1. Common IPS Radio Interface

## Overview

*TODO: Add text about the motivation, background and context. Introduce the ATN/IPS Aircraft Protocol (AIAP).*

## Introduction

This protocol is designed for exchanging information between Airborne IPS System and Airborne Radio. It covers both the control plane and the data plane.



Figure – AIAP context

Note that for VDLm2 the term Airborne Radio represents both the VDR part and the CMU part.

### Control plane

The primary purpose of the AIAP 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 status (see section 5.2.1.4), but the AIAP protocol provides structures to convey other information as well.

The basic communication pattern is outlined in the Figure 2. The Airborne IPS System sends periodically a control-plane AIAP message and the radio replies with control-plane AIAP message, bearing datalink status (and optionally also other) information. This can also serve as a health monitoring of the radio. Additionally, the radio sends an unsolicited control-plane AIAP message whenever the datalink status changes. See section 5.3 for details.



Figure – basic control-plane communication pattern

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 will be 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.

### Data plane

Optionally, the AIAP might be used to also 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 AIAP messages” (which is distinguished from “control-plane AIAP messages” by a flag in the AIAP header).



Figure – data-plane communication pattern

COMMENTARY

The data plane AIAP is provided primarily to facilitate attaching metadata, as is Service ID, to air-to-ground packets, but it is not required for the control-plane AIAP 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.

## AIAP message format

AIAP message consists of an AIAP header and a sequence of AIAP options. All integers are encoded in network byte order (big endian).



Figure – AIAP Message Format

Fields:

* *Version* is a 4-bit identifier. It is set to value 1.
* *Data-plane* (“D”) is a 1-bit flag.
	+ When set to value 1, this is a “data-plane AIAP message”. There must be exactly one Packet data option present (see section 5.1.2).
	+ When set to value 0, this is a “control-plane AIAP message”. Packet data option may not be present.
* *rsvd* is a 3-bit unused field. It MUST be initialized to zero by the sender and MUST be ignored by the receiver.
* *Options* is a variable-length field spanning to the end of this AIAP message. It consists of a sequence of one or more AIAP options. Order of options is not significant.

### AIAP option format



Figure – AIAP Option format

Fields:

* *Type* is an 8-bit unsigned integer identifying the option.
* *Length* is a 16-bit unsigned integer. It denotes length of the *Option data* (excluding the *Type* and *Length* fields) in octets.
* *Option data* is a variable-length *Type*-specific sting of bytes.

If an option with unrecognized *Type* is received, or if an option is received in a context with no defined semantics (e.g. Time to live option in control-plane AIAP message), then this option must be silently ignored and the rest of the AIAP 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 AIAP protocol is in Table 5‑1. It also indicates in which situations is the option required (“mandatory”) and in which other situations the option has a defined semantics (“optional”). Options that can be used multiple times in an AIAP message are marked as “multiple”.

Table 5‑1 – AIAP options summary

| option *Type* | option name | control-plane | data-plane |
| --- | --- | --- | --- |
| radio to IPS | IPS to radio | radio to IPS | IPS to radio |
| 1 | Datalink ID | mandatory | mandatory | mandatory | mandatory |
| 3 | Link instance | optional |  |  |  |
| 4 | Datalink context | optional |  |  |  |
| 5 | Datalink status | mandatory |  |  |  |
| 6 | Flow control | optional, multiple |  |  |  |
| 128 | Packet data |  |  | mandatory | mandatory |
| 129 | Service ID |  |  |  | optional |
| 130 | Time to live |  |  |  | optional |
| 253 | reserved for experimental use |  |  |  |  |
| 254 |  |  |  |  |

Option *Type*s 253 and 254 are reserved for experimental use.

#### Datalink ID option

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



Figure – Datalink ID option

Fields:

* *Type* 1
* *Length* 1
* *ID* is an 8-bit unsigned integer representing datalink ID.

#### 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]).



Figure – Link instance option

Fields:

* *Type* 3
* *Length* 2
* *Link instance ID* is a 16-bit unsigned integer representing combination of the datalink technology and a particular access network (and thus also a communication service provider.)

COMMENTARY

The Link Instance ID might be also used by the Airborne IPS System as a hint to the multilink decision.

This option was called “Communication service provider option” in a previous version of AIAP protocol.

#### 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 (re)send a mobility and multilink signaling message over this datalink. 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.

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.



Figure – Datalink context option

Fields:

* *Type* 4
* *Length* 1 to 8
* *Context* is a variable length (1 to 8 octets) byte string.

#### Datalink status option

This option specifies current status of one or more datalink services, managed by an Airborne Radio endpoint.

Every airborne radio endpoint must report status for *service ID* 0 (“primary service”) and may report statuses for other service. A *Service ID* may be present in a Datalink status option at most one record.



Figure – Datalink status option

Fields:

* *Type* 5
* *Length* variable
* The rest of the option is a sequence of *Length* records. Each record is 8 bits long and consists of two fields:
	+ *Service ID* is a 4-bit unsigned integer. Valid values are 0 to 14, identifying a datalink service as defined in section 5.3.2.
	+ *Status* is a 4-bit unsigned integer, indicating status of the datalink service. See below.

Status values:

* 0: Datalink service is not operational (“down”)
* 1 to 7: Datalink service is operational. Meaning of individual operational values is datalink-specific, but following values are recommended:
	+ 1: Degraded with an unknown performance and impact on the user traffic (“best effort”)
	+ 4: Degraded with a known performance degradation and impact on user traffic (“degraded”)
	+ 7: datalink service is operational with nominal performance (“up”)
* 8 to 14: reserved for future extensions. Unless configured otherwise, the receiver should treat any status in this range as “unknown”.
* 15: Status of the service is unknown. This value is intended for internal usage in Airborne Router endpoint and SHOULD NOT be used in Datalink Status Option to report status.

COMMENTARY

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

#### Flow control option

This option indicates amount of air-to-ground data that the IPS system can safely pass to the airborne radio. See section 5.3.4.3.

The Airborne Radio should use lowest possible *Data window* value, that does not impair datalink performance.



Figure – Flow control option

Fields:

* *Type* 6
* *Length* 5
* *Service ID* is a 4-bit unsigned integer. Values 0 to 14 indicates that the *data window* imposes limit on data of the corresponding service (see section 5.3.2). Value 15 indicates that the *data window* is given for all traffic, regardless of its service.
* *rsvd* is a 4-bit unused field. It MUST be initialized to zero by the sender and MUST be ignored by the receiver.
* *Data window* is a 32-bit unsigned integer. Indicate amount, in bytes, of the air-to-ground traffic (of the given service), that can be accepted by the radio.

COMMENTARY

The *Data window* value can depend on intended frequency of AIAP messages with Flow control option, datalink service bandwidth, internal needs of the Airborne radio and amount of air-to-ground data already queued for transmission over the datalink service. See example in section 5.3.4.3.

#### Packet data option

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



Figure – Packet data option

Fields:

* *Type* 128
* *Length* variable
* *Packet data* is a variable-length octet string packet containing the data-plane packet bytes.

#### Service ID option

This option may be present in any data-plane AIAP message. It indicates that the accompanied air-to-ground packet belongs to the identified datalink service (see section 5.3.2).

The Airborne radio is requested to use the identified datalink service to deliver the packet. This may be reflected by Flow control (see section 5.3.4.3) and treatment within the radio (e.g., prioritization).



Figure – Service ID option

Fields:

* *Type* 129
* *Length* 1
* *Service ID* is a 4-bit unsigned integer. Valid values are 0 to 14, identifying a service as defined in section 5.3.2.
Value 15 is reserved for future use. Receiver must ignore *Service ID* option that contains Service ID 15.
* rsvd is a 4-bit unused field. It MUST be initialized to zero by the sender and MUST be ignored by the receiver.

#### Time to live option

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

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



Figure – Time to live option

Fields:

* *Type* 130
* *Length* 4
* *Time to live* is a 32-bit unsigned integer. When set to a value other than 0, it indicates time to live in milliseconds.
When set to value 0, the time to live is not specified.

## AIAP operation

AIAP 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 a *Datalink ID*, uniquely identifying the pair within the aircraft. Every AIAP message exchanged between those endpoints must contain a Datalink ID option with this *Datalink ID*.

### Transport layer

AIAP 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 AIAP messages from one endpoint use the same addressing.

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

COMMENTARY

If the AIAP operates on top of UDP/IP for instance, then both endpoints should be configured with the same tuple of:

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

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

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

### Services

An airborne radio provides one or more datalink services. The radio must provide the primary service (having 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 AIAP message, then the service is identified by the Service ID option (see section 5.3.4.4).

A datalink service is identified by Service ID, which is an integer between 0 and 14:

* Service ID 0 is the primary service. All datalinks must provide the primary service.
* Service ID 1 to 14 are deployment specific datalink services. Not defined in this document.
* Service ID 15 is reserved. Value 15 means “any service” in the Flow control option.

This protocol uses Service ID in Flow Control option, Datalink Status option and Service ID option.

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

### Airborne IPS System endpoint operation

#### Configuration

Airborne IPS System AIAP endpoint is configured with:

* Datalink ID – an 8-bit unsigned integer matching the *Datalink ID* of the peer Airborne radio AIAP endpoint.
* ResponseTime – a time interval that Airborne IPS system endpoint waits for a response to a control-plane AIAP message sent to a Radio endpoint.
	+ Default value: 3000ms
* HelloTime – a maximal time between two consecutive control-plane AIAP 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 status (for all applicable services) is set to UNKNOWN.
	+ Default value: 2
* Configuration of transport layer (see section 5.3.1). There might be an individual configuration for control plane and data plane.

Also, the Airborne IPS system may need other configuration (with details not specified in this document) regarding inclusion of metadata in data plane (Service ID, Time to live) and processing status information from the radio (see section 5.3.3.3).

#### Control plane operation

Airborne IPS System endpoint sends a control-plane AIAP message containing appropriate Datalink ID 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 AIAP message, then another control-plane AIAP message is sent. If the IPS does not receive a response for more than MaxUnanswered control-plane AIAP messages in a row, then the datalink is considered to be broken (status is set to “unknown” for all applicable services).

Upon receiving a control-plane AIAP message with a valid Datalink ID Option, the Airborne IPS System endpoint updates its status information according to Datalink Status Option included in that message (and possibly other inputs). It may also note information from other included options. This operation is summarized in Figure 14, and the section 5.3.3.3 contains recommendations for processing of the information from the radio.

If a received control-plane AIAP 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 5.2.1.3).

If a received AIAP message contains Flow control option, then the included *Data window* comes into effect, and the Airborne IPS System should not send more air-to-ground data to the Airborne radio than specified in the *Data window*. The excess data should be kept in queues of the Airborne IPS system as necessary. The data window is valid until a new Flow control option is received or until the associated datalink service(s) becomes non-operational.

COMMENTARY

In order to achieve optimal datalink performance, the Airborne IPS System should use the provided *Data 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 *Data window*).



Figure - Airborne IPS system endpoint control plane operation

#### Status processing

*(This section contains only recommendations and no strict requirements.)*

The document does not require the Airborne IPS system to process the status information received from the Airborne radio in any particular way, but the following is believed to be usually useful:

* Datalink status option indicates the current status of datalink service(s).
	+ This is the primary indication whether the datalink can be used to convey data-plane traffic to (and from) 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 5.2.1.3).

#### Data plane operation

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

When the Airborne IPS System endpoint receives a valid data-plane AIAP 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 AIAP messages with this packet is sent to the peer radio. This AIAP message may contain metadata describing the packet.



Figure - Airborne IPS system AIAP endpoint data-plane operation

##### Data-plane AIAP message

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

* zero or one Service ID option
* zero or one Time to live option

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

### Airborne Radio endpoint operation

#### Configuration

* Datalink ID – an 8-bit unsigned integer matching the *Datalink ID* of the peer Airborne IPS system AIAP endpoint.
* Configuration of transport layer (see section 5.3.1). There might be an individual configuration for control plane and data plane, if the AIAP data plane is used.

Also, the radio may need some configuration (with details not specified in this document) regarding processing of data of different services (see section 5.3.2) and usage of Flow control.

#### Control plane operation

The Airborne Radio endpoint reacts to events, as summarized in Figure 16. Whenever

* a valid control-plane AIAP 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 control or Datalink Context update)

then the radio endpoint sends a control-plane AIAP message (see section 5.3.4.2.1).



Figure – Radio AIAP endpoint control plane operation

##### Control-plane AIAP message

The control-plane AIAP message sent by the Airborne radio contains:

* one Datalink ID option
* one Datalink Status option with the current datalink status
* zero or one Link instance option
* zero or one Datalink context option
* zero or more Flow control options (see section 5.3.4.3)

#### Flow control

Optionally, the airborne radio may provide an information about what amount of data it is willing to process by sending a *Data window* in a Flow control option (see section 5.2.1.4). The *Data window* should be the lowest possible value, that does not impair datalink service performance.

The radio might either indicate one “universal” data window (using *Service ID* = 15 in Flow control option), which applies collectively to traffic of all provided datalink services, or it might specify separate *Data windows* (in separate Flow control options) for zero or more specific datalink services.

When the Airborne IPS system receives a Flow control option, the specified data window remains valid until it receives a new Flow control option with the same *Service ID* or until the datalink service becomes non-operational (e.g. by receiving *status* = down in a Datalink status option).

The Airborne IPS system should not send more data (of the given service) than indicated by the *Data window* during validity of the window.

COMMENTARY

The airborne radio might choose not to include a Flow control option in some AIAP messages, without affecting the flow control mechanism. In other words, AIAP messages (reporting operational status) without a Flow control option do not invalidate or restart the *Data window* imposed by the last Flow control option.

The main purpose of the flow control mechanism is to limit cumulation of packets in the airborne radio (and enabling queuing these packets in the Airborne IPS system instead), without sacrificing the datalink performance.

##### Example use of flow control

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 periodically send an (unsolicited) AIAP message with a Flow control option providing a Data window to the IPS router. This makes sure (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 Data window indicated by the Airborne radio might be for example computed as

Data window := min(0,
 watermark0 + (nominal\_throughput × period) – queued\_data\_size
)

where:

watermark0 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 Flow control options and

queued\_data\_size is amount of data already waiting for transmission in the airborne radio.

#### Data plane operation

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

When the radio endpoint receives a valid data-plane AIAP 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 ID option. If the AIAP message does not contain Service ID option, Service ID 0 (the primary service) is implied. If the AIAP message indicates invalid Service ID in a Service ID option, then the radio should discard the packet.

If the AIAP message contains any other metadata (Time to live option), then this information should be associated with the packet.

Whenever a ground-to-air packet is received from ground, a data-plane AIAP messages with this packet is sent to the peer Airborne IPS System. (see section 5.1.2)

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



Figure - Airborne radio AIAP endpoint data plane operation

## References

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

[AGMI] Air-Ground Mobility Interface, version 0.9