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Agenda Item 11: Review of results of subgroup dealing with VDL Mode 4 ATN issues

Alternative approach to VDL Mode 4 data link service

Presented by Eurocontrol

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SUMMARY

This Working Paper describes the issues associated with the use of new DLS protocol to replace the AVLC. A simpler draft protocol is proposed and the issues that need further work are identified. WGM is invited to consider the proposal and provide directions

1 Introduction

The VDL Mode 4 community has been considering possible options for optimisation of VDL Mode 4 performance as an ATN subnetwork. One issue is the possible need for an alternative to the current AVLC DLS protocol. The rationale for this is set out in [R1]. The purpose of this paper is to take the proposals made in [R1] (Attachment A) a stage further to assess the impact on the current standards material of introducing an alternative protocol.

The paper is organised as follows:

- Section 2 analyses a number of issues associated with the protocol proposed in [R1].
- Section 3 summarises the extent of the changes necessary to the VDL Mode 4 Technical Manual should WG-M decide to adopt the alternative protocol.

2 Issues associated with the design of a new protocol

2.1 Structure of the DLS

The structure of the DLS in Mode 4 can be characterised in three broad areas:

- the **general protocol** for exchange of frame types. For Mode 4 this is based closely on the Mode 2 AVLC with very little modification
- the definition of **special burst formats** necessary to carry the frames. In Mode 4 three special burst types are defined: the Compressed Frame burst, the RTS and the CTS
- the definition of a **special transfer protocol** to support the general protocol. In general, this would be expected to be "glue" that joins the bottom of the DLS to the top of the VSS. In Mode 4, the short and long transmission protocols constitute these special transfer protocols.

2.2 Proposed new general protocol

In the proposals of [R1] a new general protocol is proposed which:

- requires a very simple frame set containing significantly fewer frame types than are currently needed in AVLC
- provides a simple protocol exchange in which each segment is acknowledged before moving to the next.

The protocol is easy to define and is, in fact, very similar to that used in Mode 3. Hence the Mode 3 Technical Manual can be used as the basis for the definition of the general protocol. This would entail the use of only three frame types (INFO, ACK and CTRL).

The general DLS protocol is therefore:

- sender transmits INFO or CTRL
- receiver transmits ACK

If either of these fail, the retransmission procedures within the VSS ensure that the necessary re-sends are carried out. Note that the VSS will have to inform the DLS in the event that the re-transmission procedure times out. Note also that the M-bit is used differently in Mode 3: it is used to group shorter frames into a single media access event rather than to link information carried in different access events as is proposed in [R1]. Hence some modification will be necessary.

2.3 Special transfer protocol (DLS)

A key issue is then how to map this simple protocol to the VSS protocols using appropriate special transfer protocols. Consider the following design criteria:

- if possible, all transmissions should be in pre-reserved slots
- it is easy to place the ACK in a pre-reserved slot by either placing the reservation in a transmission which precedes the INFO transmission or, if this is not possible, use a unicast reservation burst for the INFO transmission.
- reservation for the INFO frame requires a prior transmission. If the INFO is part of a longer series of INFO transfers, it would be possible to include a reservation in the immediately preceding ACK. This will occur most often in the transfer of M-bit sequences (note that an M-bit sequence is the series of transmissions required to transfer a single packet).
- if the INFO frame is not part of a longer series, a decision needs to be taken as to whether a prior transmission is beneficial. The issue has already been addressed in the current standard where short INFO frames are transferred by random access (short transmission procedures) and longer INFO frames via a prior reservation (long transmission procedures).

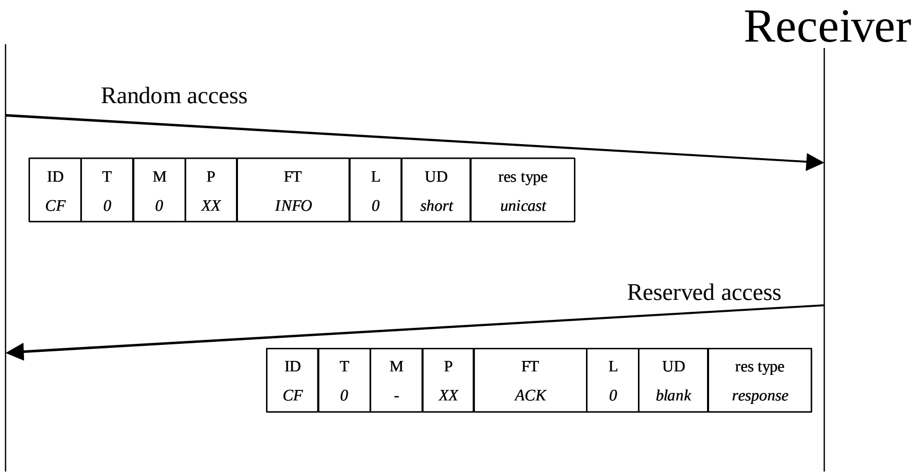
A number of transfer protocol designs are possible and need to be discussed by WG-M. However, the following sets out a possible solution for consideration.

Define a new compressed frame (CF) burst format which contains the general protocol control elements, the INFO, ACK or CTRL frame, and a field which indicates the length of the next packet in the sequence. The new burst format effectively combines the old RTS, CTS and Compressed frame formats. It should also be possible to send a blank frame (BLK) which would then be used to mimic the role of the old RTS and CTS.

The use of the fields in the new CF burst are best illustrated by examples.

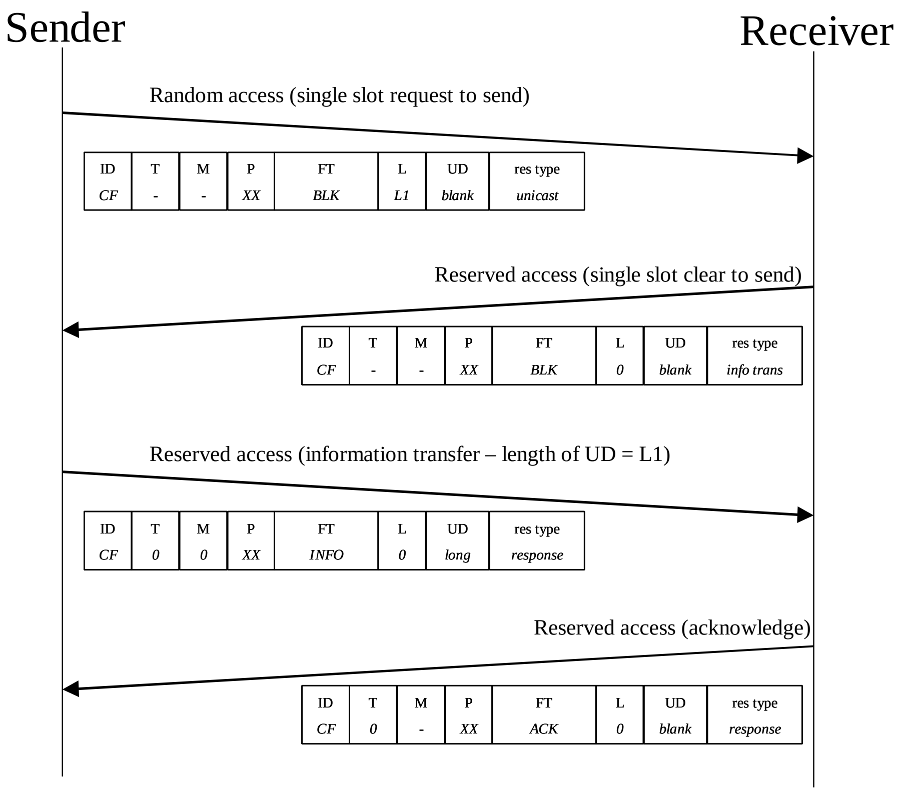
Example 1: short one-off message.

a) Sender: CF random entry containing INFO and unicast reservation for ACK. M = 0 indicates that there is only one segment to transfer.
b) receiver: CF containing ACK. T bit matches T bit in INFO frame.



Example 2: long one-off message.

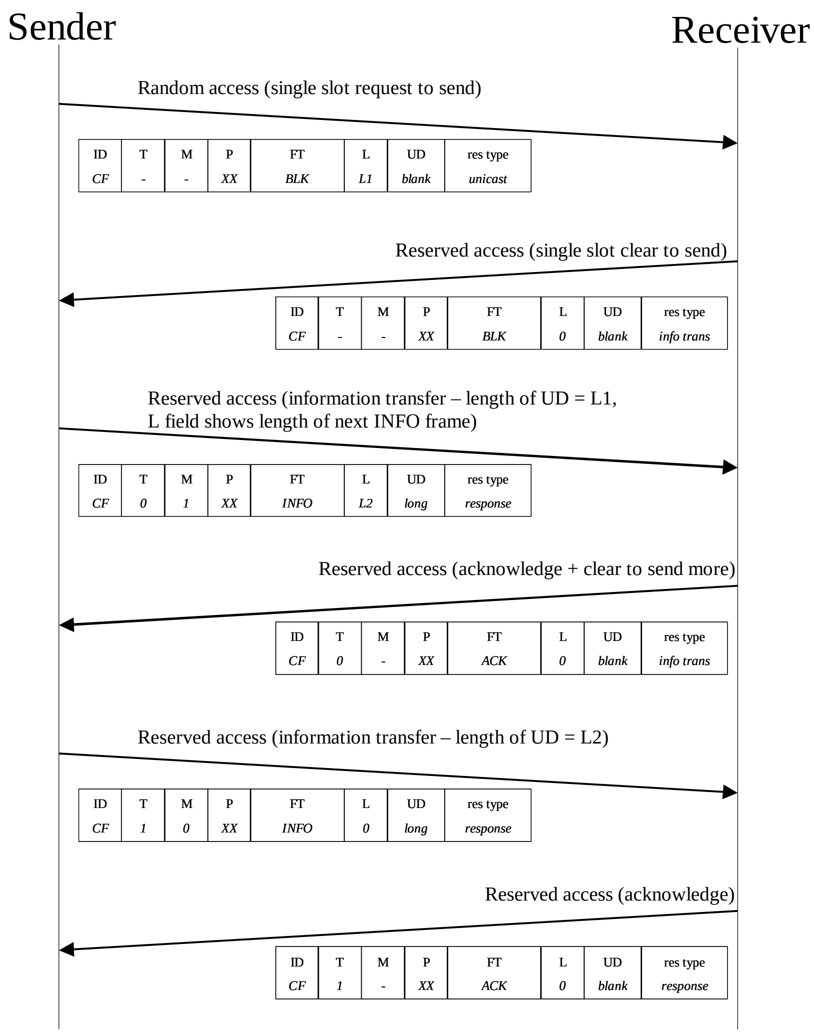
a) Sender: 1 slot CF random entry containing blank frame, L = length of INFO frame to send and unicast for response
b) Receiver: 1 slot CF containing blank frame and info transfer reservation for INFO and subsequent ACK
c) Sender: CF containing INFO
d) Receiver: 1 slot CF containing ACK



Example 3: long one-off multi-stage message. as above only

c) also contains length of next INFO field

d) contains info transfer either for resend (if stage c) fails or for next INFO.



It is assumed that an M-bit sequence will always use a relatively long segment length and hence the last of the options above is the appropriate one. However, if there is a sequence of short segments, the same linking protocol could be used except that the initial entry would be via a random access and the CF containing the first INFO would also contain a length field indicating the next segment length.

So the proposed compressed frame fields and associated procedures are:

Field	**Procedures**
message ID	Indicates compressed frame (CF) burst
toggle bit (T)	As per [R1] and Mode 3
more bit (M)	As per [R1] (note the usage is slightly different in Mode 3)
priority (P)	There two options: absolute priority and relative priority. It is could also be possible to combine these two options. (see Section 2.5)
frame type	Styled on Mode 3 (INFO, ACK, CTRL, BLK). ACK needs to include ability to signal duplicate frame.
user data	Contains packet or packet segment

Field	Procedures
length of next message	set zero if no data to follow set non-zero if more packets outstanding – indicates length of next INFO or CTRL user data in [octets]
reservation block = response	Used for • CF containing INFO frames when a prior reservation for the ACK already exists • CF containing ACK when there are no further packets to be transferred • CF containing broadcast INFO frame??
reservation block = unicast	Used for • CF containing INFO frames when a prior reservation for the ACK does not exist. Reservation provides slots for the ACK • CF containing blank frame and non-zero length field. Used to request transfer of long INFO frame (RTS). Reservation points to slots for ACK of the blank INFO frame (CTS)
reservation block = information transfer	Used for: • CF containing ACK or BLK when there are more packets to be transferred. Reservation points to slots for INFO transfer and subsequent ACK.

The appropriate slot access mechanisms are:

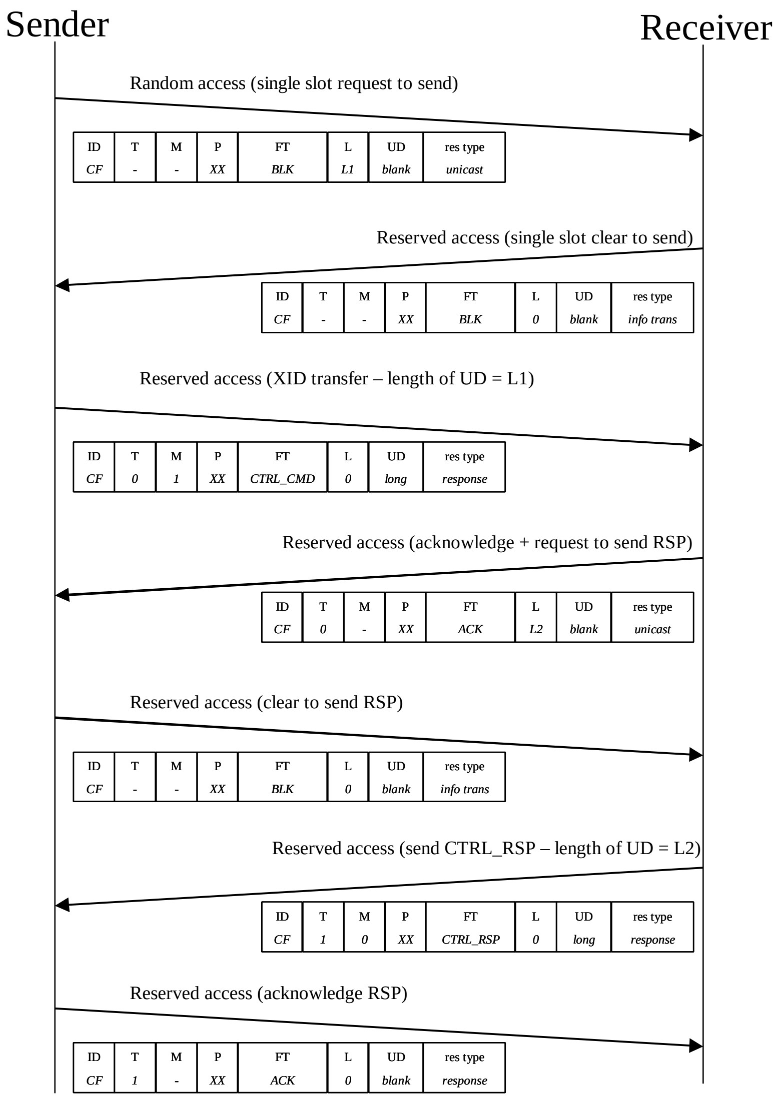
- Random for first INFO assuming UD less than some parameter
- Otherwise, random using CF with blank INFO and length field set to length of first INFO packet.

2.4 XID transfer

The transfer of XIDs needs careful study. In Mode 3, the CTLR_CMD frame is acknolwedged with a CTRL_RSP rather than an ACK. This approach could not be taken in Mode 4 because the length of the RSP was uncertain and hence it could not be included as part of an info transfer reservation (in any case, the acknowledgement is limited to a single slot). Hence, the approach is to treat transfer of CMD and RSP separately using technical acknowledgements as appropriate.

It is proposed that the same approach is used in the modified Mode 4. Therefore, although the message sets and general protocols for link management can be imported from Mode 3, the CTRL_CMD and CTLR_RSP require separate acknowledgement.

It should therefore be possible to use the same transfer protocols as set out for INFO frames. Note that the CTLR_CMD and CTRL_RSP are disconnected in the sense that the CTRL_RSP is not linked by reservation protocols to the CTLR_CMD. However a linkage could be made by treating the transmission containing the ACK for the CTLR_CMD as a request to send an CTRL_RSP as illustrated below. This is done by including a non-zero length field. It has the merit of continuing the reservation sequence but has the potential disadvantage of linking uplink and downlink streams.



2.5 Priority management

[R1] proposes the use of a relative priority scheme. The purpose of this is to control the flow of packets between two peer stations such that a higher priority stream can be started before a lower priority stream has completed. Therefore, a short high priority flight safety message can pre-empt a long lower priority AIS message.

Note however that another aspect of priority management, that is supported in Mode 4 through the long transmission protocol, is the control by a ground station of a series of parallel requests to send data from a number of mobile stations. The selection of which station should transmit must be carried out against an absolute priority scheme. Hence, as a minimum, absolute priority, using the mapping already defined in Mode 4, should be carried in the bursts.

The absolute priority mapping in Mode 4 is defined in the table below.

Message categories	Priority	Q1
Network/systems management	high	2
Distress communications	high	2
Urgent communications	high	2
High priority flight safety messages	high	2
Normal priority flight safety messages	high	2
Meteorological communications	medium	1
Flight regularity communications	medium	1
Aeronautical information service messages	medium	1
Network/systems administration	medium	1
Aeronautical administrative messages	low	0
Urgent priority administrative and UN charter communications	low	0
High priority administrative and state/government communications	low	0
Normal priority administrative	low	0
Low priority administrative	low	0

The absolute priority scheme can support pre-emption between two peer stations, although the pre-emption decision is now based on, and therefore limited by, the reduced 4 level priority scheme. In other words, it would not be possible to distinguish between two different priority messages if they had the same priority level in the reduced scheme. Using the table above, the absolute priority scheme could be used to distinguish between flight safety and AIS messages, but could not differentiate between high and normal priority flight safety messages. In the relative scheme, a flow of messages between two peer stations consisting of high and low priority messages could be delivered as two separate streams.

The simplest approach for the new protocol is to use the absolute priority scheme only. However, it would be possible to introduce a second relative priority field for the purpose of distinguishing different peer-to-peer channels if WG-M feel that there is a need to allow differentiation within the priority groups currently defined for VDL Mode 4.

2.6 Other issues to consider during drafting

The following issues must be taken account of during drafting of the new protocol:

- Procedures need to be written to handle broadcast INFO frames (which are unacknowledged).
- The segment/acknowledge cycle will be contained within a request-response VSS cycle, using reservation protocols as appropriate. This means that delivery of each segment is either assured by VSS re-transmission procedures or notification is made by the VSS to the DLS that delivery has not been possible. Therefore it is

necessary to define a DLS response in the event that the packet cannot be transmitted by VSS. The options include:

- re-send packet. This seems pointless if the same quality of service parameters are used since the VSS has already failed to deliver the packet. Re-sending with more favourable quality of service parameters should be considered. Chopping the packet into smaller parts could also be considered.
- discard packet. Possibly useful depending on packet type. Note that the toggle bit should not be updated, otherwise the next successful packet will be discarded by the receiver as a duplicate.
- declare the station unreachable. Effectively this triggers a leave event.

- In the current standard, the procedures for long and short transfer are DLS procedures and not VSS procedures. It generally seems a good idea to decouple the long and short procedures from the details of the DLS message exchange. One reason why the short and long procedures appear in the DLS in the current specification is that the procedures depend very much on the type of frame contained within the bursts. In fact, the procedures for INFO and XID transfer are rather different. It may be possible to avoid this in a new protocol such that a cleaner protocol, can be defined which is broadly independent of frame type.

3 Adaptation of VDL Mode 4 DLS and LME

This section summarises which sections of the current standard would have to be changed to accommodate the proposed protocol. Source material for the initial drafting of the modified standard is identified as coming either from the Mode 3 standard, the existing Mode 4 standard or based on the outline in [R1].

Protocol element	Current Standard reference	Reference for modified standard
VSS		
	Includes re-transmission	Re-transmission to be maintained in VSS and removed from DLS and LME
DLS		
Basic data exchange protocol	AVLC – largely defined in Mode 2 (VDL Mode 4 section 5). 1.4.2, 1.4.3, 1.4.5 Mode 2: 5.3.3, 5.3.5 to 5.3.11	Bisync – based on [R1] and also close to that used in Mode 3. Note that in Mode 3 frame grouping is used to fill the fixed packet length with separate frames – this is assumed not relevant to Mode 4 particularly as concatenation is carried out in the Frame Mode SNDCF. Hence, in Mode 4 the M bit is to be used in a different way: indicating that there is a further segment of the same frame to follow. [R1] Section 4.2 Mode 3: 5.6.1.3, 5.6.2 – 5.6.4
Burst format	Compressed frame/RTS/CTS 1.4.2.1, 1.4.2.2 Mode 2: Table 5-3, 5.3.3.3.2, 5.3.3.3.5 to 5.3.3.3.7, 5.3.3.4, 5.3.3.5, 5.3.3.6	New formats based on amalgamation of R1 proposals with need to provide ongoing reservations. This note proposes a single revised compressed frame burst format which can be used for RTS, CTS and frame transfer.
Additional transfer protocol	Maps AVLC INFO frame transfer onto long or short transmissions protocols 1.4.3.1, 1.4.4.1 to 1.4.4.4	New protocols need to be developed. This note proposes protocols based closely on the existing long and short protocols but providing an extension to allow linking of M-bit sequences via reservation protocols Note that all responses should have ability to reserve for next segment. It would be good to design the new protocol to avoid as far as possible dependence on frame type and also to support XID transfer.
LME		
Basic XID exchange protocol	Based on Mode 2 1.5.6, 1.5.7, Table 1-97 Mode 2: 5.4.4 Tables 5-46	Mode 3 seems to provide an alternative basis for this protocol, supplemented by Mode 4 private parameters already defined in the current standard. Note that some changes may be necessary to the protocol. For example, CTRL_CMD may need a technical acknowledgement. Mode 3: 5.7
Burst format	Compressed XID/RTX 1.5.3	To use the new compressed frame burst. Will still be necessary to define a compressed XID to handle broadcast XIDs, as per the current standard.
Additional transfer protocol	Modified short and long procedures 1.5.8	Assuming that CTLR_CMD is separately technically acknowledged, should be able to use the same set of protocols as for INFO exchange.
Parameters exchanged	Mode 2 + Mode 4 1.5.4 Mode 2 5.4.2	Use an amalgamation of Mode 3 plus the VDL Mode 4 private parameters defined in the current standard.
Link event generation	Mode 4 PECT 1.5.5.1, 1.5.6.2	Use Mode 4 PECT
Subnetwork layer		
	Mode 4 includes separate SVCs for each priority level Section 2	Not required if Frame Mode SNDCF is adopted. See separate change proposal.
SNDCF		
	Mode 2	Simple text calling up Frame Mode and saying that Mode 4 must provide join/leave events and data transfer service. See separate change proposal

5 References

[R1]: “Using VDL Mode 4 as an ATN datalink”, Eurocontrol (author T Whyman).

6 Recommendations

It is recommended to AMCP WGM to:

- take note of the analysis presented in this paper and the alternative data transfer protocol presented here,
- provide guidelines in the resolution of the open issues, and
- agree to replace the AVLC based data transfer procedures in VDL Mode 4 with this alternative data transfer protocol.

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ATN PROJECT

Using VDL Mode 4 as an ATN Datalink

ATN Ref. : DIS/COM/ProATN_Sup/DCI/AW_94

Author : Tony Whyman

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SECTION	DATE	REV. NO.	REASON FOR CHANGE OR REFERENCE TO CHANGE
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1. Introduction

1.1 Background

The VDL Mode 4 SARPs have been accepted in ICAO for surveillance applications. Following discussions in AMCP/WGC, the AMCP Working Group M (AMCP/WGM), which is responsible for the maintenance of the VDL Mode 4 SARPs decided to investigate the extension of the applicability of the VDL Mode 4 SARPs to cover point to point ATN communications.

In this frame of activities, a proposal has been discussed to adopt Forward Error Correction (FEC) techniques to improve the data transfer efficiency of the VDL Mode 4 system. This has made VDL Mode 4 considereably more appropriate to support Air/Ground datalink ATC communications. It is now necessary to consider how the VDL Mode 4 subnetwork is to be specified as an ATN subnetwork.

1.2 Scope

This paper does not consider any possible use of ISO 8208 to develop ATN services. The ATN Panel has specified the Frame Mode SNDCF for all future air/ground communications. ISO 8208 is now regarded as old technology and practical difficulties have also been experienced using ISO 8208 with other VHF technologies i.e. in terms of overhead and handoff between Ground Stations. Due to these problems, a proposal is made to WGM to replace in the VM4 specification the ISO 8208 layer with the Frame Mode SNDCF. This paper assumes the adoption of the use of the Frame Mode SNDCF.

This paper considers:

- the subnetwork requirements laid down by the ATN Frame Mode SNDCF (section 2),
- how VDL Mode 4 meets those requirements (section 3), and
- the emerging issues and any changes that may be necessary for VDL Mode 4 to operate as an ATN Subnetwork (section 4).

2. ATN Frame Mode SNDCF Requirements

Figure 1 illustrates the architecture of the ATN Frame Mode SNDCF. The role of this function is to adapt different types of subnetwork to the requirements of CLNP and specifically, in the case of Air/Ground communications, to support data compression and management of the mobile communications.

It is not the intention of this paper to describe the internal architecture of the SNDCF as this is described elsewhere. However, the reader's attention is drawn to the Data Link Layer functions.

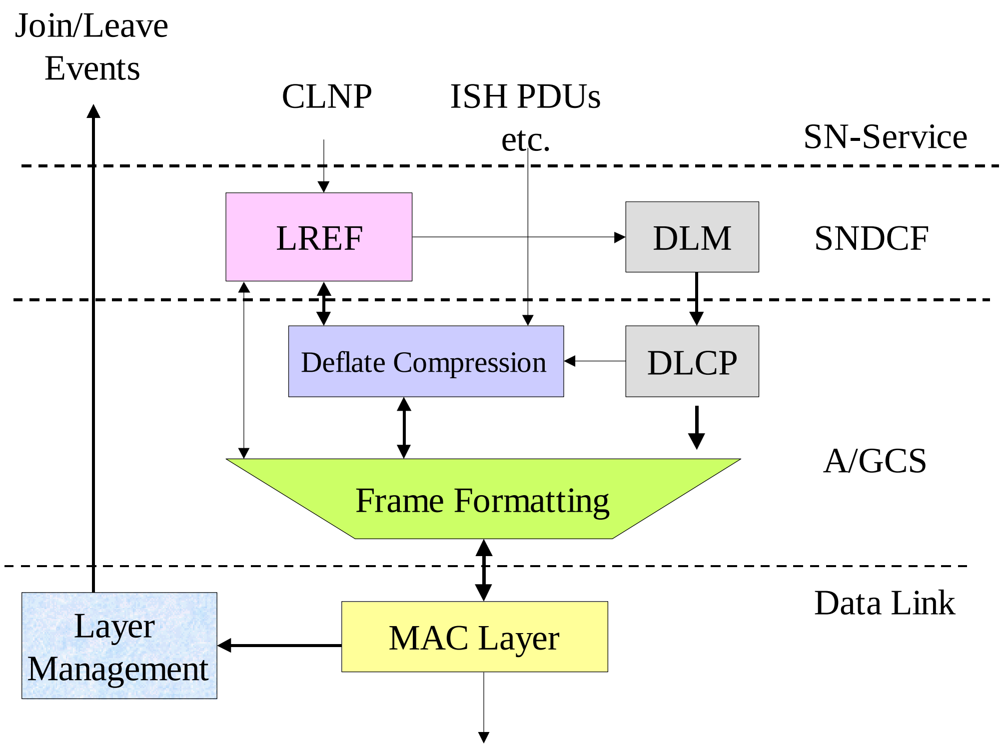

Figure 1 ATN Frame Mode SNDCF Architecture

The Data Link is not part of the Frame Mode SNDCF or its Air/Ground Communications Sublayer (A/GCS). It is provided by the underlying subnetwork and its architecture can vary according to the type of subnetwork being used.

The Frame Mode SNDCF is intended to operate directly over a data link layer such as that provided by the VDL Mode 2 AVLC or the VDL Mode 3 Frame Mode Service and avoids the need for a packet layer protocol such as ISO 8208.

The Frame Mode SNDCF assumes that the data link layer provides the following service:

1. A "Join Event" to report that connectivity is now available to another system. The Join Event is typically generated on the airborne side and reports that communication with a Ground Station is now possible, and identifies the Ground Station either by its address of some local (connection) reference.

2. A "Leave Event" to report that connectivity to another system has been lost. The Leave Event is typically generated on both airborne and Ground sides to report that an aircraft has left a network. The timely generation of Leave Events is an important performance

parameter that affects the acceptability of a given air/ground datalink for use with CNS/ATM applications.

3. A Data Transfer service that provides for the transport of (optionally) prioritised packets (or frames) of data between two communicating systems. Point-to-point bi-directional binary data transfer is required, and the network must provide a minimum packet size i.e. a guarantee that it can transport all packets up to and including that minimum packet size in length.

It is assumed that data transfer only takes place between the receipt of a Join Event and the later receipt of a corresponding Leave Event. Data transfer at any other time is not guaranteed, and generally not possible.

Note that there is no concept of a “Handoff” event in the Frame Mode SNDCF. This was introduced purely as an artefact of the VDL Mode 2 ISO 8208 handoff and is not required by the Frame Mode SNDCF.

In terms of performance, a subnetwork is expected to meet the following requirements:

1. The *Transit Delay* over the subnetwork must be compatible with application end-to-end requirements.

2. The *Data Integrity* should meet ATN SARPs requirements i.e. the undetected error rate should be no worse that 1 in 10^8.

   Note.—This requirement is not as absolute as it may seem. It was originally specified by ATNP/1 when it was assumed that the undetected error rate of subnetworks would contribute to the overall undetected error rate. However, since then reliance has been placed on end-to-end mechanisms. Even so, an undetected error in a subnetwork is expensive as it requires an end-to-end retransmission and a re-synchronisation of the data compression mechanisms. This figure is thus retained as a target for good practice.

3. The subnetwork is also required to prevent mis-delivery and duplication of packets. The probability of mis-delivery or duplication should be of the same order as the Data Integrity requirement.

4. The *Availability*, *Continuity* and *Reliability* must all be compatible with OPLINK Panel requirements for Air/Ground Communications.

3. The VDL Mode 4 Data Link Service

VDL Mode 4 provides a point-to-point packet orientated data transfer service for the bi-directional transfer of binary data. It has the following characteristics, in respect of ATN requirements.

3.1 Join Event Processing

VDL Mode 4 provides a well defined network entry procedure. This starts with a MAC layer network entry procedure that is common for both Air/Air and Air/Ground communications. If a suitable ground station is available, an exchange of XID messages (as in VDL Modes 2 and 3) is then used to initiate the datalink or to agree handoff from one Ground Station to another.

The completion of the XID exchange, whether for Data Link Initiation or Handoff can be specified as the point at which the Join Event is generated. This is appropriate because data transfer is now possible andthe identities of both sides are known to each other.

Note that in the adaptation of the Frame Mode SNDCF for VDL Mode 2 and 3, the possibility of raising the Join Event prior to the XID exchange has been discussed. This is to permit the merging of the XID exchange with the first exchange of synchronisation packets and in both cases this is believed to have performance benefits. In the case of VDL Mode 4, it is not believed that the case for this is as strong and thus the simpler strategy (i.e. no merging of XID and user data) is believed to be more appropriate.

Note.—In VDL2 the cost of gaining access to the medium is relatively high and it makes sense to combine transmissions wherever possible. However, in VDL4 as the network utilisation increases, the probability of finding many contiguous slots decreases and hence it is likely that longer transmissions will anyway have to be fragmented. Hence, it is unlikely that any significant benefit will accrue from combining XID and initial data exchanges.

3.2 Data Transfer

VDL Mode 4 provides two MAC Layer mechanisms for data transfer:

1. **Short Message Transfer**

   Short messages (typically up to 83 octets or three slots) are transferred as a single one-off burst. This may be in a slot reserved by (e.g.) a periodic broadcast (using incremental reservation procedures) or transmitted in an unreserved slot. The burst contains the I-Frame containing the information to be transferred and also contains a reservation for a response from the destination station.

   If no response is received in the reserved slot then the original transmission is repeated as described above. After ‘n’ retries with no response, the transmission attempt fails.

2. **Long Message Transfer**

   Longer messages start with an “RTS” burst. This is a short single slot message sent to the recipient to request the sending of a long message. It includes information on the priority and number of frames in the message. The RTS burst also contains a slot reservation for the response.

   This procedure includes retransmission of the RTS in the event of no response and takes full advantage of the VDL4 reservation protocols in order to optimise performance.

At the data link layer, VDL Mode 4 currently specifies the use of the VDL Mode 2 AVLC. This specifies the formats for the XID messages used for data link initiation and handoff and makes use of standard HDLC procedures for data transfer. It provides for reliable data transfer including detection and rejection of duplicate transmissions, using a “sliding window” mechanism for flow control and acknowledgement.

3.3 Performance

3.3.1 Transit Delay

The transit delay offered by VDL Mode 4 is assumed to be appropriate to application requirements and is anyway outside of the scope of this paper. It is noted that the use of the FEC is intended to improve the overall transit delay.

3.3.2 Data Integrity

VDL Mode 4 includes a CRC on every data transmission. This is believed to meet the ATN requirement for data integrity.

Additionally, addressing information is included within the scope of the CRC and this can be used to detect and reject mis-deliveries.

Duplicate detection and rejection is handled by the AVLC.

3.3.3 Availability, Continuity and Reliability

This performance characteristics are outside of the scope of this paper and are assumed to be satisfied through systems engineering principles applied to the deployment of network components.

4. Use of VDL Mode 4 as an ATN Subnetwork

4.1 Issues

There are a number of issues associated with the use of AVLC:

a) Both the VDL 4 MAC Layer and the AVLC include mechanisms to recover from lost transmissions or responses. It is not clear where the responsibility for this function lies and therefore this needs to be clarified in the VM4 specifications.

b) The AVLC procedures support concatenation of small frames into a single transmission. However, so does the Frame Mode SNDCF.

c) The MAC layer maximum frame size can vary dynamically according to conditions. The availability of an FEC makes practicable Long Message Transfers of (e.g.) 1024 bytes. However, network loading may mean that the number of contiguous slots available is insufficient to send a long message, and a large message will have to be segmented into several smaller transmissions. On the other hand, the AVLC provides no mechanism to support this and relies upon the service user to send messages appropriate to the dynamic conditions.

d) The AVLC provides timers that enable loss of communications to be detected (a.k.a. the Leave Event). However, in VDL 2 this anyway relies upon the aircraft monitoring all transmissions from a Ground Station and has a known problem with the Ground Station detecting an aircraft going out of range. This is because the timer is set to a very long period (60 minutes) in order to minimise channel load.

   Reliance on AVLC Leave Event generation appears to imply that timely generation of Leave Events on the ground may not occur.

   In the case of VDL4, Periodic Broadcasts (typically for ADS-B purposes) could provide an alternative and more efficient MAC Layer mechanism for determining when an aircraft has left the NET.

e) The AVLC does not provide support for message priority. Thus once a given message has been transmitted, it is not possible to send a higher priority message until the first message has been acknowledged. However, the VM4 specifications provide a way to support message priority by setting up multiple SVCs (one for each priority). Nevertheless, this mechanism may not be fully optimum and will provide additional overhead to the load of the link.

In summary the above analysis has shown that:

a) AVLC mechanisms duplicate MAC Layer functions for reliable transmission and Leave Event Generation and Frame Mode SNDCF functionality in respect of concatenation.

b) AVLC does not provide any mechanism to support priority and segmentation of large packets into smaller ones. This is a potentially serious performance problem as CLNP and the Frame Mode SNDCF are predicated on the assumption that the minimum packet size is a static parameter varying at most on a per connection basis, and does not vary on a per packet basis. The lack of support for segmentation in the AVLC means that the minimum packet size has to be set at a conservative value (e.g. 128 bytes). This is highly undesirable as it means that the benefit of the FEC is not going to be fully realised and will result in inefficient use of the network. Furthermore, the protocol overhead is substantially increased for longer messages. Segmentation in Internet Protocols such as CLNP or IP is always viewed as a last resort due to the overhead implied. For CLNP, each fragment has to have a full CLNP header plus an additional 6 byte segmentation header.

In the VDL Mode 4 data link protocol, a single header bit (a "more" bit) should be sufficient to segment large messages for transfer over the datalink. In this case, the maximum message size may vary dynamically according to load conditions and the datalink should segment user messages in an efficient manner in order to optimise network resources.

c) The unique function of AVLC at present is duplicate detection and rejection and the "sliding window" scheme for flow control and acknowledgement. However the usefulness of the sliding window mechanism without segmentation is questionable, and in any case there may be no benefit from this procedure in a VDL Mode 4 context due to the operation of the short and long message transfer procedures.

It is also clear that in order to resolve some of the above issues, changes will be necessary to the specification of the use of AVLC in VM4 (i.e to clarify the Leave Event issue in order to make the MAC Layer responsible for this function).

However in the light of the changes required, this raises the question of whether the VM2 AVLC is best suited for use in VM4. VDL Mode 3 does provide an alternative model. This too uses the XID message formats for data link initiation but uses a much simpler protocol for data transfer. Nevertheless, this simpler protocol does support duplicate detection and rejection, and segmentation. A similar approach may more be appropriate here.

It is not possible to simply import the VDL Mode 3 scheme, but it is possible to propose an adaptation of this scheme for use by VM4.

4.2 An Alternative Data Link Layer Protocol

It is first assumed that the existing MAC Layer principles are used for detection of loss of a transmission and retransmission, and that Leave Event generation is performed from analysis of received Periodic Broadcasts.

4.2.1 Transmission Message Format

4.2.1.1 The format of a data transmission burst (replacing the compressed frame burst) shall be as illustrated in Table 1.

Description	Octet	Bit Number							
		8	7	6	5	4	3	2	1
Protocol Control Info	5	0	R	R	T	M	R	P_1	P_0
User Data	6								
	7								
	8								
	9								
	...								
	n								

Table 1 Data Transmission Burst Format

4.2.1.2 The burst shall consist of a single byte header followed by the user data.

4.2.1.3 All header bits labelled R are reserved and shall be set to zero.

4.2.1.4 The T (Toggle) bit shall be alternately set to zero and one on each successive transmission, except for retransmissions.

4.2.1.5 The M (More) bit shall be set to zero to indicate End of Message and to one to indicate that this segment is not the last segment in a multi-segment message and that further segments will be transmitted.

4.2.1.6 P_1 and P_0 are a two bit relative priority field providing for four relative priorities encoded as an unsigned two bit binary field.

4.2.1.7 P_1 shall be the most significant bit.

4.2.2 Response Message Format

4.2.2.1 The format of a Data Message Response burst shall be as specified in **Table 2.**

Description	**Octet**	**Bit Number**							
		8	7	6	5	4	3	2	1
Protocol Control Info	5	1	R	R	T	R	R	P_1	P_0

Table 2 Data Message Response Burst Format

4.2.2.2 The burst shall consist of a single byte header.

4.2.2.3 All header bits labelled R are reserved and shall be set to zero.

4.2.2.4 The T (Toggle) bit shall be set to the same value as that given in the Data Transmission Burst for which this is a response.

4.2.2.5 The relative priority bits shall be set to the same value as that given in the Data Transmission Burst for which this is a response.

4.2.3 Data Transmission Procedures

Note. 1—The intention is that the sender determines whether or not a message needs to be segmented for transmission and the appropriate MAC Layer procedures (i.e. short or long message transmission) to use. Each segment is then sent in the above format with a separate response returned for each segment. Using MAC Layer procedures a segment is retransmitted for up to n times if no response is received before declaring a transmission error.

Note 2.—The T (Toggle) bit is sufficient to provide duplicate detection and rejection.

Note 3.—The M (More) bit is set to 0 if a message is sent as a single segment or on the last segment of a segmented message and to 1 otherwise. The receiver reassembles segmented messages on reception before passing them to the user.

Note 4.—The four priority levels provide separate data streams and permit a higher priority message to be sent before a multi-segment message has been sent in its entirety or even before a response has been received for a given segment. Messages are normally sent at *priority level zero and are only sent at a higher priority level when the actual message has a higher priority than the one in transit. The priority levels are not semantically linked to message priority and serve only to inform the receiver about the relative priority of each message.*

4.2.3.1 Message Transmission

4.2.3.1.1 A sending system shall maintain a prioritised queue of messages for transmission.

4.2.3.1.2 When determining which message to transmit, the highest priority message shall be sent first.

4.2.3.1.3 The sender shall determine for each message whether it should be segmented for transmission and which MAC Layer transmission procedure is appropriate for the transmission of each segment.

4.2.3.1.4 A single segment message shall be transferred using the chosen MAC Layer transmission procedure as contents of a single data transmission burst.

4.2.3.1.5 In the data transmission burst header byte:

a) The M bit shall be set to zero.

b) The P bits shall be set to zero unless this transmission is pre-empting another transmission (see 4.2.3.4).

c) The T bit shall be set to:

   i. zero for the first transmission to a given station and with the same value of the P bits, following completion of the Data Link Establishment or Handoff procedures with that station, or

   ii. to the inverse of the T bit setting of the preceding successful transmission to a given station, and with the same value of the P bits, in all other cases.

4.2.3.1.6 A multi-segment message shall be transferred as a series of individual data transmission bursts.

4.2.3.1.7 In each case, the segment header shall be identical except for the value of the Mbit which shall be set to 1 for each transmission except the last.

4.2.3.1.8 The M bit shall be set to 0 for the transmission of the last segment of a multi-segment message.

4.2.3.1.9 The remaining header bits shall be set as for a single segment message transfer.

4.2.3.1.10 Following the transmission of a single segment message or each segment of a multi-segment message, the sender shall wait for a response before sending the next segment or another message with the same message priority.

4.2.3.2 Message Reception

4.2.3.2.1 When a data transmission burst is received without errors from another station, the value of the T bit shall be inspected and recorded.

4.2.3.2.2 If this is:

a) the first Data Transmission burst to be received from the sending station with a given value of the P bits following completion of the Data Link Establishment or Handoff procedures with that station, or

b) the value of the T bit is the inverse of the last accepted Data Transmission Burst with the same value of the P bits,

then the message segment shall be accepted.

4.2.3.2.3 Otherwise, the received message shall be discarded as a duplicate.

4.2.3.2.4 For each message received without error, a Data Message Response Burst shall be returned.

Note.—Even if the message is discarded as a duplicate, a Data Message Response Burst has to be returned.

4.2.3.2.5 In the Data Message Response Burst Header byte:

a) The T bit shall be set to the value of the T bit in the received Data Transmission Burst.

b) The P bits shall be set to the value of the P bits in the received Data Transmission Burst.

4.2.3.2.6 If any preceding message segments had been received with the same value of the P bits and with the M bit set to one, then the user data part of the received Data Transmission Burst shall be concatenated to the end of those message segments.

4.2.3.2.7 If the M bit is set to zero on the received Data Transmission Burst, then the user data part of the received Data Transmission Burst, including any message segments received earlier and with which it has been concatenated, shall be passed to the service user as a single incoming message.

4.2.3.2.8 Otherwise, the received user data shall be retained awaiting the arrival of the remaining parts of the multi-segment message.

4.2.3.3 Receipt of a Response

4.2.3.3.1 When a Data Message Response Burst is received without errors from another station, the values of the T and P bits shall be inspected.

4.2.3.3.2 If the settings of these bits are identical to the corresponding bits in the Data Transmission Burst to which the response was received, then the Data Transmission Burst shall be assumed to have been successfully received.

4.2.3.3.3 Otherwise, the response is discarded.

Note.—Under VDL Mode 4 a response is received in a slot reserved by the original transmission. It is thus possible to directly correlate a response to a transmission burst.

4.2.3.3.4 Once a Data Transmission Burst has been successfully received, either the next segment in a multi-segment message or the next message in the transmission queue, if any, shall be sent using the procedures of4.2.3.1.

4.2.3.4 Message Pre-emption Procedures

4.2.3.4.1 If a message is queued for transmission that has a higher priority than any message that is currently being sent, either as a single segment transmission awaiting a response or as a multi-segment message, the higher priority message shall also be transmitted using the procedures of 4.2.3.1, except that the value of the P bits shall be set to a numerically higher value.

Note.—00 is the lowest numerical value. P bits values are assigned in the sequence 00,01,10,11.

4.2.3.4.2 If the message being transferred has the highest available P bit setting then the higher priority message shall be queued until transmission of that message is complete.

4.2.4 Protocol Limitations

There are two known limitations of the above protocol:

1. There is no flow control mechanism.

2. Data transfer occurs with a window of one.

The lack of flow control is not believed to be an issue. End to end flow control is provided by the ATN Transport layer and given the performance limitations of the underlying channel it is very unlikely that there will ever be a need to provide data link flow control.

The window of one limitation requires that for every transmission there is a separate response. This keeps the protocol very simple but does not allow for any opportunity to send more than one transmission without waiting for a response.

However, analysis of the operation of the VDL 4 Mac Layer shows that it is unlikely that there is value in allowing for such a situation. Both the short and long message transfer procedures are based on the principle of returning a response for every transmission and hence fit the credit of one model.

Otherwise, this simple procedure provides:

- Duplicate detection and rejection,

- Segmentation and re-assembly of larger messages

- Priority based data transfer.

Using MAC Layer mechanisms, it also supports reliable data transfer.

5. Conclusions and Recommendations

Generally, VDL Mode 4 with the FEC enhancement provides a good basis for ATC Air/Ground datalink communications. However, the current specification does have a number of issues (see 4.1), which will require changes to the AVLC in order to resolve.

This paper has noted that there is already considerable duplication between the AVLC and underlying MAC Layer functions, or functions provided by the Frame Mode SNDCF, and thus questions whether it is worthwhile modifying the AVLC.

Instead, it is proposed to adapt the approach used in VDL Mode 3, whereby XID Frames are still used for datalink management, but a simpler protocol is used for data transfer. A suitable protocol is described in section4.2.

It is recommended that:

1. AMCP WG/M consider the analysis presented in this paper and the alternative data transfer protocol presented here.

2. Replace the AVLC based data transfer procedures in VDL Mode 4 with this alternative data transfer protocol.

3. Specify that Leave Event generation is performed using information derived from Periodic Broadcasts.