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Proposed Guidance Material for the Frame Mode SDNCF

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SUMMARY

This document provides draft Guidance Material for the Frame Mode SNDCF. It has been prepared for input to ATNP/WG2.

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1. Introduction

1.1 Scope

This document provides draft Guidance Material for the Frame Mode SNDCF. It has been prepared for input to ATNP/WG2.

2. Draft Guidance Material for the Frame Mode SNDCF

The first generation of ICAO air/ground datalinks all used ITU-T recommendation X.25 as their network access protocol. This provided a common service interface using an industry standard, but is not necessarily the most efficient way to provide access to a mobile subnetwork.

This is particularly true of the ICAO VHF Digital Link (VDL). VHF communications are largely constrained to line of sight operations and to maintain communication while in flight, an aircraft must necessarily switch from one VDL Ground Station to another. This process is known as Handoff. Maintaining X.25 virtual circuits across a Handoff has proved to be a particular complex procedure with significant overhead.

Recognising these problems, VDL Mode 3 (VDL3) has been improved to include a Frame Mode whereby the service provided is a simple reliable data link that supports packet oriented transfers between an aircraft and a Ground Station, without any additional functionality; the complexity imposed by X.25 is simply discarded.

This approach is satisfactory for the ATN because the packets exchanged over the data link are routable CLNP packets being transferred between two routers and a simple frame mode service is sufficient for CLNP to operate.

A Frame Mode SNDCF has therefore been developed to provide support for VDL 3 Frame Mode. It is also suitable for any air/ground datalink that provides a similar datalink service including connection mode datalinks (e.g. the VDL Mode 2 AVLC).

The “Frame Mode SNDCF” comprises the following functions:

- A new Air/Ground Communications Sublayer (A/GCS) to provide for multiplexing of different data streams and support of stream mode data compression algorithms (e.g. Deflate).
- LREF based CLNP compression
- CLNP Header reformatting (to improve Deflate compression).

The resulting SNDCF has the following characteristics:

1. It can operate over any data communications service providing a low probability of packet loss, duplication, corruption or re-ordering, including the acknowledged connectionless service provided by VDL Mode 3, the VDL Mode 2 AVLC, and ground-ground services such as Frame Relay.
2. It incorporates features known to be missing from the current Mobile SNDCF concerned with the introduction of new functions in a backwards compatible manner.
3. It supports maintenance of the Data Compression State across data link Handoffs.
4. It includes optional security features for data link authentication.
5. Deflate Dictionaries and re-synchronisation are supported.
6. Other Routable protocols such as IPv4 can also be supported concurrent with CLNP.

2.1 VDL Mode 3 Frame Mode

The VDL3 Frame Mode has been a major input to the development of the Frame Mode SNDCF, and in order to present the design of the Frame Mode SNDCF, it is first useful to discuss the VDL Mode 3 datalink.

2.1.1 VDL Mode 3 Frame Mode Architecture

The expected network architecture in support of VDL3 Frame Mode is shown in Figure 2-1. The basic concept is that the ground infrastructure comprises a number of VDL3 Ground Stations, which are organised into clusters. Typically, the Ground Stations in a cluster will be geographically adjacent, or may even have overlapping areas of coverage – especially when they use different frequencies. The Ground Stations in a cluster will each be connected to some concentrator – the Ground Network Interface (GNI) - which interfaces them to an ATN Air/Ground Router.

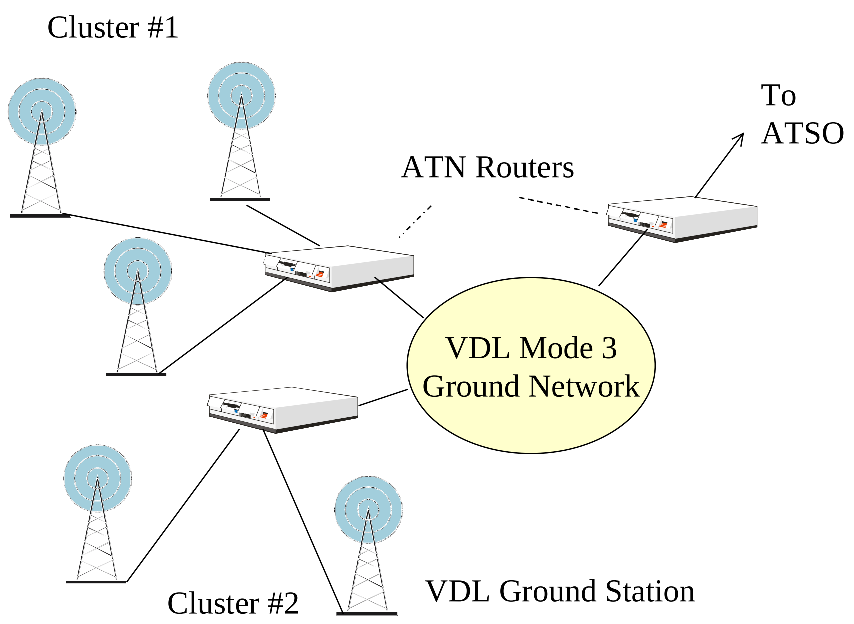

Figure 2-1 VDL Mode 3 Network Architecture

The Air/Ground Routers supporting each cluster will themselves be interconnected by a ground network, which will also support ATN ground-ground Routers for interconnection with ATSOs and other users. The ATN Routers are expected to form a single Routing Domain. Together, the Ground Stations and Air/ground Routers comprise a *Ground System* under a common management authority; the internal architecture of this ground network is of no interest to air/ground communications. A VDL Service Provider may operate one or more Ground Systems.

2.1.2 VDL Mode 3 Overview

VDL Mode 3 has been designed to provide firstly a digital voice communications service to replace the current analogue voice communications service. VDL Mode 3 operates in the same 25khz channels as analogue voice, while using a Time Division Multiplexing Access (TDMA) method to divide the 25khz channel into four 4.8kbps channels. These subchannels may be used for voice or data. There are also separate data link management subchannels and transmissions in these channels are known as “M-bursts”.

VDL Mode 3 is controlled through the Ground Station which is responsible for managing the use of each subchannel.

Each of the four 4.8kbps subchannels can be used for voice or data. However, the actual configuration (purpose of each channel) is usually pre-configured. Typical configurations are shown in Figure 2-2.

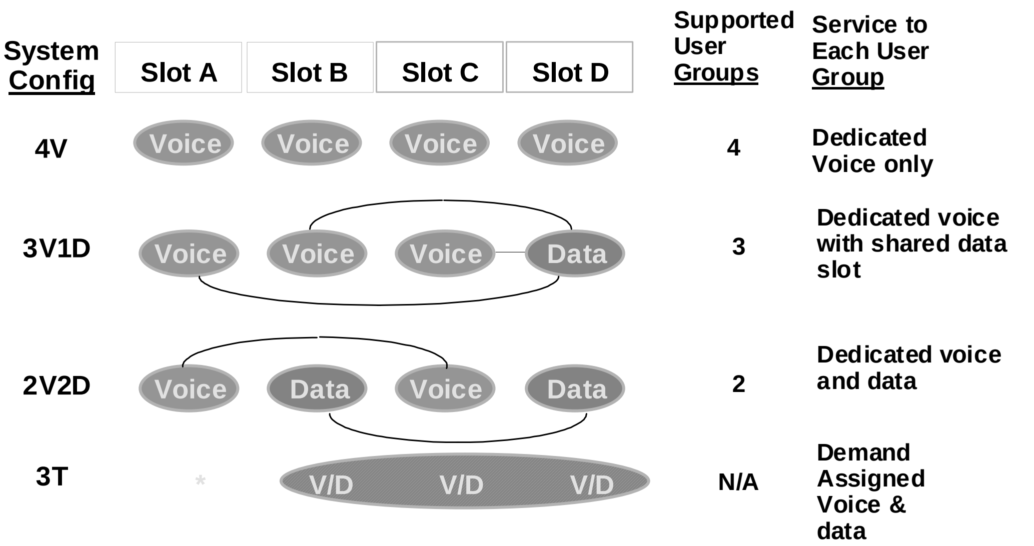

Figure 2-2 VDL Mode 3 System Configurations

For example, the 4V configuration is used for purely voice operations with no data, while with the 3V1D configurations a single data channel is shared amongst the users of the remaining three voice channels.

The voice communications service is designed to emulate the "party line" of analogue voice. Associated with each digital voice channel is a "user group" of up to sixty aircraft. An aircraft has to formally join a user group through an M-burst message exchange and only then is it permitted to transmit in that channel, and when explicitly permitted to do so by the ground station. Typically, such a user group is associated with an air-traffic controller and is the group of aircraft under his/her control.

When a data channel is also present in the configuration and associated with the voice channel, the aircraft can receive uplinks in the data channel and may also request use of the channel for downlinked messages.

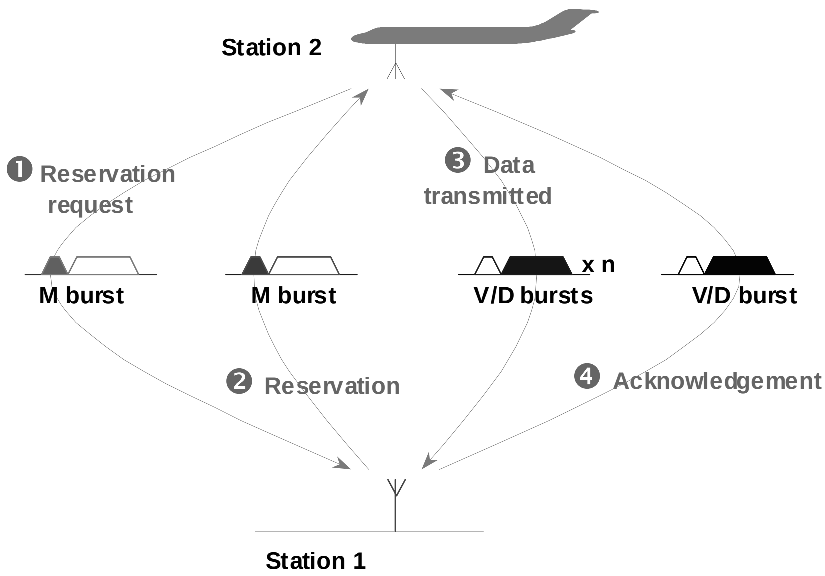

Figure 2-3 Example VDL Mode 3 Data Exchange

Uplink messages are queued in priority order. When a Ground Station has an uplink message to send to a given aircraft, it will send it using the data channel. Correct receipt of the message is acknowledged by the aircraft in an M-burst (see Figure 2-3).

Downlink messages are similarly queued in priority order. When an aircraft has a downlink message to send, it notifies the Ground Station of this and the message's priority. This is done as an M-burst either in response to a "poll" from the Ground Station, or by accessing the management subchannel using a CSMA (slotted ALOHA) procedure. The Ground Station will then arbitrate between competing requests for the data channel (from different aircraft and its own uplink queue) and "give the channel" to the highest priority message. If this is on an aircraft's downlink queue, then the aircraft is notified of this via an M-burst, the message is downlinked in the data subchannel and the Ground Station acknowledges safe receipt – also in the data subchannel.

VDL Mode 3 thus provides for a prioritised acknowledged connectionless data communications service. In addition to the above, it also provides a connectionless broadcast service from ground to air only.

As with analogue voice, the aircraft will have to change to a different user group when control passes from one controller to another. This may also involve changing frequencies and Ground Stations. This "Handoff" may be controlled by the pilot forcing a change to a new user group or by a data link management message uplinked by the Ground Station.

2.1.3 The Datalink Service

The data link service described above is sufficient for most data communications use and as an ATN subnetwork. It is the basis of the VDL 3 Frame Mode Service.

Formally, the datalink service provided to an aircraft is that of a simple data transfer service which may be either "available" (the aircraft is a member of one of the Ground Station's user groups) or "unavailable". Data transfer is normally reliable, as the underlying service is responsible for ensuring delivery on a per frame basis. The service elements are listed in Table 2-1 for the aircraft and the ground user of the GNI.

There is also a broadcast service, ground to air only. This is formally an unreliable unacknowledged data transfer service.

When an aircraft first joins a user group which has a data channel associated with it, this will result in an L-Service.Available[1] event being sent to the network user on both ground and air. On the ground side, this will notify the service user that the identified aircraft has joined to a user group via the identified Ground Station (attached to the GNI). On the air side, this will notify the service user of the Ground Station Address.

Following an L-Service.Available event, packets may be uplinked or downlinked to the aircraft or Ground Station respectively using the SN–UnitData.Request. This service primitive takes the user data, the destination address and an optional priority as its parameters. The subnetwork service will then attempt to deliver the message returning success or failure as a result code. On receipt, the packet is delivered using an SN–Unitdata.Indication.

As discussed above, broadcast data transfers are also possible for uplinks. However, if a broadcast address is used (conventionally this address is “all ones”) as the destination then successful completion simply implies that the packet has been broadcast and does not imply actual receipt.

As an aircraft continues on its flight, a Handoff may take place to another Ground Station. When this occurs, it is signalled to both airborne and ground users by another SN–Service.Available, and simultaneously by an L-Service.Unavailable for communication via the previous Ground Station. The L-Service.Available will identify the new ground station that both air and ground user must now use to communicate. Note that an SN–Unitdata.Request may fail if a Handoff occurs whilst it is in progress, in which case the correct action is to retry using the new Ground Station Address.

Service Primitive	Parameters	
	Ground	**Air**
L-Unitdata.Transfer	✈ Aircraft Address ✈ User Data ✈ Priority	✈ Ground Station Address ✈ User Data ✈ Priority
L-UnitData.Indication	✈ Aircraft Address ✈ User Data	✈ Ground Station Address ✈ User Data
L-Service.Available	✈ Ground Station ID ✈ Aircraft Address	✈ Ground Station Address
L-Service.Unavailable	✈ Ground Station ID ✈ Aircraft Address	✈ Ground Station Address

Table 2-1 Subnetwork Service

Note.—The above service primitives do not actually occur in the VDL3 SARPs. The are abstracted from the description given there of the datalink service.

As long as Handoff is between Ground Station’s attached to the same GNI, the data path between an aircraft and the same Ground User is preserved. However, when the GNI changes, the Ground User also changes.

[1] the VDL SARPs present this as a Join Event. However, the ATN SARPs Join event is more specific than this relating to the actual establishment of datalink service.

2.1.4 Summary

The basic model of operations is derived from voice communications and is based on the user group. Associated with a user group is a voice subchannel and access to a possibly shared data subchannel. While in contact with a given Ground Station (i.e. a user group member), packets may be uplinked and downlinked using a data subchannel associated with the user group.

2.2 VDL Mode 3 Frame Mode and the ATN

2.2.1 Overview

The users of the VDL3 Frame Mode Service will be ATN Routers. There is a single ATN Router on board each aircraft and every packet uplinked to an aircraft will be received by that ATN Router. Similarly, on the ground, there will be an Air/Ground ATN Router for each cluster (i.e. GNI), and any packets downlinked to a Ground Station in a given cluster will be received by that ATN Router. The Air/Ground ATN Router can send singlecast or broadcast uplinks to aircraft, although an aircraft can only downlink packets to a single Air/Ground Router (i.e. broadcast is not possible).

CLNP and other ATN specified packets (e.g. ISH PDUs) may thus be exchanged between the routers. For most ATN uses they will be sent singlecast. However, there is the possibility to uplink the ISH PDU using the broadcast approach and in order to improve RF efficiency – although this is not part of the current Frame Mode SNDCF.

The ATN also makes extensive use of data compression. The algorithms used require a reliable stream oriented communications medium in order to be used efficiently, although they can recover from occasional lost packets. The underlying data communications service offered by VDL3 Frame Mode offers the required level of reliability and should be sufficiently stream oriented provided that there is no attempt to transfer a packet until successful completion of the transfer of a preceding packet.

In order to operate successfully in a mobile environment, the ATN requires that the availability of a communications path air to ground is signalled by a “Join” event and conversely, the loss of such a path is signalled by a “Leave” event. The L-Service.Available and the SN–Service.Unavailable service elements meet this requirement – or at least the Join and Leave Events can be derived from them.

2.2.2 First Contact

When an aircraft first comes into contact with a VDL3 network there will be some network specific interactions but provided all is well, both the aircraft’s ATN Router and the Air/Ground Routers attached to the nearest Ground Station will receive an L-Service.Available message. This can be viewed as equivalent to the ATN’s Join Event.

With an ISO 8208 datalink, ATN SARPs require that in response to a Join Event, the Airborne Router’s *IS-SME* stimulates the Mobile SNDCF to initiate an ISO 8208 connection to the destination system identified by the Join Event. An ISH PDU is then sent to the Air/Ground Router, identifying the Airborne Router to it, and the Air/Ground Router returns its own ISH PDU. In normal use, the ISH PDUs are encapsulated within the Call Request/Accept ISO 8208 packets. They are also used to signal Router capabilities and by the Air/Ground Router to signal information about the subnetwork (e.g. ATSC Class).

In VDL3 Frame Mode there is no ISO 8208 Call Request/Accept and so this sequence has to be modified.

On the airborne side, the correct response to a Join (L-Service.Available) message will be to send the Airborne Router's ISH PDU to the identified Ground Station Address and hence to the Air/Ground Router. On the ground side, a similar response can be specified.

The exchange of ISH PDUs also allows each router to enter the NET of the other router in its own forwarding table and associate the path to the NET as being via the VDL3 subnetwork and the Ground Station Address from which the ISH PDU was received. CLNP PDUs can then be routed between the two routers.

Once the ISH PDU exchange has been completed, the ATN SARPs specify that an IDRP connection is established and routing information exchanged. IDRP communicates using CLNP and this should now take place without any further ado.

However, there will always be a small probability of ISH PDU loss in either direction and there will thus need to be a mechanism to restart the router to router communications in the event of data being received before an ISH PDU has been received.

2.2.3 Compression and Data Transfer

The ATN SARPs originally specified three data compression procedures: the LREF, Deflate and ACA algorithms. ACA has never been widely implemented and was dropped from edition three of the SARPs. However, both LREF and Deflate are in use, together give a typical compression ratio of four to one for the current generation of ATN Applications, and are clearly valuable. They should also be part of a Frame Mode SNDCF.

The ISO 8208 Mobile SNDCF negotiates the use of the compression algorithms and agrees the LREF parameters during the ISO 8208 Call Request/Accept exchange. Clearly this has to be modified for VDL3 Frame Mode.

With ISO 8208, the approach is of an "offer" and "accept" type negotiation. The call requester offers a possible set of compression algorithms and parameters, and the responder may either reject the call or accept it and accept either all offered algorithms or a subset of those offered. There are currently proposals to extend this procedure to include the negotiation of a set of initial dictionaries for Deflate compression.

This approach could be repeated for VDL3 Frame Mode. However, this would require a separate packet exchange to initialise the compression algorithm before any data transfer took place, which is not RF efficient. Ideally, the initialisation of the compression algorithms would be combined with the ISH PDU exchange.

To achieve this will need a change from the offer/accept approach to an approach where both sides "offer" and the agreed set of compression algorithms and procedures is essentially the intersection of the two offers. It will then be possible for both air and ground sides to identify the compression algorithms, LREF directory sizes, Deflate dictionaries, etc. supported in their ISH PDUs, and thence to identify the agreed set as soon as they receive the other side's ISH PDU. Compressed data transfer can then begin.

However, because the negotiation of compression options is now an "in-band" process (with the small possibility that ISH PDUs may have to be retransmitted – and may be so anyway if they are broadcast), it is important to be able to distinguish compressed packets from uncompressed packets. If LREF compression is used alone, then this is already possible. However, the specification of Deflate assumes that all data is compressed and hence there is no mechanism to distinguish Deflate compressed packets from uncompressed packets. This is possible, but will require the addition of another header octet to each compressed packet.

This is also needed for error recovery. In the ISO 8208 Mobile SNDCF, if (e.g.) a Deflate checksum error is detected, a Network Reset is used to signal the error and to reset the compression algorithm. As with negotiation, this is an out-of-band approach and which needs to be recast as in-band for VDL3 Frame Mode. Indeed, greater RF efficient could be achieved by signalling any such problems in the header of a returned packet (which may also include compressed data).

Regarding error recovery, it has already been proposed that instead of a complete reset of the Deflate compression algorithm following an error, it is only necessary to reset the compression window to the end of the last correctly received packet, and this feature should be added with such a change.

2.2.4 Handoff

A Handoff between Ground Stations in the same cluster has only a minor impact on either air or ground. L-Service.Available and L-Service.Unavailable events will signal the transition. However, this should not be recognised as an ATN Join Event because the cluster has not changed i.e. the Air/Ground Router has not changed. The only impact of the event is to update the forwarding information base to change the Ground Station used for the transfer. Indeed, in the aircraft, it is only necessary for the subnetwork user (i.e. the ATN Router) to keep track of Ground Stations when it also needs to be able to use more than one Ground System simultaneously. If it does not, then the “current ground station” can be determined by the subnetwork software without needing to bother the ATN Router about any changes.

The compression algorithms should not be affected by this Handoff as the communication end-points are unchanged. There is the small risk of packet loss/duplication on Handoff but this should be recoverable.

A Handoff between Ground Stations in different clusters will have more of an impact as the communication end point clearly changes (and hence the compression algorithms may have to be reset) and the Air/Ground Router will also change. Such a transition is also signalled by an L-Service.Available event signalling a change in both Ground Station and Cluster.

There are two issues to be considered here: the first is can the compression state be retained –and hence avoid the overhead of rebuilding the compression state; and the second is, is there a need to establish a new IDRP connection with the new cluster’s Air/Ground Router.

2.2.4.1 Retention of the Compression State

Retention of the compression state requires that the Air/Ground Routers can exchange the state information in a timely manner. For LREF this is a relatively small table, but could be up to 64KB of information for Deflate. However, given the bandwidth of modern communications lines and the time constants involved, this is not an impossible objective.

Passing over the compression state also requires a very definite end to the use of one Ground Station and starting the use of a new one. This is because there cannot be any overlap in the transmissions if compression state is to be retained. With VDL3, Handoff is immediate and hence this condition can be met.

Retention of the compression state should be an optional capability. A ground-ground protocol will also be required to transfer the compression information – a simple request/response (e.g. an http GET method) is the kind of approach needed. The new Air/Ground ATN Router will need to have some means of identifying the previous Air/Ground Router so that the compression state can be obtained.

Handoff between clusters thus needs to be recognised by the ATN Router. If the compression state retention capability is indicated as being supported by the Air/Ground Router then from the airborne point of view there is no change to the compression state (the procedures are the same as Handoff in the same cluster). If the compression state is not retained then compression is restarted as in the case of the first contact.

As there is no additional capability required on the air side to support compression state retention, it is purely a matter for the Air/Ground Router as to whether or not it retains compression state. If it can then it will compress the next uplink using the retained state, otherwise the compression will be re-initialised.

Note that from this consideration, it follows that the re-initialisation of compression state has to be signalled in the packet header.

2.2.5 Service Unavailable

The L-Service.Unavailable event occurs when an aircraft goes out of range of a VDL3 subnetwork and is thus equivalent to the ATN SARPs Leave Event. However, this should not result in immediately discarding the compression state. This is because communication may be establish shortly afterwards via another VDL3 Ground Station and which would be able to re-use the compression state. Compression state should thus be retained for a short period after the Leave Event.

2.3 Design Approach to a new SNDCF

The design of the original Mobile SNDCF was predicated on an ISO 8208 base and is heavily influenced by it. The new Frame Mode SNDCF is predicated on a much more basic service, that of a simple packet mode service that can be either:

- a singlecast acknowledged connectionless service, or
- a broadcast connectionless service.

An acknowledged connectionless service can provide the reliable communications service that the data compression algorithms expect. However, there will still be a need to negotiate compression options and to provide for recovery in the event of data corruption. In short, there needs to be some aspects of a connection mode service in order to build and maintain a relationship between compressor and decompressor. This is especially true of Deflate, although it is possible to operate LREF in a true connectionless fashion – but only at the expense of regularly sending uncompressed CLNP PDUs.

There are also several proposed enhancements for Deflate that need to be taken into account and specifically:

- Use of Deflate Dictionaries in order to speed the convergence of the compression algorithm to the optimal compression ratio.
- Recovery from checksum errors by returning to the last received packet rather than restarting the compressor.

There may also be a need to have separate dictionaries for different data types (e.g. AOC and ATC) because of the different characteristics of the data streams, and this in turn implies that multiple Deflate compressed data streams may have to co-exist. But only if there is a clear performance gain.

Recently, there has also been attention paid to the need for backwards compatibility when introducing new features and the new SNDCF must ensure that this can be done.

2.3.1 Analysis

Considering the above, it is clear that (at least for non-broadcast use) there will have to be some sort of Data Link Management protocol to negotiate compression options and to maintain the data communications path.

Modern communications networks tend to use an “out-of-band” approach to data link management. This is true of Frame Relay, Asynchronous Transfer Mode and ISDN. This technique ensures independence between data link management and data transfer and enables a very lightweight protocol approach to data transfer. A similar approach to the data link management protocol is specified here. This simplifies the specification and is bandwidth efficient.

However, no out-of-band communications service is readily available from (e.g.) VDL Mode 3. Therefore, there is a need to provide for this by some sort of frame level protocol. The design approach for the Frame Mode SNDCF is thus:

1. The air/ground data stream is subdivided into a number of individually prioritised bi-directional “logical channels”, each identified by a channel number.

2. Data packets including data link management packets are always sent in the context of a logical channel i.e. they are encapsulated with a simple header identifying the channel and priority.

3. Subject to maintaining the semantics of data priority, packets sent on different channels may be concatenated and sent as a single transmission frame.

4. A Data Link Control Protocol (DLCP) is specified in order to negotiate data link capabilities and compression options, and to manage the purpose and use of each channel. Channel zero is reserved for the DLCP.

5. A channel assignment can specify that the data packets are Deflate compressed before transmission on a given channel. It is also possible to have multiple Deflate compressors with different groups of channels assigned to different compressors.

The channel concept firstly allows the separation out of the DLCP from user data and secondly allows for different Deflate compressed streams to be multiplexed together. It is also extensible as it permits other compression protocols to be introduced later (e.g. ADCMP for audio compression) and used in parallel to Deflate on other channels. Some channels (in addition to channel zero) could also be uncompressed, if that was needed.

The specification also deliberately groups multiple channels together for compression as a single data stream. This is done to ensure the most efficient compression while still allowing the channel concept to be used to differentiate different data streams. Essentially, a Deflate Compressor becomes a Server asked to compress a packet before it is encapsulated with a channel header and appended to the transmission frame. The channel determines the choice of compression Server.

At least two user data formats are foreseen. These are ISH PDUs, and CLNP PDUs that cannot be LREF compressed – or more generally any ISO TR 9577 identifiable protocol – and LREF compressed CLNP PDUs. However, the channel concept can readily extend to supporting other data formats including IP and even ACARS messages.

2.3.2 Architecture

The architecture of the proposed approach is really more than an SNDCF. As illustrated in Figure 2-4, it is proposed to break down the specification into two parts: the SNDCF proper and an Air/Ground Communications Sublayer (A/GCS). The A/GCS comprises the multiplexing of many logical channels, the DLCP and the Deflate compression (which operates across channels). The SNDCF itself is responsible for providing the L-Service over the A/GCS and also incorporates LREF compression, which is CLNP specific.

There may be other users of the A/GCS in addition to the Frame Mode SNDCF. For example, if IPv4 packets are also conveyed then IPv4 will be a separate user of the A/GCS.

The underlying Data Link Layer is assumed to provide:

- A singlecast communications service that provides reliable delivery and preservation of frame transfer sequence order. It may thus be a connection mode service (e.g. VDL2 AVLC) in addition to the acknowledged connectionless service of VDL3.
- an optional broadcast ground to air unacknowledged connectionless service.
- “Join” and “Leave” events to signal contact with a new Ground Station/Aircraft, and loss of contact, respectively.

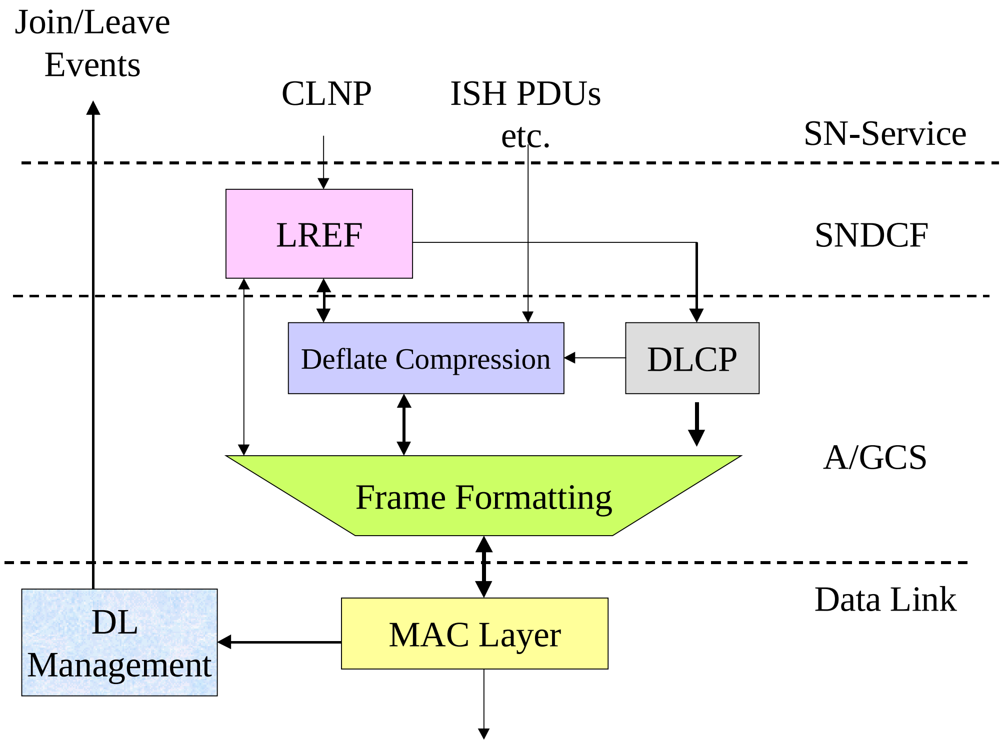

Figure 2-4 Proposed Architecture

The A/GCS provides a (DLCP supported) Data Link Management service to its user and a data communications service. The Data Communications service is channel oriented, with channel assignment performed through the Data Link Management interface. The data communications service is packet oriented and is guaranteed to maintain packet delivery order but does not guarantee to deliver all packets. The probability of packet loss is small but can come about (e.g.) through detection/recovery from a Deflate checksum failure.

The SNDCF provides the required L-Service. It will use the A/GCS Data Link Management Service to maintain at least one channel for ISH PDUs, and CLNP PDUs that cannot be compressed using LREF. Otherwise, the SNDCF will use the A/GCS to assign a new channel for each local reference needed and use this channel to transfer LREF compressed CLNP PDUs associated with that Local Reference.

2.3.3 Broadcast Mode

The underlying communications media typically support broadcast mode operations in the ground to air direction and the A/GCS and SNDCF are designed to permit seamless use of the broadcast service.

In broadcast mode:

- the DLCP is limited to channel assignment and channel assignments have a time limited validity i.e. they automatically lapse after a set period of time.
- if Deflate is used then it is applicable to each channel individually i.e. each channel is compressed as a separate data stream.
- LREF is supported as normal.
- Broadcast Channel allocations are independent of singlecast channel allocations.

The broadcast service will be used when a Multicast CLNP service is included in the SARPs.

In use, it is expected that the Ground Station will only periodically re-allocate each LREF channel – as otherwise there will be no benefit from LREF compression given that the first packet has to be sent uncompressed.

The above means that every aircraft will always be able receive and process broadcast ISH PDUs, but on coming into range of a Ground Station, and aircraft will have to wait for channel re-allocation before being able to receive LREF compressed PDUs.

2.4 Understanding the Frame Mode SNDCF

2.4.1 Channels

A channel is simply a labelled flow of data. The label is a 12 bit number (the channel number) and, initially, zero is the only defined label. Channel 0 is reserved for the DLCP, and the DLCP is used to assign further channel numbers i.e. define the data types associated with each channel.

A Frame may consist of more than one data packet, each on a different channel, concatenated together. It is thus possible for a DLCP message defining the use of a channel to be immediately followed by the first data packet that uses that channel number. Indeed, this is how it is meant to be used with a channel only defined when it needs to be used.

Each such data packet may also have a priority associated with it. There is no requirement for all data packets on the same channel to have the same priority, but there are rules on when packets with different priorities can be concatenated together into the same transmission frame. These rules are there to ensure that higher priority data is not denied access to the medium by lower priority data.

Allowing different data packets on the same channel to have different priorities is only possible because there are no rules for the sequencing of data packets sent on the same channel.

2.4.2 Compression

Deflate compression is an integral part of the A/GCS specification. However, it is not the only data compression algorithm that can be supported. The specification is deliberately designed as extensible to enable other data compression algorithms to be introduced later on in a backwards compatible fashion.

The basic concept is that a sender has one or more Deflate compressors associated with each Peer System and that each compressor may be associated with one or more channels. The reason for allowing for more than one compressor per Peer System is that each may be initialised with a different “dictionary” that allows compression to rapidly converge on an optimal compression state for a specific type of data.

In this context, a "dictionary" is simply a well known string (less than 32KB long) of frequently occurring symbols. It is feed into the compressor (and the output discarded) when the compressor is initialised; the same string is similarly feed into the decompressor in the Peer System. Provided that the symbols in the dictionary re-occur less than 32KB into the data stream (from where they occur in the dictionary) they will be immediately compressed on transmission.

When a channel is assigned, a Deflate compressor may be associated with it. The actual compressor is identified by a Dictionary Identifier that is known *a p*riori by both sender and receiver.

As Deflate is a stream compression algorithm it is very important that the decompressor works on an identical data stream to the compressor. Compressed packets are thus decompressed in strict transmission order and the underlying datalink is assumed not to re-order packets.

In order to provide for error recovery, each compressed packet is appended with a checksum taken on the uncompressed data. If this checksum cannot be verified on reception, the data is discarded and a Link Reset message returned (using the DLCP) identifying the offset into the data stream of the last correctly received byte. Compressed data on the affected streams continues to be discarded until the compressor acknowledges the reset and restarts from the identified stream offset.

This procedure allows for recovery from the occasional re-ordering or packet loss. However, throughput will suffer if this event is more than infrequent.

2.4.3 Security

The A/GCS provides a framework for authentication of the source of each frame.

The DLCP provides for the exchange of security related information on link establishment which permits a shared encryption key to be agreed. This may then be used to compute an encrypted checksum for each transmission frame, which may be appended to the concatenated data packets in each frame. A receiver can use this to verify the source and integrity of the data.

2.4.4 The DLCP

The DLCP is a channel management protocol and does not itself transfer any user data. Its functions are:

- Data Link Initialisation
- The assignment of channel numbers and the semantics of the data carried over a channel.
- Compression algorithm Management, and
- The optional authentication and verification procedures.

The protocol is designed to be robust (i.e. it can recover from data loss, duplication, etc.) but is also lightweight and avoids acknowledgements unless necessary. For example, Channel Assignment is unacknowledged; however, if this message is lost then the peer system will respond with an error when data is sent on an unassigned channel.

On data link initialisation, information on the capabilities of each peer system are exchanged including the compression algorithms supported, with each Deflate Dictionary supported being treated as a separately identified compression algorithm.

A channel is simply allocated by a “Channel Start” message identifying the channel number, the data type associated with the channel and an optional compression identifier. Data types are currently defined for:

- ISO TR 9577 formatted NPDUs (e.g. ES-IS and uncompressed CLNP)
- LREF compressed CLNP
- CLNP NPDUs with reformatted headers (for optimal Deflate compression)
- IPv4 packets.

Channels are symmetric once assigned i.e. have the same data type and compression algorithm associated with them in each direction. To avoid conflicts when allocating channel numbers, each side starts with either high or low channel numbers and at least one channel must remain unassigned.

There is no requirement for a data type to be associated exclusively with a single channel. For example, LREF compressed data may be associated with different channels each themselves associated with a different compression algorithm (or Deflate Dictionary). The sender can then send data with different Traffic Types using the most appropriate compressor for that Traffic Type. As local references are associated with the datalink rather than the channel, there is no loss in LREF efficiency here.

Channel numbers may be de-assigned with a Channel Deallocate message and reset by a Channel Reset message. The purpose of the latter message is really data type specific and may be used, for example, by LREF error recovery procedures.

The DLCP also supports retention of compression state and channel assignments across Ground Station Handoffs. Each datalink session is labelled on initialisation by a Ground Station and, on Handoff the old session identifier is presented to the new Ground Station which will recover the compression state and channel assignments if possible.

This technique avoids an aircraft having to keep track of whether or not a Handoff is to a new GNI or not. In both cases, it simply presents the old session identifier and it’s up to the Ground User to recognise whether the compression state information is local or whether it has to be retrieved from another Air/Ground Router.

It should be noted that the DLCP specifically requires that an aircraft initiates the data link procedures. This is to optimise the procedures for retention of compression state on handoff.

2.5 The Frame Mode SNDCF

The A/GCS is an important part of the Frame Mode SNDCF, but is not the complete SNDCF. This additionally includes the LREF Compression and the optional CLNP Header Reformatting scheme.

The LREF compression algorithm is much the same as for ISO 8208 except that its parameters are sent as user parameters by the DLCP on data link initialisation. It also uses the Channel Reset mechanism when error recovery is being performed rather than a Network Reset.

The CLNP Header Reformatting algorithm is the result of a recent performance analysis that suggests that the reason why LREF and Deflate offer better compression than Deflate alone is due to the order of the parameters in a CLNP Header not reflecting the order of volatility. Deflate is thus unable to find long strings to compression and thus compresses, with lower efficiency, shorter strings. The reformatting algorithm re-orders the CLNP header fields into the assumed order of volatility and therefore should provide equivalent compression performance to LREF + Deflate but with less computational overhead.

2.6 A/GCS Compatibility with other Datalink Users

The A/GCS may be introduced on datalinks for which aircraft are equipped to use earlier datalink protocols (e.g. VDL Mode 2 and ISO 8208) or when other protocols must co-exist with the use of the A/GCS (e.g. the CLNP Header compression algorithm specified for VDL Mode 3 and GA users). A simple mechanism is thus needed for a Ground Station to determine whether an aircraft uses the A/GCS or an alternative datalink protocol.

The approach chosen is to use the first octet of the first frame downlinked as the means to determine the frame format and hence the datalink protocol the aircraft uses. With the A/GCS this must always be zero; any other value implies an alternative frame format. This is because the first A/GCS packet downlinked will always contain a DLCP packet on channel zero.

In VDL Mode 3, the first octet in the frame is the payload octet and a value of zero is not assigned at present. This should remain the case. When the A/GCS is used with VDL Mode 3 there should be no payload octet and the A/GCS occupies the whole frame. With other formats (e.g. ISO8208, direct use of ISO8473) there is a payload octet as defined in the VDL Mode 3 SARPs.

2.7 A/GCS over VDL Mode 3

As implied by the above, when the A/GCS is used over VDL Mode 3, A/GCS formatted frames occupy the entire data portion of the frame; there is no payload octet. The frame's priority reflects the highest priority data packet in the frame.

2.8 A/GCS over VDL Mode 2

When the A/GCS is used over VDL Mode 2, A/GCS formatted frames occupy the entire data portion of an AVLC frame. An A/GCS frame may also be sent in the "Expedited Subnetwork Connection Parameter" of an XID frame used for Datalink Establishment or Handoff. In the this case, this will be to convey datalink initialisation information including a DLCP Datalink Initialisation message. A Channel Assignment followed by an ISH PDU in the assigned channel may also be present.

The above technique can also be used to distinguish A/GCS frames from other VDL Mode 2 protocols (i.e. ISO 8208 and AOA). In the former case, an initial zero octet can only occur when a General Format Identifier has a value that is reserved for other applications and which is not legal for VDL Mode 2. Hence, initial ISO 8208 and A/GCS frames can always be distinguished from each other.

Similarly, AOA frames always start with an all ones octet, again ensuring that they can be distinguished from A/GCS frames.