Protocol-based networking services. Also referred to as IPS.

## ATTACHMENT 2
## GLOSSARY

**ATN/IPS Network / System**

Internetwork consisting of ATN/IPS nodes and networks operating in a multinational environment in support of Air Traffic Services (ATS) as well as aeronautical industry service communication such as Aeronautical Operational Control (AOC) and Aeronautical Administrative Communications (AAC).

**Control Plane**

Data exchanged to manage communication sessions between users. The control plane includes protocols providing information needed to move traffic from one device to another through the network. Routing protocols and DNS belong to the control plane.

**Data Plane**

The collection of resources across all network devices responsible for forwarding traffic to the next hop along the path to the selected destination network according to the control plane logic.

**Downlink**

A unit of data sent from an aircraft to a ground-based system.

**IPS (aka IPS for Safety Services)**

Refer to the definition for ATN/IPS.

**IPS Node**

A device that implements IPv6. There are two types of IPS nodes: an IPS Host and an IPS Router. Note: An IPS Gateway could be considered an IPS Node.

**IPS Router**

A node that forwards Internet protocol (IP) packets not explicitly addressed to itself. A router manages the relaying and routing of data while in transit from an originating IPS Host to a destination IPS Host. [Source: ICAO Doc. 9896]

**IPS System**

The IPS System is the all-encompassing aviation internet that provides data transport, networking, routing, addressing, naming, mobility, multilink and information security functions to the aviation services. The IPS System includes the Layer 3 and Layer 4 functions of the ISO/IEC 7498-1 OSI 7-layer Reference Model. The IPS System does not include the underlying subnetwork functions that provide connectivity or the applications. [Source: RTCA DO-379 and EUROCAE ED-262]

**Link Local Address**

Link-Local addresses are for use on a single link. Link-Local addresses are designed to be used for addressing on a single link for purposes such as automatic address configuration, neighbor discovery, or when no routers are present.

**Multilink**

Ability to use all available air-ground access networks in order to provide the specified performance.

## ATTACHMENT 2
## GLOSSARY

**Network**

A group of two or more devices (nodes) that communicate using a common set of communication protocols.

**Network Layer**

Protocol layer based on Internet Protocol (IP) ensuring global routing over interconnected packet-switched communication networks.

**Physical and Link Layers**

Functions within the subnetworks that handle the physical interface with the transmission medium (i.e., radio links).

**QoS – Quality of Service**

A framework where the overall performance of an application or a computer network is stated. Some examples of parameters are: Integrity, Availability, Delay, Continuity, bit rate, throughput, delay, etc.

**Satcom – Satellite Communications**

Communication service providing data, voice, and fax transmission via satellite. Allows aircraft to communicate in BLOS areas.

**SESAR – Single European Sky ATM Research**

European air traffic control infrastructure modernization program. SESAR aims at developing the new generation ATM system capable of ensuring the safety and fluidity of air transport worldwide over the next 30 years.

**Subnetwork**

An actual implementation of a data network that employs a homogeneous protocol and addressing plan and is under control of a single authority. [ICAO Doc. 9705]

**Transport Layer**

Protocol layer used to provide reliable or unreliable communication services over the IPS System. Those include TCP for reliable transport services and UDP that is used to provide best effort service.

**Uplink**

A unit of data sent from a ground-based system to an aircraft.

# APPENDIX A CIRI PROTOCOL BACKGROUND

The material in this appendix summarizes the background information that served as a baseline for definition of the CIRI protocol, which addresses the needs of the Common IPS Radio Interface.

The information provided is based on work performed under the SESAR 14.2.4 project that summarized its results in Functional Requirements Document [FCI-FRD].

## A-1 Common IPS Radio Interface Requirements

This section defines a set of requirements defining the needs of the Common IPS Radio Interface.

The following tables present control plane, data plane, flow control, and robustness requirements. Mandatory protocol requirements are identified using "shall" and recommendations are identified using "should" and italicized text.

**Table A-1 – Control Plane Requirements**

| No. | Requirement | Note | CIRI Protocol Compliance |
|---|---|---|---|
| 1 | The Common IPS Radio Interface protocol **shall** enable the Airborne Radio to report datalink operational status to the Airborne IPS System. | At a minimum, distinguishing available ("link_up") and not available ("link_down") | Service Status option |
| 2 | The Common IPS Radio Interface protocol **shall** be able to able to distinguish multiple different operational statuses. | For example, distinguishing between "link_up" and "link_degraded".<br><br>Although defining a fine-grained metric that would allow comparing "fitness" of datalinks of various technologies proves to be extremely difficult, ability to indicate a non-nominal, degraded performance is considered to be useful. | Distinguishes up to 7 distinct operational statuses |
| 3 | The Common IPS Radio Interface protocol **shall** enable the Airborne Radio to report operational status separately for multiple services when multiple services are provided by the datalink. | The "Service" identifies a subset of air-to-ground traffic, that is treated by the Airborne Radio together.<br><br>This is necessary to support SATCOM operation described in Requirement 6, to distinguish status of the provided "higher-priority" (RCP/RSP-bound, e.g., ATS) and "lower-priority" (non-RCP/RSP-bound, e.g., AOC) services.<br><br>An Airborne Radio may provide and announce just single service that will be used for all traffic. | Service Status option<br><br>Allows reporting status for up to 255 services. |
| 4 | The Common IPS Radio Interface protocol **shall** enable the Airborne Radio to report the current access network identifier. | This information is necessary for the mobility and multilink signaling (e.g., AGMI).<br><br>The "access network" identifies a combination of the datalink technology and a communication service provider. | Link Instance option<br><br>The option is chosen such that the received Link Instance ID can be used directly in the AGMI protocol. |

APPENDIX A
CIRI PROTOCOL BACKGROUND

| No. | Requirement | Note | CIRI Protocol Compliance |
|---|---|---|---|
| | | For example, a Link Instance ID as defined in the AGMI protocol.<br>This information might be also important for multilink selection in the aircraft. | |

**Table A-2 – Data Plane Requirements**

| No. | Requirement | Note | CIRI Protocol Compliance |
|---|---|---|---|
| 5 | The Common IPS Radio Interface protocol **shall** enable the Airborne Radio and the Airborne IPS System to exchange data-plane packets not exceeding 1280 bytes. Larger packets may be supported. | For this basic requirement, no special protocol would be needed. | Data Plane message with Packet Data option |
| 6 | The Common IPS Radio Interface protocol **shall** enable the Airborne IPS System to indicate a service for air-to-ground packets passed to the Airborne Radio. | This is needed for safety-certified datalink operation, that can simultaneously handle RCP/RSP-bound communication (higher priority/"ATS" traffic) and communication without RCP/RSP constraints (lower priority/"AOC" traffic).<br>• The higher priority traffic needs this to satisfy the RCP/RSP even in the presence of the uncontrolled traffic.<br>• For example, satcom is envisioned to provide dedicated underlying channels for the higher priority traffic and the lower priority traffic.<br>The requirement could be satisfied by deploying multiple plain data-plane channels between the Airborne IPS System and the Airborne Radio. | Service Identifier option |

Note that although the Requirements 5 and 6 and could be satisfied by one or several “plain” channels for the data plane packets; however, the Common IPS Radio Interface defines a more scalable and extensible alternative, in form of the data plane CIRI message.

**Table A-3 – Flow Control Requirements**

| No. | Requirement | Note | CIRI Protocol Compliance |
|---|---|---|---|
| 7 | The Common IPS Radio Interface protocol **shall** enable the Airborne Radio to inform the Airborne IPS System about the number of bytes that it can accept in a flow. | The “flow” is a subset of air-to-ground traffic. See Requirements 8 and 9. | Flow control mechanism |

**APPENDIX A**
**CIRI PROTOCOL BACKGROUND**

| No. | Requirement | Note | CIRI Protocol Compliance |
|---|---|---|---|
| 8 | The Common IPS Radio Interface protocol **shall** support multiple flows, where each flow consists of air-to-ground packets belonging to a single service (as described in Requirement 3). | I.e., the protocol can provide flow control on a per-service basis | Flow control mechanism |
| 9 | *The Common IPS Radio Interface protocol **should** support a flow that consist of all air-to-ground packets (regardless of the service).* | I.e., the protocol can provide flow control for all traffic together. | Flow control mechanism |

The operation of the proposed flow control mechanism is also influenced by the following Robustness requirements.

**Table A-4 – Robustness Requirements**

| No. | Requirement | Note | CIRI Protocol Compliance |
|---|---|---|---|
| 10 | The Common IPS Radio Interface protocol **shall** be robust against: | | Flow control and/or stateless operation of the CIRI protocol |
| 10.1 | … Airborne IPS System restarts (losing its Common IPS Radio Interface-related runtime state) | | |
| 10.2 | … Airborne Radio restarts (losing its Common IPS Radio Interface-related runtime state) | | |
| 10.3 | …interleaved messages in opposite directions. | Case shown in the following diagram:   | |
| 11 | *The Common IPS Radio Interface protocol **should** be robust against change of message delivery order.* | This is assumed to be much a much less probable situation than the one described in Requirement 10.3. | CIRI protocol converges to a valid state with the next received CIRI message |
| 12 | The Common IPS Radio Interface protocol **shall** allow future backward compatible extensions, that will interoperate with implementations of the older protocol version. | | CIRI header contains 3 reserved bits that are ignored by older implementations<br>New CIRI TLV options can be defined, which will be ignored by the older implementations.<br>Most current CIRI options can be |

APPENDIX A
CIRI PROTOCOL BACKGROUND

| No. | Requirement | Note | CIRI Protocol Compliance |
|---|---|---|---|
| | | | extended. The extra bytes will be ignored by the older implementations.<br><br>CIRI options used in cases with undefined semantics are ignored. |
| 13 | The Common IPS Radio Interface protocol **shall** allow future non-backward compatible versions. | | CIRI header Version field will be incremented if this becomes necessary |

**Table A-5 – General Protocol Operation Requirements**

| No. | Requirement | Note | CIRI Protocol Compliance |
|---|---|---|---|
| 14 | The Common IPS Radio Interface protocol **shall** enable the Airborne IPS Systems to have up-to-date datalink status information from the Airborne Radio. | The “datalink status information” is defined by requirements in Section 5.3.1. | CIRI request-response communication pattern allows the Airborne IPS System to fetch the current information after startup.<br><br>CIRI “trap-like” unsolicited messages sent by the Airborne Radio convey changes in datalink status information without a delay. |
| 15 | The Common IPS Radio Interface protocol **shall** enable the Airborne IPS System to detect loss of connection with the Airborne Radio. | This “health monitoring” detects when the radio goes down or when the connection between the Airborne IPS System and the Airborne Radio is broken. | CIRI protocol assumes the Airborne Radio is “broken” if answers to consecutive requests are not received. |

## A-2 Protocol Design Principles

The following bullets define key design principles for a Common IPS Radio Interface Protocol:

- The protocol should be as simple and as possible.
  - Facilitates certification
  - Facilitates implementation
- The protocol should be as stateless and as possible.
  - Facilitates recovery after restart of either peer.
- The protocol should not need any information from the lower layers (e.g., IP address, UDP port) to distinguish messages for/from different datalinks.

**APPENDIX A**
**CIRI PROTOCOL BACKGROUND**

## A-3 Candidate Protocol Alternatives – Initial Assessment

The following alternatives were considered as implementation options for the Common IPS Radio Interface protocol.

### A-3.1 Custom Layer 2 Protocol

Common IPS Radio Interface messages are implemented using a simple custom protocol that is carried directly by layer 2 (L2) frames (e.g., Ethernet) with no IP layer involved.

The main benefit of this approach is that it is lightweight – the Airborne Radio would not need an IPv6 network stack implementation. However, this approach is very nonstandard in the "TCP/IP" protocol suite, and consequently, this is the only alternative that does not use either a TCP/IP or UDP/IP stack.

### A-3.2 SNMP

This protocol is a de-facto industry standard, but it is (despite its name) rather complex and heavyweight. It offers plenty of configurable features (e.g., fine-grained access control, discovery procedure) while the Common IPS Radio Interface would only benefit from several specialized types of messages periodically sent between the peers.

To use SNMP for the Common IPS Radio Interface, it is necessary to know MIB and "operational protocol" – which party sends which message at which occasion, usage of SNMP requests/traps &c.

There are basically two options:

- Each radio uses its own MIB with its own semantics
    - This is simple, as there is nothing to standardize.
    - On the other hand, this approach leaves fundamental parts of the Common IPS Radio Interface operation unspecified. A considerable amount of radio-specific configuration, and possibly adaptation layer software, is needed for each radio
    - Because this approach does not result in a "standardized Common IPS Radio Interface", it is not further investigated in this document.
- There is a common MIB and standardized mode of operation supported by all complaint radios.
    - This is the preferred approach when using SNMP
    - The following must be standardized:
        - Common IPS Radio Interface MIB
        - SNMP configuration for Common IPS Radio Interface, e.g., configuration of security model
        - Common IPS Radio Interface "operational protocol."

Consequently, defining the Common IPS Radio Interface protocol on top of SNMP still necessitates further definition and standardization.

**APPENDIX A**
**CIRI PROTOCOL BACKGROUND**

### A-3.3 ARINC 839 MAGIC

Although ATN/IPS is not a MAGIC-complaint system per ARINC 839, the Common IPS Radio Interface bears some similarities to the Common Link Interface specified in ARINC 839.

- The Common Link Interface is based on MIH_LINK_SAP from IEEE 802.21, which is not designed to operate between different nodes over a network.
- There is not any standard way to transfer MIH_LINK_SAP primitives over a network; however, IEEE 802.21 defines structure of MIH_LINK_SAP primitives and a serialization into a stream of octets.
- MIH_LINK_SAP primitives are quite complex and hold lots of information. Only a fraction of included information has been identified to bring a benefit to ATN/IPS environment.
- The purpose of MIH_LINK_SAP seems not to align with ATN/IPS needs well.
    - The MIH_LINK_SAP primitives are focused on commanding and controlling the “Data Link Module”
    - Common IPS Radio Interface is used only to retrieve information about a datalink.

Noe that any implementation of Common IPS Radio Interface messages can be treated as an implementation of a subset of MIH_LINK_SAP primitives (Link_Up, Link_Down, etc.).

### A-3.4 TCP-based Data Plane Protocol

TCP was evaluated as an option for flow-control capable data-plane for the Common IPS Radio Interface. TCP is quite complex and provides unnecessary functionality, like congestion control and retransmissions. Although there are COTS implementation ready, the complexity would probably make the certification difficult.

Since TCP is stream-oriented protocol, it would be necessary to define how the stream is constructed from and then split into a sequence of data-plane packets. This is a minor issue, but it highlights complexity of addressing this for Common IPS Radio Interface unnecessary functionality of the TCP.

The COTS TCP flow control is driven purely by the receiver application (e.g., Airborne Radio) reading the packets from TCP queues. This would probably need to be changed, because the Airborne Radio needs to have a better control of the flow window provided to the Airborne IPS System.

Additionally, at the transmitting endpoint, if a COTS implementation is to be used, the data waiting for a flow window are stored in the queues of the TCP implementation and out of control of the transmitter (e.g., Airborne IPS System), preventing implementation of most of the envisioned benefits of the flow control, such as rerouting and fine-grained prioritization within the Airborne IPS System.

### A-3.5 Custom UDP-based Protocol – Common IPS Radio Interface Protocol (CIRI)

Common IPS Radio Interface messages are implemented using a simple custom protocol that is carried by UDP/IP. UDP adds little overhead in comparison to just IPv6 stack and provides a standard way to transport data payload.

APPENDIX A
CIRI PROTOCOL BACKGROUND

The proposed protocol is simple and easy to implement. It is designed to be future-proof and can be easily extended with new "options." While this requires the need to specify a new protocol, all of the other candidate protocols would also need a new standard (or a "profile") specifying how the particular protocol should be used to satisfy identified requirements.

### A-3.6 Candidate Protocol Summary

The following table provides a summary comparison of the candidate protocols described in this section.

**Table A-6 – Protocol Comparison Matrix**

| Criteria | SNMP | MAGIC | Custom L2 | TCP | Custom UDP (CIRI) |
|---|---|---|---|---|---|
| Control plane support | Yes | Yes | Yes | No | Yes |
| Data plane support | No | No | Yes | Yes | Yes |
| COTS layers | (L2)<br>IPv6<br>UDP<br>SNMP | (L2)<br>IPv6<br>UDP or TCP | (L2) | (L2)<br>IPv6<br>TCP (modified) | (L2)<br>IPv6<br>UDP |
| To be specified / standardized | Operation, MIB | Transport, operation | Transport, operation, message format | Operation | Transport, operation, message format |
| To be implemented | Operation, MIB | Operation | Operation, message format | TCP modifications | Operation, message format |
| Protocol complexity | High | High | Low | High | Low |
| Approach commonality | High | Medium | Low | High | Medium |
| Certification complexity | High | High | Medium | High | Medium |

Although the transport, operation, and message format must be specified for the Custom UDP (CIRI) protocol, the low protocol complexity also minimizes the complexity of the standardization effort, as conveyed in the body of this document.

## A-4 Candidate Protocol Alternatives – Secondary Assessment

Subsequent to the candidate assessment presented in A-3, the Dynamic Link Exchange Protocol (DLEP), per RFC 8175, was also assessed as a potential radio interface protocol. DLEP is designed to communicate datalink characteristics between a "modem" and a "router," which matches the nature of the Common IPS Radio Interface. However, it diverges somewhat from needs of the IPS. For example:

- DLEP assumes the possibility of multiple "destinations" directly reachable through the managed datalink, and datalink characteristics can be specified per-destination.
- DLEP can be used to indicate IP addresses and subnets assigned to destinations, possibly replacing Neighbor Discovery on the link.
- DLEP also supports plug-and-play style deployment, where the router can discover modems and then the peers negotiate used parameters for DLEP session.

Because DLEP, including standardized extensions, does not elegantly provide all features per the Common IPS Radio Interface requirement, an option of using DLEP with a custom extension is also evaluated.

APPENDIX A
CIRI PROTOCOL BACKGROUND

## A-4.1 Comparison Overview

The following tables compare characteristics and the ability to meet the CIRI requirements specified in Section A-1 of this appendix.

**Table A-7 – Basic Characteristics**

| Characteristic | Custom UDP (CIRI) | DLEP (COTS) | DLEP + custom extensions |
|---|---|---|---|
| Peering | Preconfigured | Possibly plug-and-play | Possibly plug-and-play |
| Transport | UDP | TCP | TCP |
| COTS | No | Yes | No |

**Table A-8 – Ability to Meet CIRI Requirements**

| Requirement per Section A-1 | | Custom UDP (CIRI) | DLEP (COTS) | DLEP + custom extensions |
|---|---|---|---|---|
| No. | Short Description | | | |
| 1 | Report datalink operational status | Yes | Yes | Yes |
| 2 | Multiple different operational statuses | Yes (7) | Yes (99) | Yes (99) |
| 3 | Separate operational status for multiple datalink services | Yes | Only using ugly hacks | Yes (custom extension needed) |
| 4 | Report current access network identifier | Yes | No | Yes (custom extension needed) |
| 5, 6 | Data plane | Yes | No | No |
| 7 | Flow control | Yes | Yes (only pause/resume) | Yes (only pause/resume) |
| 8 | Flow control: flow per datalink service | Yes | Only using ugly hacks | Yes (custom extension needed) |
| 9 | [optional] Flow control: one universal flow | Yes | Yes | Yes |
| 10.1, 10.2 | Robustness against restarts | Yes | Yes | Yes |
| 10.3 | Robustness against interleaved messages in opposite directions | Yes | Yes | Yes |
| 11 | [optional] Robustness against change of message delivery order | Partial | Yes | Yes |
| 12 | Support for future backward compatible extensions | Yes | Yes | Yes |
| 13 | Support for future non-backward compatible versions | Yes | Yes | Yes |
| 14 | Timely delivery of status information | Yes | Yes | Yes |
| 15 | Radio health monitoring | Yes | Yes | Yes |

## A-4.2 DLEP Profile for the Common IPS Radio Interface

In the context of DLEP, the Airborne Radio is a DLEP "modem," and the Airborne IPS System is a DLEP "router."

### A-4.2.1 Signaling Datalink Status (Requirements 1 and 2)

The Airborne Radio indicates, in the Session Initialization Response Message and in subsequent Session Update Messages, datalink status using DLEP Data Items Relative Link Quality (Receive) and Relative Link Quality (Transmit). Relative Link Quality 0 indicates "datalink not operational", other values indicate "datalink operational." Relative Link Quality 100 should indicate the nominal operational performance (“link_up”), other values can be used for non-nominal performance (e.g., “link_degraded”).

### A-4.2.2 Signaling Status for Multiple Datalink Services (Requirement 3)

DLEP, including currently standardized extensions, does not provide a clean way to signal separate sets of parameters for multiple services provided by the datalink. Several options are described in the following sub-sections.

#### A-4.2.2.1 Option 1: Separate DLEP Sessions

One option is to establish a dedicated DLEP session for each service, effectively treating them as separate datalinks. This is probably the cleanest option achievable with currently standardized DLEP, but this approach has a significant impact on Mobility and Multilink signaling (i.e., the AGMI protocol).

#### A-4.2.2.2 Option 2: Abusing DLEP Destinations

Another option would be to treat datalink services as DLEP “destinations” and signal the *Relative Link Quality* for these destinations. DLEP destinations are identified using MAC addresses, so it would be necessary to define a special MAC address for each supported datalink service. Alternatively, service-specific destinations might use single common MAC address in combination with service-specific Link Identifier as introduced by DLEP Link Identifier Extension [RFC8703].

#### A-4.2.2.3 Option 3: Custom DLEP Extension

Third option would be to develop a custom DLEP extension, that would ~~for example~~ define, for example, the following new service-specific messages to signal relative link quality:

- Service Up Message
- Service Up Response Message
- Service Update Message
- Service Update Response Message
- Service Down Message
- Service Down Response Message
- Service Identifier Data Item (present in every Service * Message)

This option may be best, but it defeats the benefit of using a COTS protocol.

### A-4.2.3 Reporting Auxiliary Information (Requirement 4)

DLEP does not provide a way to communicate auxiliary datalink information as is Access network identifier (Link instance ID) or Datalink Context. However, it would be straightforward do define a DLEP extension to convey such information.

### A-4.2.4 Data Plane (Requirements 5 and 6)

DLEP is not intended to handle data-plane traffic, so another channel must be used for data plane. Note that the data plane must identify a “service” for each air-to-ground data-plane packet.

### A-4.2.5 Flow Control (Requirements 7, 8, and 9)

The Control-Plane-Based Pause DLEP Extension (per RFC 8651) provides a simple flow control mechanism. The Airborne Radio declares a set of “queues,” where each queue is defined by a set of DSCPs, and at any point in time, the Airborne Radio can instruct the Airborne IPS System to “pause” data-plane flow for any declared queue. The “pause” instruction can be issued for the entire DLEP session, or per DLEP destination. So, this mechanism is compatible with both Option 1 and Option 2 described in Sections A-4.2.2.1 and A-4.2.2.2, respectively.

Note that although this mechanism might be sufficient, it is subject to some race conditions, e.g., the radio might receive some data-plane packets after sending the pause message. For comparison, flow control in CIRI allows the Airborne Radio to indicate how much data (in bytes) the radio can accept from the Airborne IPS System, ensuring that the Airborne Radio will never receive more air-to-ground data that it is willing to handle.

#### A-4.2.6 Robustness (Requirements 10, 11, 12, and 13)

Because the DLEP uses TCP connection, then restart of any peer inherently leads to establishment a new DLEP session. TCP also prevents ordering issues within the DLEP session. On the other hand, because the data plane is not handled by DLEP, there are still some possible outstanding ordering issues (see the race condition described in Section A-4.2.5.)

DLEP uses TLV to encode information (similar to the CIRI protocol) providing sufficient room for future backwards-compatible extensions. DLEP also employs an extension negotiation procedure at the beginning of every DLEP session. Although this increases the complexity of the protocol implementation, it may further facilitate incremental deployment of future extensions.

#### A-4.2.7 General Operation (Requirements 14 and 15)

The Airborne Radio sends a DLEP message (Session Update Message or another, see section 3.2) immediately after detecting change of datalink status, ensuring the timely delivery of the status information. In absence of other messages, DLEP endpoints periodically send a Heartbeat Message, enabling detection of loss of a DLEP peer.

### A-4.3 DLEP Comparison Summary

The Common IPS Radio Interface protocol, as specified in the main body of this document, is recommended over DLEP. The rationale for this recommendation includes:

- DLEP uses TCP transport, and there have been strong objections against specifying the use of TCP for IPS, particularly in the avionics implementations (e.g., similar discussion regarding Enrolment over Secure Transport protocol for certificate enrolment)
- A COTS instance of DLEP does not fully meet the Common IPS Radio Interface requirements; therefore, custom extensions are necessary to address the gaps
- DLEP with custom extensions detracts from the attractiveness of being a COTS solution
- Compared to the DLEP, the CIRI protocol is simple and lightweight, which is especially attractive for the Airborne Radio implementation

APPENDIX A
CIRI PROTOCOL BACKGROUND

- As part of IPS prototyping and validation activities, the CIRI protocol has been implemented by multiple Airborne Radio suppliers and validated in both the lab environment as well as during flight tests.