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ATN SARPs Problem when supporting VDL Mode 2 Handoffs

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SUMMARY

Unlike the Mode S Subnetwork, VDL Mode 2 does not hide transitions between Ground Stations from the service user (e.g. an ATN Router). These are called Handoffs in VDL Mode 2 and require the service user to establish new virtual circuits through each new Ground Station as an aircraft moves on its course. However, the ATN Internet SARPs do not have any provision for recognising or responding to a Handoff, although they do support the necessary features for retaining the data compression state. This paper argues for the addition of a "Handoff" event to complement the existing Join and Leave Events, and records that a PDR is raised on this issue.

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1. Introduction

1.1 Scope

VDL Mode 2 has introduced the concept of the “Handoff”. This impacts the subnetwork users i.e. an ATN Router, however, the semantics of Handoff are not described in the ATN SARPs. This paper investigates the issues surrounding Handoff and what if any need there is to amend the ATN Internet SARPs.

1.2 Purpose of Document

This paper has been produced in order to alert implementers to a potential architectural issue and to determine whether a defect report needs to be submitted on the ATN or VDL SARPs.

2. Problem Statement

The ATN SARPs require that an ATN subnetwork provides transparent data transport and unique addressing of all users of the network. However, the Route Initiation procedures and the specification of the Mobile SNDCF do make further assumptions about the service provided by an air/ground data link, such that in addition to the above general requirement, ATN air/ground datalinks are expected to:

1. Supply Join and Leave events when a mobile user attaches to and detaches from an air/ground data link (this is not mandatory but the alternative is very inefficient polling). The Join event reports, to an ATN Router, information about the network and/or information about a new user of the data link, while the Leave event reports that a given user or network is no longer available.
2. Provide an ISO 8208 compatible service for use by the Mobile SNDCF Data Compression algorithms.

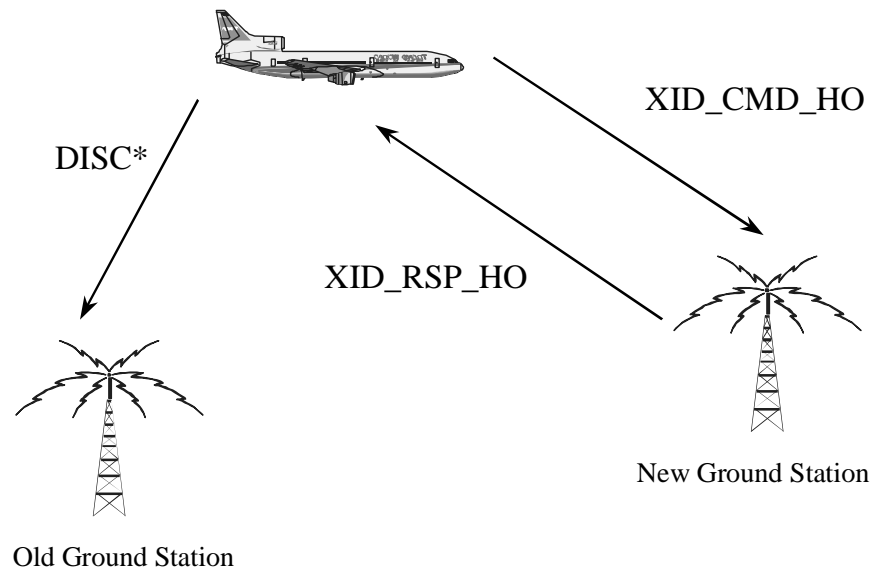
The ICAO VDL Mode 2 air/ground datalink does provide an ISO 8208 compatible service. It also has clearly identifiable interactions that can meet the requirements of Join and Leave events. However, it also introduces the “Handoff” mechanism, which has no corresponding provisions in the ATN Internet SARPs.

“Handoff” is the process by which an aircraft changes the VDL Mode 2 Ground Station it uses to access the network. A Handoff can be air or ground initiated, and involves an exchange of HDLC Exchange Identity (XID) frames with additional parameters specific to VDL. The Handoff initiator sends a VDL XID variant (the XID_CMD_HO) frame and the responder rejects or accepts the Handoff with an XID_RSP_HO frame. Following successful Handoff, the aircraft “drops” the old Ground Station data link by sending it an HDLC DISC Frame when the Handoff is also between Service Providers. Otherwise, the virtual circuits through the old Ground Station are simply timed out. These procedures are illustrated in Figure 2-1 and Figure 2-2.

Associated with the idea of Handoff is “Subnetwork Connection Maintenance”. Under this procedure, new virtual circuits are established through the new Ground Station, between the aircraft DTE and any ground DTEs (ATN Routers) with which virtual circuits already exist through the old Ground Station. Furthermore, the SNDCF data compression context is transferred from old to new virtual circuits. These new virtual circuits are initiated by the airborne or ground DTE (depending on whether the Handoff was air or ground initiated) and the procedure can take place immediately after the Handoff has taken place (explicit subnetwork connection maintenance) or (and more efficiently) as part of the Handoff XID exchange (expedited subnetwork connection maintenance). The XID_CMD_HO and

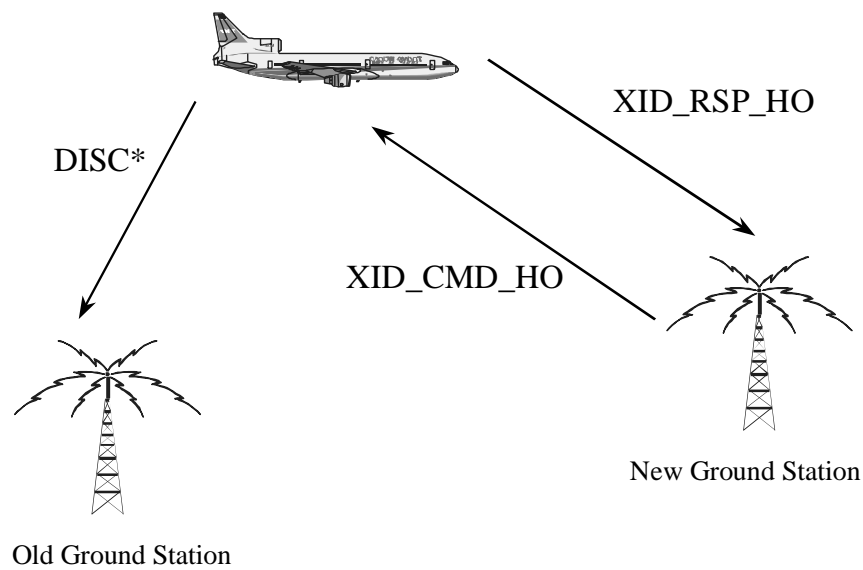
XID_RSP_HO allow the Call Request, Call Confirm packets to be included in the frame and thus to expedite subnetwork connection maintenance.

In the ATN SARPs, the concept of maintaining the data compression state between successive virtual circuits is included in the Mobile SNDCF. However, the procedures for subnetwork connection maintenance, as part of the Handoff procedure, have no corresponding specification in the ATN Internet SARPs. Because of this, an ATN Internet SARPs compliant Router will not necessarily have the capability to support VDL Handoff unless such a capability is explicitly added. The absence of such a specification is a potential SARPs defect.



*Only sent when moving between Service Providers

Figure 2-1 Air-initiated Handoff



*Only sent when moving between Service Providers

Figure 2-2 Ground Initiated Handoff

3. Discussion

There were discussions between the AMCP and the ATNP that led to the inclusion of the concept of “subnetwork connection groups” within the Mobile SNDCF in order to share/pass the compression state between virtual circuits which are themselves between the same pair of DTEs. However, this was not followed through to the issue of subnetwork connection management. A subnetwork such as VDL cannot itself “initiate” a new virtual circuit. Such a request has to come from the user of the subnetwork service which, in this case, is the ATN Router - either Airborne or Air/Ground depending on whether the Handoff is air or ground initiated, respectively.

Logically, the existing Join and Leave events need to be complemented by a “Handoff” event from the subnetwork. The ATN Router’s IS-SME can then react by initiating the subnetwork connection maintenance procedure.

At this stage in the implementation of the ATN, it can be rightly asked whether it is really necessary to introduce a new event. In order to answer such a question, it is necessary to investigate the underlying procedures of both the Join Event and the putative Handoff event in VDL.

3.1 The Join Event

VDL Ground Stations regularly transmit a Ground Station Identification Frame (GSIF). This is a modified HDLC XID frame that identifies the Ground Station, the ATN Routers available through it, and other useful information. An aircraft that is currently without VDL service, scans known VDL frequencies for GSIFs. When a suitable GSIF for VDL service is received, this may be viewed as a Join event. However, the VDL SARPs identify two different procedures for initiating communications over VDL. These are the *Explicit Subnetwork Connection Initiation* and the *Expedited Subnetwork Connection Initiation*, and both need to be investigated.

3.1.1 Explicit Subnetwork Connection Initiation

Under Explicit Subnetwork Connection Initiation, the establishment of virtual circuits across the VDL subnetwork is performed separately from the data link initiation, as illustrated in Figure 3-1.

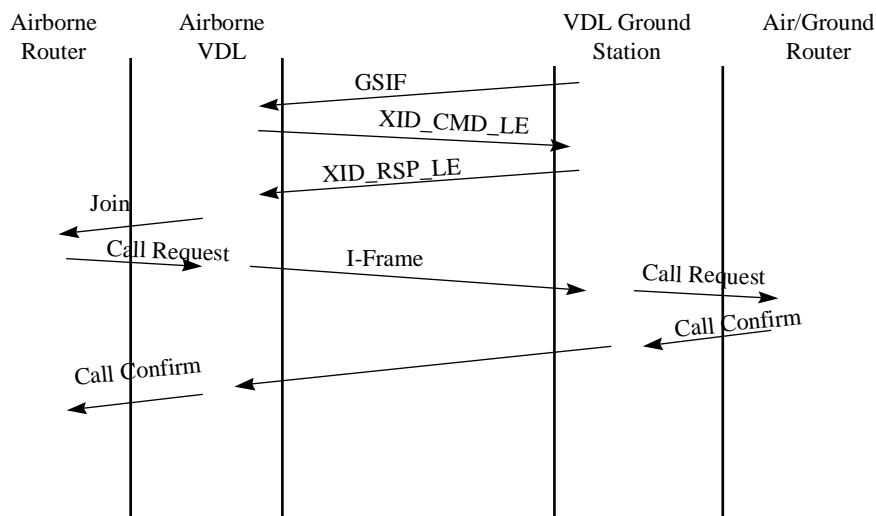


Figure 3-1 Explicit Subnetwork Connection Establishment

Once a GSIF has been received, an exchange of two more modified XID frames is performed to establish the data link. These are the XID_CMD_LE and the XID_RSP_LE. Once an XID_RSP_LE has been received from the Ground Station confirming that the data link is established, a Join Event can be sent to the router reporting the NETs of the ATN Air/Ground Routers available through the Ground Station.

The response to the Join event will be as described in the ATN Internet SARPs for air initiated data links: the Join event is received by the IS-SME, which generates a Call Request addressed to one of the ATN Routers, with the ISH PDU encapsulated in the Call Request User Data. This is transported over the VDL data link in an Information (I) frame, received by the addressed Air/ground Router, which should then respond with a Call Confirm, and so on until the Route Initiation procedures are complete, as described in the ATN Internet SARPs.

3.1.2 Expedited Subnetwork Connection Initiation

The *Expedited Subnetwork Connection Initiation* procedures are designed to optimise bandwidth utilisation by combining virtual circuit establishment with data link initiation, and are illustrated in Figure 3-2

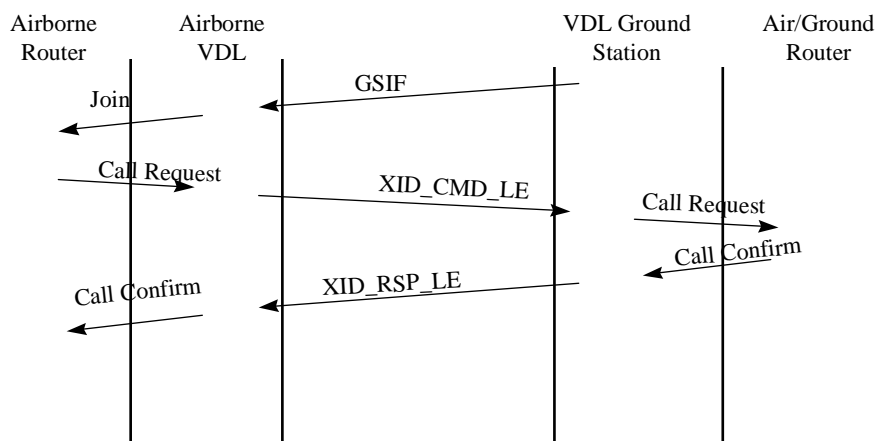


Figure 3-2 Expedited Subnetwork Connection Establishment

Under these procedures, the Join event is generated as soon as a GSIF is received, but without a preceding data link initiation. The IS-SME will still handle the event as described in the SARPs and generate a Call Request. However, this Call Request may be buffered by the VDL subnetwork before it is despatched as part of the data link initiation.

With *Expedited Subnetwork Connection Initiation*, an XID_CMD_LE can contain several Call Requests. A VDL subnetwork, even on board an aircraft, may have several users each receiving a Join event and it should give each user a chance to process the Join event and respond with one or more Call Requests before proceeding with data link initiation. The VDL subnetwork may thus wait until some timer has expired, before continuing. Alternatively, a local interface may be specified with some explicit "Join Event Processing Complete" message that is sent from the VDL user to the VDL subnetwork. Data Link Initiation may then commence as soon as all users that received the Join event have responded with "Join Event Processing Complete".

The XID_CMD_LE is then sent with the Call Request(s) contained within the frame. This is received by the Ground Station, which extracts the Call Request(s) and delivers them to their address destination. It will then wait for the responding Call Confirms or Rejects to be received before including them in the XID_RSP_LE uplinked to the aircraft in response.

Similarly, the aircraft VDL software will extract the Call Confirms/Rejects and pass them to the address local users. Route Initiation will then proceed as described in the SARPs.

3.2 The “Handoff” Event

Once a VDL datalink has been established, it is the responsibility of the subnetwork (e.g. VDL) to measure parameters (e.g. signal strength, network loading, etc.) that determine the quality of service being provided, and to determine when the virtual circuit(s) between a given aircraft and ground DTE need to be routed through a different Ground Station, and to identify that Ground Station. When such a situation occurs, the VDL Handoff procedures are invoked to make the transfer. However, these procedures are not hidden from the user, which has to participate in the establishment of new virtual circuits and the transfer of the Mobile SNDCF Data Compression state from old to new virtual circuits. Handoff thus needs to be reported to the VDL user as a “Handoff”. In an air initiated Handoff, the Handoff event is reported to the airborne DTE while, in a ground initiated Handoff, it is reported either to the Airborne or the Ground DTE.

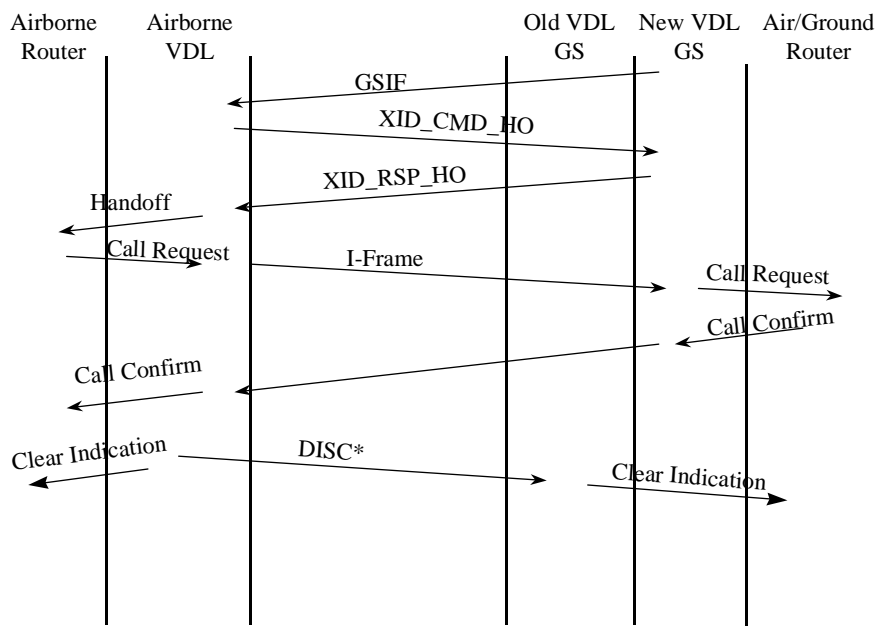
The parameters of a Handoff event will probably be:

- a) The list of DTE Addresses affected
- b) Subnetwork specific information identifying the new data link path (for an airborne DTE, this could be the new Ground Station’s VDL Address, for a Ground DTE, this information would also identify the new Ground Station, perhaps by its DTE address).

As with data link initiation, Handoff has both explicit and expedited procedures known as *explicit subnetwork connection maintenance* and *expedited subnetwork connection maintenance*.

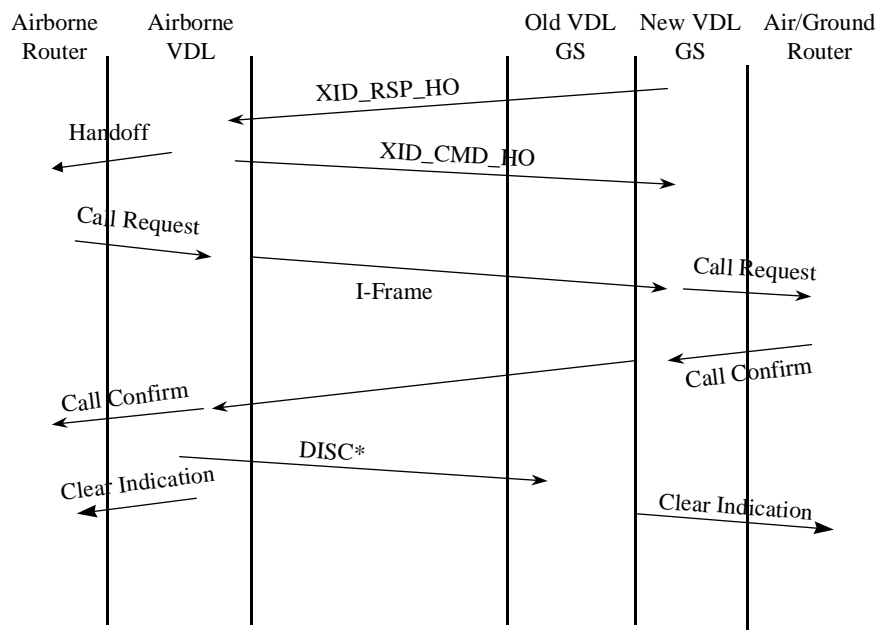
3.2.1 Handoff with explicit subnetwork connection maintenance

Under the “explicit subnetwork connection maintenance” procedures defined in the VDL SARPs, the Handoff event follows the successful exchange of XID frames and comes before the DISC frame is sent to the old ground station (see Figure 2-1 and Figure 2-2). The receiver of the Handoff event responds to it by initiating new virtual circuits to the DTE Addresses identified on the Handoff event and directing them via the appropriate Ground Station, according to local procedures. This is illustrated in Figure 3-3 for air initiated Handoffs and Figure 3-3 for ground initiated Handoffs.



*Only sent when moving between Service Providers

Figure 3-3 Explicit Subnetwork Connection Maintenance (Air Initiated Handoff)



*Only sent when moving between Service Providers

Figure 3-4 Explicit Subnetwork Connection Maintenance (Ground Initiated Handoff)

Note that for Ground Initiated Handoffs, the Handoff event is still processed by the Airborne Router.

If Handoff takes place between Ground Stations operated by two different Service Providers (the LME changes), then a DISC frame is sent by the aircraft to the old Ground Station in order to clear the old virtual circuits. Otherwise, these are simply timed out.

In the former case, there is an issue over co-ordination of the sending of the DISC frame with the successful completion of the Handoff. Starting a timer from the exchange of XIDs and sending the DISC after the timer has elapsed will probably be the best strategy. This has to happen anyway in order to avoid various error conditions and avoids having to have additional interactions. Keeping the datalink with the old Ground Station open for longer than necessary should not cause a serious problem as all data will be routed over the new datalink as soon as it is available and, keeping the old one open for a reasonable period also ensures that data in transit when the Handoff occurred is not lost due to the datalink being cleared down too quickly.

3.2.2 Handoff with expedited subnetwork connection maintenance

With the expedited procedures, the sending of the Handoff event to the subnetwork user must precede the XID exchange. However, the response to the event is the same, that is the subnetwork user will issue Call Requests to the identified DTE addresses and direct them via the identified Ground Station. There will at this time be no data link between the aircraft and that Ground Station. As with expedited subnetwork connection initiation, the Call Requests will therefore have to be buffered by the subnetwork until either all DTE Addresses identified in the Handoff event have Call Requests buffered up or a timer has expired. The XID exchange can then take place, with the Call Requests sent on the XID_CMD_HO.

Before an XID_RSP_HO can be returned, the Call Requests must be forwarded to the identified DTEs and Call Confirms returned and similarly buffered until either all expected

Call Confirms have been received or, again, a timer expires. The `XID_RSP_HO` can then be returned, including the Call Confirms, which are then passed to the initiating DTEs.

As the new virtual circuits are in place as soon as the XID exchange has been completed, the `DISC` can be sent to the old Ground Station soon after the XIDs have been exchanged, or the virtual circuits timed out when Handoff does not change Service Provider.

Note that with Ground Initiated Handoffs, the Ground DTE is required to initiate the new calls. This is so that the Call Requests are sent on the `XID_CMD_HO` and the Call Confirms on the `XID_RSP_HO`. The Ground DTE must therefore, in this one case, be able to initiate virtual circuits.

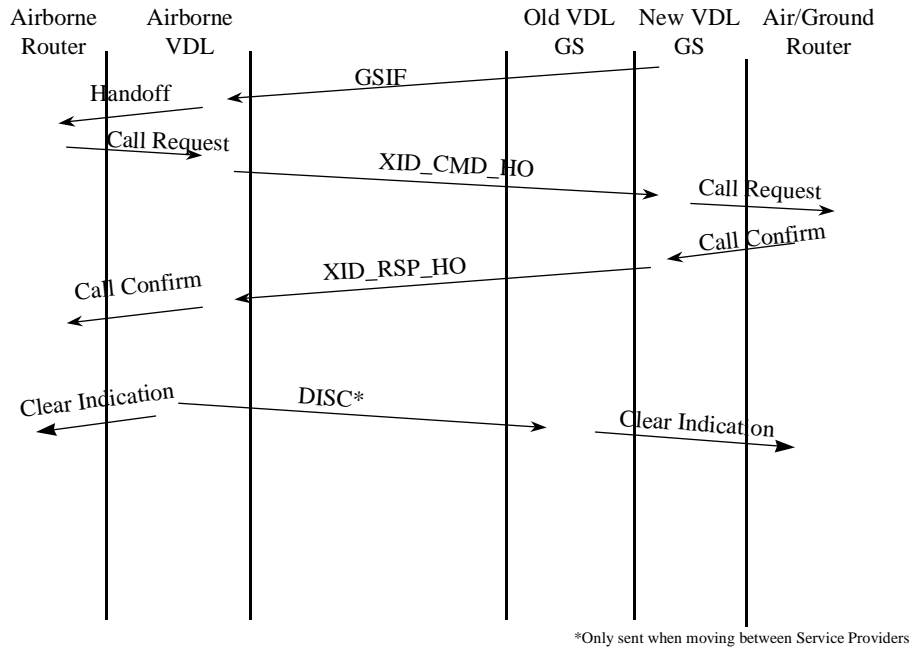


Figure 3-5 Expedited Subnetwork Connection Maintenance (Air Initiated Handoff)

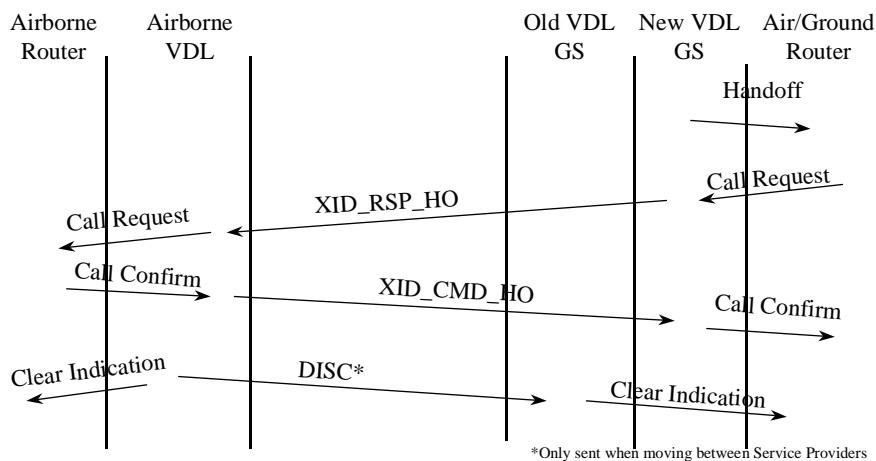


Figure 3-6 Expedited Subnetwork Connection Maintenance (Ground Initiated Handoff)

3.2.3 Transfer of Data Compression Context

In the ATN SARPs specification of the Mobile SND CF, the data compression context will be shared by virtual circuits if they are part of the same subnetwork connection group. The virtual circuits in a subnetwork connection group all share the same called and calling DTE addresses, data compression procedures and priority. A subnetwork connection group is established when a Call Request is received with the M/I bit in its call request header set to one and there is no other virtual circuit between the same DTEs with the same priority and data compression procedures. A virtual circuit is added to an existing subnetwork connection group when a Call Request is received with the M/I bit in its call request header set to one and there is an existing subnetwork connection group comprising one or more virtual circuit(s) between the same DTEs with the same priority and data compression procedures.

Thus, with VDL provided the ATN Router always sets the M/I bit, virtual circuits established during Handoff will match the subnetwork connection group of the existing virtual circuits and the compression context will be passed on.

3.3 Do we need a Handoff Event?

Inspection of the above procedures shows that Handoff is very similar to the response to a Join Event. Under VDL, the initial establishment of new subnetwork connections is always air initiated, but there is still the same basic structure to the procedures. There is *explicit subnetwork connection establishment*, when the Call Request is sent after the XID exchange that performs the initial logon to the VDL subnetwork, and there is *expedited subnetwork connection establishment*, where the Call Request/Confirms and exchanged as part of the XIDs. Essentially the same procedures are followed as with Handoff. However, two key differences can be readily identified:

1. VDL is always air initiated and Ground ATN Routers will not expect to receive Join events from VDL subnetworks. However, Ground ATN Routers will get Handoff events when Ground Initiated Handoffs are in progress and the expedited subnetwork connection maintenance procedures are used.
2. A Join event will provide a list of ATN Routers that can be accessed through a newly available subnetwork. The ATN Router determines the ATN Router it is to communicate with, if any, on this list. On the other hand, the Handoff event identifies the ATN Router(s) - typically only one - that a new virtual circuit must be established with if communication is not to be lost. Its impact is more imperative than that of the Join Event's.

The first issue has a significant impact on Air/Ground Routers which may not have made provision for subnetwork connection initiation procedures. This is a new semantic to those identified in the current ATN SARPs, and which needs to be added.

On the airborne side, the semantic is sufficiently different to warrant a SARPs distinction, but the impact on implementations should not be significant. Every Handoff may also have join event semantics as new ATN Routers may be available through a new Ground Station in addition to those that the aircraft was in contact with, and hence an implementation could reasonably combine the two events.

4. Conclusion

There is a distinct Handoff event that is applicable to VDL and similar air/ground data links, and this event and its semantics should be added to the ATN Internet SARPs. The impact on airborne systems appears to be small and should make clear an area which has been unclear. The omission is more serious for Air/Ground Routers, which formally had no

subnetwork connection initiator role for air initiated networks. With Ground Initiated Handoffs in VDL, this is not the case.