

Doc 9776
AN/970



Manual on VHF Digital Link (VDL) Mode 2

Approved by the Secretary General
and published under his authority

Second Edition — 2015

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Published in separate English, Arabic, Chinese, French, Russian
and Spanish editions by the
INTERNATIONAL CIVIL AVIATION ORGANIZATION
999 University Street, Montréal, Quebec, Canada H3C 5H7

For ordering information and for a complete listing of sales agents
and booksellers, please go to the ICAO website at www.icao.int

First edition 2001
Second edition 2015

Doc 9776, Manual on VHF Digital Link (VDL) Mode 2
Order Number: 9776
ISBN 978-92-9249-681-4

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AMENDMENTS

Amendments are announced in the supplements to the *Publications Catalogue*; the Catalogue and its supplements are available on the ICAO website at www.icao.int. The space below is provided to keep a record of such amendments.

RECORD OF AMENDMENTS AND CORRIGENDA

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FOREWORD

Standards and Recommended Practices (SARPs) for very high frequency (VHF) digital link (VDL) Modes 1 and 2 were developed by the Aeronautical Mobile Communications Panel (AMCP) and introduced in Annex 10, *Aeronautical Telecommunications*, Volumes III and V in 1997 as a part of Amendment 72 to the Annex. References to VDL Mode 1 were removed from the Annex as part of Amendment 76 to Annex 10. The VDL system provides air-ground subnetwork services within the aeronautical telecommunication network (ATN).

During the development of the VDL SARPs and validation activities, the AMCP produced the material contained in this manual.

The purpose of the manual is to provide guidance when implementing VDL Mode 2. This manual is to be used in conjunction with the relevant provisions in Annex 10, Volumes III and V.

Comments on this document would be appreciated from all parties involved in the implementation of aeronautical mobile communication. These comments should be addressed to:

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ACRONYMS AND ABBREVIATIONS

ABM	asynchronous balanced mode
ACK	acknowledge(ment)
ADM	asynchronous disconnected mode
A/G	air-ground
AIHO	Aircraft-initiated handoff
AMCP	Aeronautical Mobile Communications Panel
AMS(R)S	aeronautical mobile-satellite (route) service
AOC	aeronautical operational communication
AOA	ACARS over AVLIC
ARS	administrative region selection
ATC	air traffic control
ATN	aeronautical telecommunication network
ATS	air traffic services
ATSC	ATS communications
AVLC	aviation VHF link control
BCD	binary coded decimal
BER	bit error rate
BIS	boundary intermediate system
CAA	civil aviation administration
CCIR	International Radio Consultative Committee
CLAMN	called line address modification notification
CLNP	connectionless network protocol
CMD	command (frame)
CNS	communication, navigation and surveillance
COTS	connection-oriented transport service
CPU	central processing unit
C/R	command/response (bit)
CSC	common signalling channel
CSMA	carrier sense multiple access
CU	control unit
CW	continuous wave
D8PSK	differentially encoded 8 phase shift keying
DCE	data circuit-terminating equipment
DISC	disconnect (frame)
DLE	data link entity
DLPDU	data link protocol data unit
DLS	data link service
DM	disconnected mode (frame)
DOC	designated operational coverage
DSB-AM	double sideband-amplitude modulation
DTE	data terminal equipment
DXE	denotes either: data terminal equipment, or data circuit-terminating equipment
ES-IS	end systems-intermediate systems
FCS	frame check sequence
FEC	forward error correction
FIB	forwarding information base

FRM	frame reject mode
FRMR	frame reject (frame)
FSL	frequency support list
GI	group identification (field)
GRAIHO	ground-requested aircraft-initiated handoff
GS	ground station
GSIF	ground station information frame
HDLCL	high-level data link control
HIC	highest incoming channel
HO	handoff
HOC	highest outgoing channel
HTC	highest two-way channel
ID	identification (identifier)
IDRP	inter-domain routing protocol
INFO	information (frame)
ISH	intermediate system hello (packet)
ISO	International Organization for Standardization
IS-SME	intermediate system – system management entity
ITU-R	International Telecommunication Union — Radio Communication Sector
IUT	internal uniform timer
LCR	link connection refused
LIC	lowest incoming channel
LLC	logical link control
LME	link management entity
LOC	lowest outgoing channel
lsb	least significant bit
LTC	lowest two-way channel
MAC	media access control
msb	most significant bit
MSC	message sequence chart
MSK	minimum shift keying
NET	network entity title
OSI	open systems interconnection
PDU	protocol data unit
PEC	peer entity contact table
P/F	poll/final (bit)
PN	pseudo noise
Q-bit	qualifier bit
QOS	quality-of-service
REJ	reject (frame)
RF	radio frequency
RGS	remote ground station
RNR	receive not ready (frame)
RP	routing information exchange protocol
RR	receive ready (frame)
RSP	response (frame)
RVC	redirected virtual circuit
SABM	set asynchronous balanced mode
SARPs	Standards and Recommended Practices
SDL	specification and description language
SDU	service data unit
SME	system management entity

SNAcP	subnetwork access protocol
SNDCF	subnetwork dependent convergence function
SNPA	subnetwork point of attachment
SNPDU	subnetwork protocol data unit
SNR	signal to noise ratio
SNSAP	subnetwork service access point
SN-SME	subnetwork – system management entity
SQP	signal quality parameter
SP	service provider
SREJ	multi-selective reject
SRM	sent selective reject mode
SVC	switched virtual circuit
TDMA	time division multiple access
TCP/IP	transport control protocol /internetworking protocol
UA	unnumbered acknowledgement (frame)
UI	unnumbered information (frame)
VDL	VHF digital link
VDLM2	VHF digital link Mode 2
VDR	VHF data radio
VHF	very high frequency
VME	VHF management entity
VSDA	VDL specific DTE addressing
XID	exchange ID (frame)
XOR	exclusive OR

PART I

Implementation aspects

Chapter 1

DEFINITIONS AND SYSTEM CAPABILITIES

1.1 BACKGROUND

The very high frequency (VHF) digital link (VDL) communications system is one of a number of aircraft-to-ground subnetworks that may be used to support data communications across the aeronautical telecommunication network (ATN) between aircraft-based application processes and their ground-based peer processes. The data communications functions, in turn, are supported by the digital communication protocols employed by the VHF data transceiver and supporting avionics of the VDL system.

1.2 COMPATIBILITY

The international aviation community is expected to adhere to the separation of communication functions as specified in the open systems interconnection (OSI) reference model developed by the International Organization for Standardization (ISO). The OSI reference model permits the development of open communications protocols as a layered architecture comprising seven functional separate layers. VDL communications functions are compatible with the OSI model for data communications and constitute the first step toward a fully OSI-compatible protocol stack. The VDL system will provide code transparent communications between ATN conformant systems. Specifically, they are performed by the lower three layers of the OSI model: the physical layer, the data link layer and the lowest sub-layer of the network layer (i.e. the subnetwork layer). Figure I-1-1 presents the VDL system within the ATN protocol architecture.

1.3 GENERAL ARCHITECTURE

1.3.1 In the absence of operational requirements, the VDL Design Guidelines were developed to be used as a baseline document for the VDL system design and as an interface control document for other working groups and panels.

1.3.2 The VDL system is based on the OSI reference model and, therefore, has been designed in a modular fashion which separates the functions of the physical, data link and lower sub-layer of the network layers. The modulation scheme that has been defined for the VDL physical layer can interoperate with the upper layers without affecting the protocol stack.

1.3.3 The aviation VHF link control (AVLC) layer conforms to the high-level data link control (HDLC) as specified by ISO 3309, ISO 4335, ISO 7809 and ISO 8885. However, given that HDLC was designed to primarily support stationary network terminals where bandwidth for the most part is not scarce, the AVLC has been optimized to take into account the fact that the VDL network terminals are in a mobile environment with limited bandwidth available. The VDL subnetwork layer protocol used across the VHF air-ground (A/G) subnetwork conforms to ISO 8208.

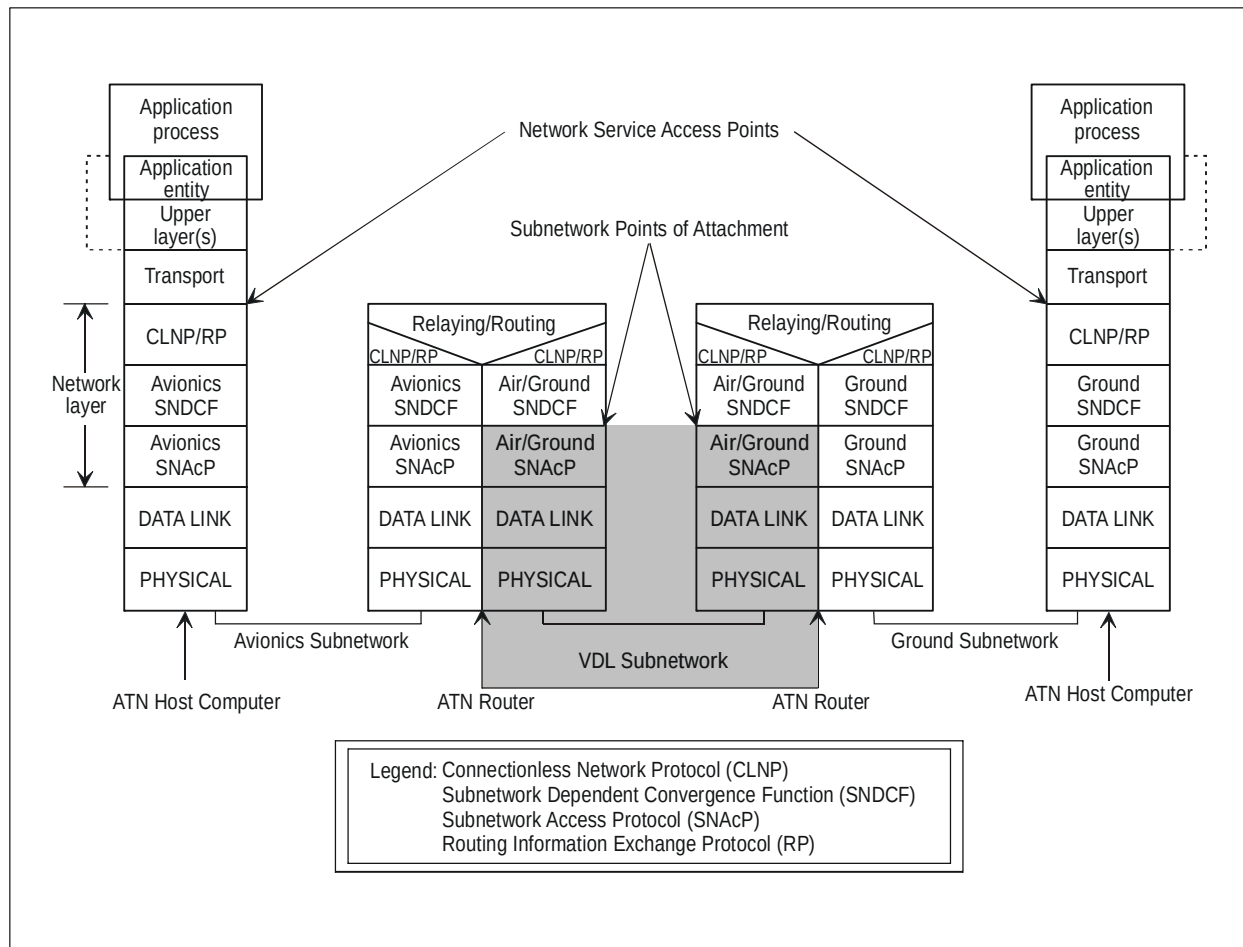


Figure I-1-1. ATN protocol architecture

1.4 GROUND INFRASTRUCTURE OPTIONS

In principle, the VDL SARPs should in no way restrict the ability to choose a particular VDL ground infrastructure based on the specific requirements of the ICAO Member States and various telecommunication institutions. The following scenarios may describe the situation in a State:

- VDL and ATN network operated by the Civil Aviation Administration (CAA)* — only CAA-operated VDL ground stations, connected to CAA router(s), providing at least ATS communications (ATSC);
- VDL and ATN network operated by a commercial services provider* — only ground stations operated by a commercial services provider, supporting aeronautical operational communication (AOC) and, if so required by the local CAA, ATSC, and connected to the service provider router, which may be located in a different State;
- VDL network and ATN network operated by both a commercial services provider and the CAA* — ground stations providing both AOC and ATSC, simultaneously connected to an AOC router (which may be outside the State) and to a CAA router (within the State); and

- d) *VDL and ATN network operated by both a commercial services provider and the CAA* — CAA ground stations (for ATSC) and commercial service provider ground stations (for AOC), operating within the same designated operational coverage.

1.5 INTEROPERABILITY

The VDL communications functions will provide subnetwork services so that interoperability among subnetworks can be maintained. Interoperability allows an application process to send or to receive data messages over any of the available subnetworks without having to select a particular subnetwork or to know which subnetwork is being used for a particular message. These other subnetworks might include, but are not limited to, aeronautical mobile-satellite (route) service (AMS(R)S), Mode S data link, HF data link, VDL Mode 3 and VDL Mode 4.

1.6 SUBNETWORK SELECTION

The choice of the specific subnetwork to be used is a function of the quality-of-service (QOS) requested by the application, the QOS of the available subnetworks and the specific user and network provider policies.

1.7 FREQUENCY MANAGEMENT

Frequency management is a cooperative effort between the ground network and the aircraft. Ground service providers dynamically assign operational frequencies within a particular airspace to resolve factors beyond the control of the aircraft. The resulting system is able to adjust frequencies freely to account for designated operational coverage (DOC), air traffic control (ATC) sector boundaries, ATN administration domains and local traffic conditions.

1.8 COMMON SIGNALLING CHANNEL

The designation of a common signalling channel (CSC) provides a ready means for an aircraft first to log on to the system. When coverage exists in an area, it will always exist at least on the CSC. Once a connection is established on the CSC, an aircraft can be returned to any discrete frequency within the assigned frequency range. The CSC also may be utilized as a common channel, when there is an emergency, or as a default channel whenever communication is lost; when traffic is light in an area, it may be used as a normal data channel.

1.9 NAMING CONVENTION

The following leading identifiers are used to identify with which protocol sub-layer a primitive or protocol entity is associated:

<i>Protocol sub-layer</i>	<i>Single-letter identifier</i>	<i>Two-letter identifier</i>
Physical layer	P	PH
Media access control sub-layer	M	MA
Data link sub-layer	D	DL
Link management entity sub-layer	G	LM
Subnetwork layer	S	SN

1.10 SUB-LAYER RELATIONSHIP

Figure I-1-2 shows the relationship between the sub-layers, including the primitives which flow between the sub-layers. The primitives outlined in Figure I-1-2 are also outlined in the Appendix to Part 1 of this manual in the form of message sequence charts (MSC) which depict the sequence of events for the key VDL processes such as:

- a) VHF subnetwork initiation process (explicit subnetwork connection);
- b) VHF subnetwork explicit subnetwork handoff (HO);
- c) VHF subnetwork expedited subnetwork HO; and
- d) VHF subnetwork termination process.

1.11 EXTERNAL INTERFACES

The external interfaces to the VDL are noted by connections between a module and the containing box. The leading identifier of the connection names the transmitting entity:

<i>Protocol sub-layer</i>	<i>Identifier</i>
Subnetwork dependent convergence facility	N
Broadcast subnetwork dependent convergence facility	B
Internetworking services system management entity	IS
Exceptions processing entity	E
Radio frequency	RF

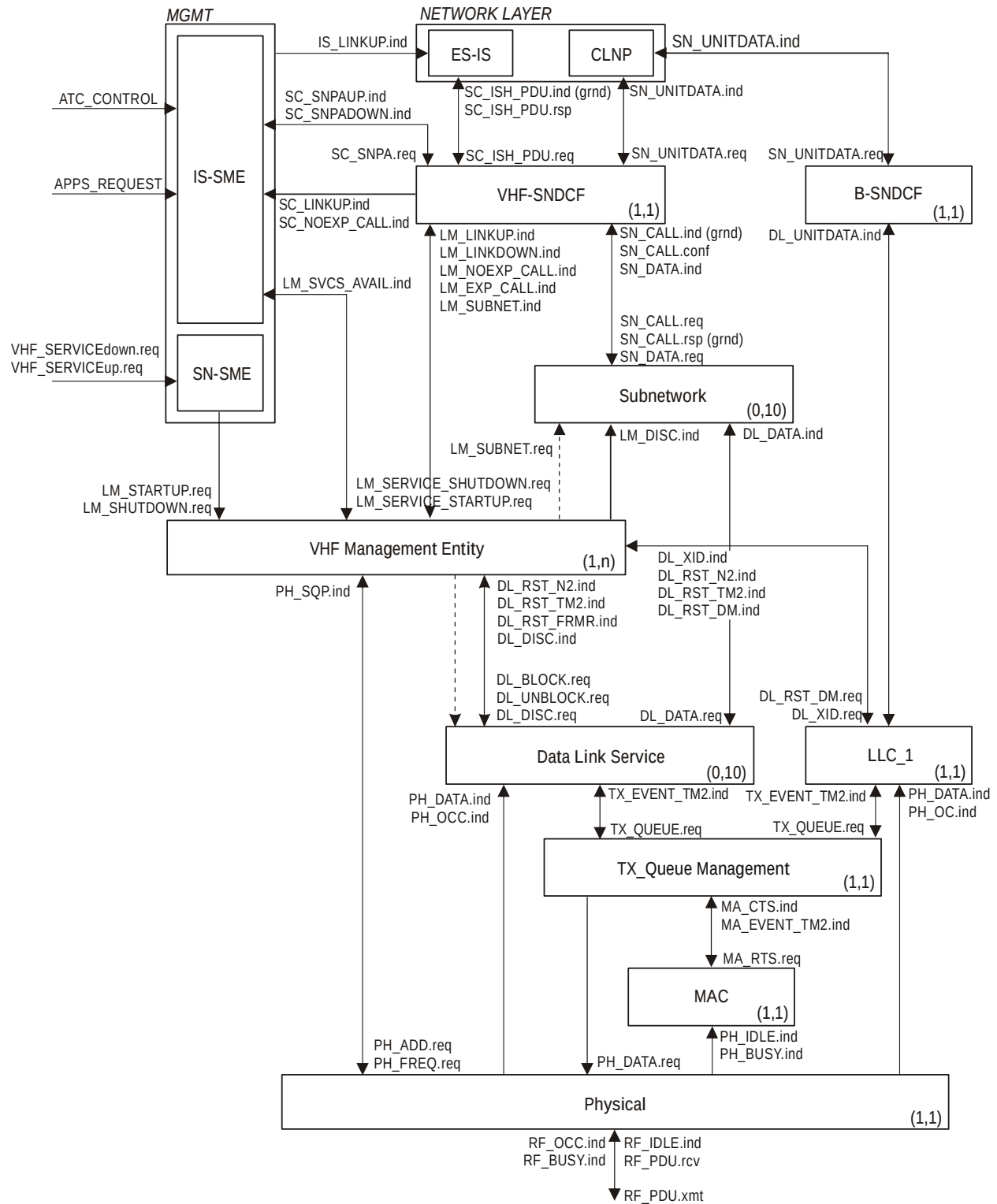


Figure I-1-2. Primitive flow diagram

Chapter 2

PHYSICAL LAYER PROTOCOLS AND SERVICES

2.1 INTRODUCTION

2.1.1 The physical layer provides services to activate, maintain and de-activate connections for bit transmission in the data link layers. The following service elements are the responsibility of the physical layer:

- a) activation of the transmission channel;
- b) establishment of bit synchronization;
- c) physical data transmission by an appropriate radio system;
- d) channel status signalling;
- e) fault condition notification;
- f) local network definitions; and
- g) service quality parameters.

2.1.2 Data link layer user data is passed to the physical layer on primitives. Data link user data received by the physical layer entity from a remote physical layer entity via the VHF medium is passed up to the data link layer on a primitive. Any indications required for diagnostic or error conditions are passed between these layers on service primitives.

2.2 FUNCTIONS

2.2.1 Transceiver control

Frequency selection will be performed upon requests passed on from the link layer. Transmitter keying will be performed on demand from the data link layer to transmit a frame.

2.2.2 Notification services

Signal quality indication will be performed on the demodulator evaluation process using parameters such as phase distortion, coherence and signal-to-noise measurements and on the receive evaluation process using parameters such as signal strength, carrier detect and output power.

2.2.3 Transmission characteristics for VDL Mode 2

2.2.3.1 **VDL Mode 2 modulation.** Differentially encoded 8 phase shift keying (D8PSK) may be produced by combining two quadrature radio frequency (RF) signals which are independently suppressed carrier amplitude modulated by baseband filtered impulses. The baseband impulse filters have a frequency response with the shape of a raised cosine with an excess bandwidth factor equal to 0.6. This characteristic allows a high degree of suppression of adjacent channel energy, with performance dependent only upon hardware implementation of the modulating and amplification circuits.

2.2.3.1.1 **Multi-phase encoding.** The VDL Mode 2 modulation scheme will use the Gray Coding method to map or assign the 3-bit information bits into one of the eight possible phases. Gray Coding is one in which adjacent phases differ by one binary digit as illustrated in Figure I-2-1. The most likely errors caused by noise involve the erroneous selection of an adjacent phase to the transmitted signal phase; by using the Gray Coding method only a single bit error occurs in the 3-bit sequence.

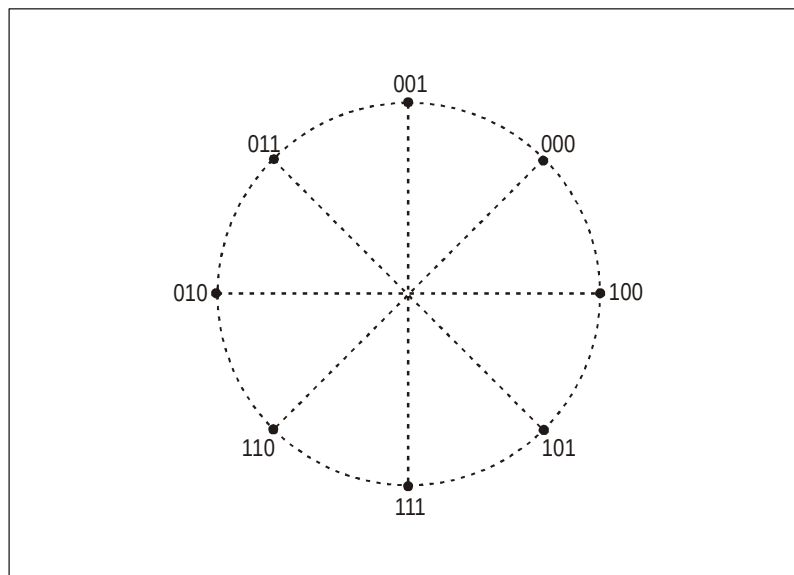


Figure I-2-1. Phase diagram of D8PSK with gray coding

2.2.3.1.2 **VDL Mode 2 rate.** Future modes of VDL that incorporate time division multiple access (TDMA) schemes may employ the baseband symbol clock to maintain timing for media access. In this case, it is expected that ground equipment supporting TDMA schemes will require a tolerance in the baseband symbol clock of at least ± 0.001 per cent.

2.2.3.2 **Forward error correction (FEC).** The systematic, lightweight Reed-Solomon code selected is simple to code and can be decoded with progressively more complicated decoding techniques as shown by Table I-2-1.

Table I-2-1. FEC coding gain

<i>Decoding technique</i>	<i>Coding gain</i>	<i>Complexity</i>
none	0 dB	trivial to skip code bits
hard-decision	1.5 dB	COTS chipsets to perform decoding algorithm available
soft-decision	4 dB	CPU power required to perform decoding not feasible with 1994 technology

2.2.3.3 **Functional block diagram.** Figure I-2-2 shows a functional block diagram for VDL Mode 2 message encoding.

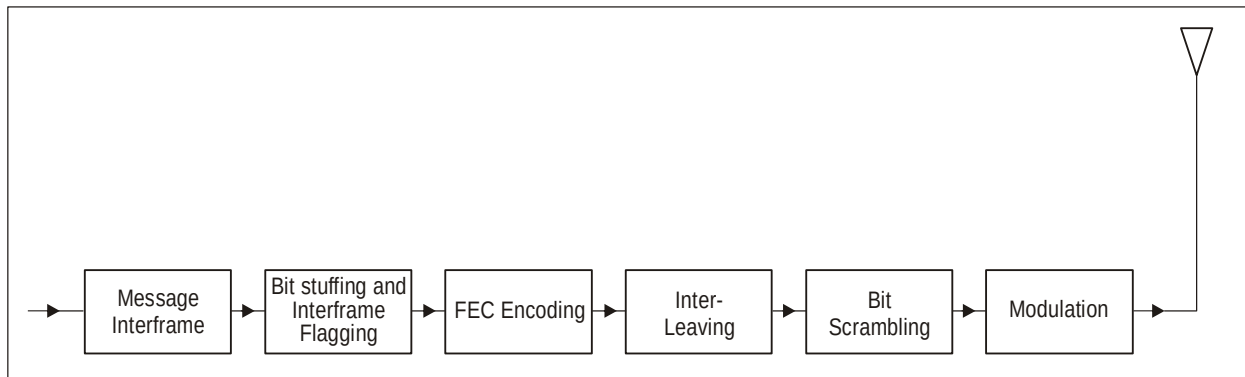


Figure I-2-2. Message encoding block diagram

2.2.3.4 Training sequence for VDL Mode 2

2.2.3.4.1 **Unique word.** In an environment with an E_b/N_0 of 13 dB (a bit error rate (BER) of 10^{-3}), a synchronizer using sixteen samples per symbol and a desired probability of false alarm of 10^{-10} will have a probability of missed synchronization of 10^{-8} .

2.2.3.4.2 **Header FEC.** The block code is capable of correcting all 1-bit errors and detecting, but not correcting, about 25 per cent of the possible 2-bit errors.

2.2.4 Channel sense algorithms

2.2.4.1 When running a carrier sense multiple access (CSMA) algorithm prior to transmitting data or packetized voice, the VDL Mode 2 receiver can determine if the channel is idle by using an energy sensing algorithm. However, because the local noise floor is not a constant, an estimator is needed. This section provides an example of one possible estimator.

Note.— The MAC sub-layer declares the channel idle after the channel sense algorithm reports that the received signal power level has crossed below the busy threshold.

2.2.4.2 Channel quiescent value. Whenever the VDL Mode 2 is not transmitting or receiving a message, the VDL calculates a channel quiescent value, T_b , according to the following algorithm:

$$T_q[n+1] = \begin{cases} T_q[n] + k(L, T_q[n]) (L - T_q[n]), & L \leq T_{\max} \\ T_{\max}, & \text{otherwise} \end{cases}$$

where

L is the rms received signal level in hard μ volts calculated over the preceding 1 ms;
 $T_{\max}$ is a value in the range of 15 to 30 hard μ volts (exact calibration is not necessary);
 $T_q[n]$ is the estimate of the noise floor at time n ;

and

$$k(L, T_q) = \max(0.01^{(L/T_q)}, 1/16384)$$

Note.— The non-linear function $k()$ is designed to quickly adjust to a reduced noise level and to slowly adjust to an increased level.

2.2.4.3 Channel busy threshold. The channel busy threshold, T_b , is defined as $1.4 T_q$. The channel is declared idle until the rms received signal value, L , exceeds T_b . Then the channel is declared busy and the channel sense algorithm is suspended while synchronization is attempted.

2.2.4.4 Synchronization. If synchronization is not achieved (i.e. the unique word is not detected) within 2.5 milliseconds, then a new value is taken for the rms received signal level, L , and processed to yield the channel quiescent value, T_q , and the channel sense determination.

2.2.4.5 Receiver/transmitter interactions. The receiver/transmitter interactions are given in Figure I-2-3.

Note.— The attack and delay characteristics are not shown to scale.

2.3. PHYSICAL LAYER SYSTEM PARAMETERS

The minimum transmission length that a receiver is capable of demodulating without degradation of BER for VDL Mode 2 is 131 071 bits. However, this is the maximum length expected to be transmitted.

$$P1_{\text{Mode 2}} = [2^{17} - 1] = 131\,071 \text{ bits.}$$

The VDL Mode 2 transmission length is more than the maximum transmission length of seven frames and only applies to the ground system that can uplink frames to more than one aircraft in one transmission.

2.4 INTERFACE TO UPPER LAYERS

Note.— Primitives associated with the VDL Mode 2 are as detailed in 2.4.1 through 2.4.6.

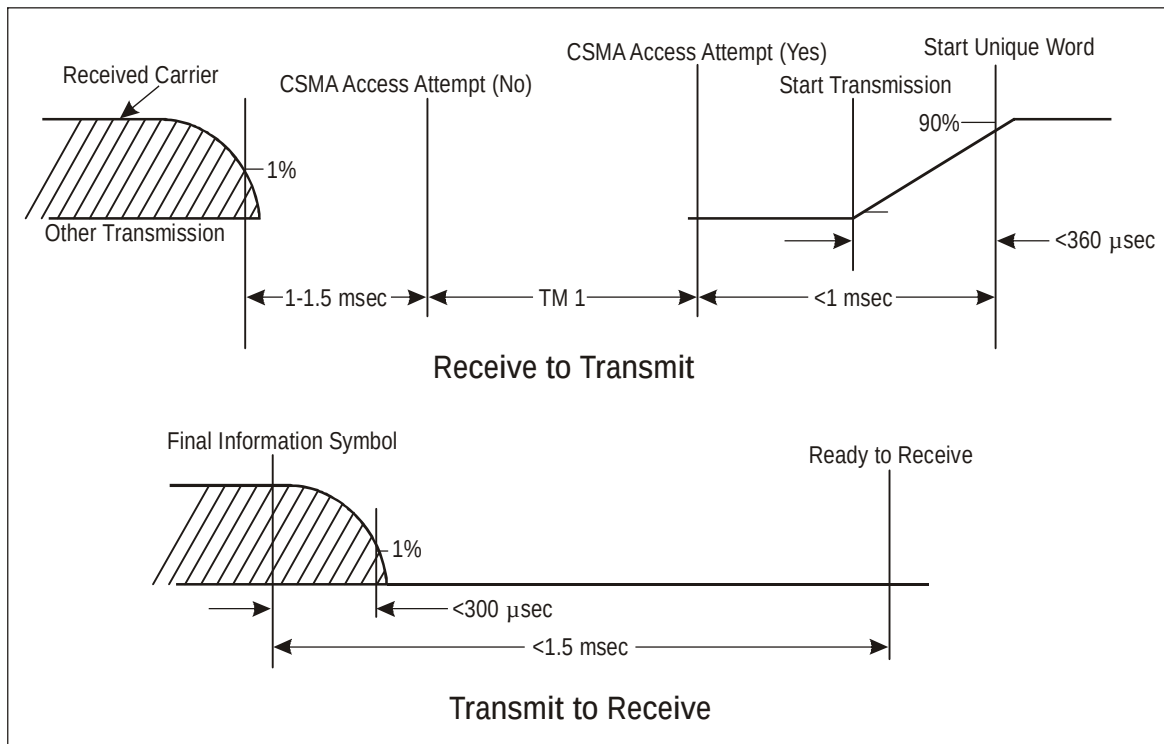


Figure I-2-3. Turnaround time requirements

2.4.1 Data

The PH_DATA primitives are passed between the data link service (DLS) sub-layer and the physical layer to transfer user information between entities. The following primitives are associated with this service:

PH_DATA.request
PH_DATA.indication

2.4.1.1 Request. PH_DATA.request is the service request primitive for the data transfer service. This primitive is generated by the DLS sub-layer and passed to the physical layer to request user data transmission. The receipt of this primitive by the physical layer causes the physical layer to transmit user data.

Parameters: User data parameter (mandatory (M)) (contains physical layer service data unit [SDU]).

2.4.1.2 Indication. PH_DATA.indication is the service indication primitive for the data transfer service. This primitive is generated by the physical layer and passed to the DLS/LLC-1 sub-layer to transfer received user data.

Parameters: User data parameter (M) (contains physical layer SDU).

2.4.2 Change frequency and mode

PH_FREQ.request is the service request primitive for the frequency request service. This primitive is generated by the link management entity (LME) sub-layer and passed to the physical layer. The receipt of this primitive by the physical layer causes the local physical layer to select the VHF frequency and mode requested by the PH_User.

Parameters: Desired frequency (M)
 Desired mode (M)

2.4.3 Channel sense

2.4.3.1 The following primitives are passed from the physical layer to the media access control (MAC) sub-layer to support the CSMA algorithm:

PH_BUSY.indication
PH_IDLE.indication

2.4.3.2 **Busy.** PH_BUSY.indication is the service indication primitive for the busy detection service. This primitive is generated by the physical layer and passed to the MAC sub-layer whenever the channel transitions from idle to busy.

2.4.3.3 **Idle.** PH_IDLE.indication is the service indication primitive for the idle detection service. This primitive is generated by the physical layer and passed to the MAC sub-layer whenever the channel transitions from busy to idle.

2.4.4 Signal quality

PH_SQP.indication is the service indication primitive for the signal quality service. This primitive is generated by the physical layer and passed to the LME sub-layer to indicate the signal quality of the current transmission. This primitive is generated usually once per received transmission and applies to the entire transmission.

Parameters: Signal quality parameter (M)
 Source station address parameter (M)

2.4.5 Peer address

PH_ADD.indication is the service indication primitive from the LME sub-layer to the physical layer to indicate the link address of a peer station. The physical layer will use this information to filter and route the incoming frames to the appropriate DLS entity. This primitive is generated whenever a link is established or disconnected.

Parameters: Source station address parameter (M)
 Source station related DLS process ID (M)

Note.— A process ID of null will indicate that the associated link has been disconnected.

2.4.6 Channel occupancy

2.4.6.1 PH_OCC.indication is the service indication primitive for channel occupancy service. This primitive is generated by the physical layer and passed to the DLS/LLC /LME to indicate the channel occupancy which will be used to compute the retransmission interval. This primitive is generated periodically with a value between 0 and 1.

2.4.6.2 The following is an example of one control unit (CU) calculation approach that can be used:

CU can be calculated in the transceiver by sampling the channel to determine occupancy every 1 second averaged over the past 100 seconds. CU can range in value from 0 to 1 with 1 corresponding to a channel that is 100 per cent occupied. The channel is considered to be occupied if either the transceiver or another station is determined to be transmitting at the time the sample is taken.

Parameters: Channel occupancy (M)

2.5. INTERFACE TO PHYSICAL PROCESSES

Note.— Primitives associated with the VDL Mode 2 are as detailed in 2.5.1 and 2.5.2.

2.5.1 Data

The RF_PDU primitives are passed between the physical layer and the physical processes to transfer user information between entities. The following primitives are associated with this service:

RF_PDU.xmt
RF_PDU.rcv

2.5.1.1 **Transmit.** RF_PDU.transmit is the service transmit primitive for the data transfer service. This primitive is generated by the physical layer to transmit user data.

Parameters: User data parameter (M)

2.5.1.2 **Receive.** RF_PDU.receive is the service receive primitive for the data transfer service. This primitive is received by the physical layer when receiving data.

Parameters: User data parameter (M)

2.5.2 Channel sense

The RF primitives are passed between the channel occupied detection algorithms and the physical layer to indicate the current state of the RF transmission media. The following primitives are associated with this service:

RF_BUSY.indication
RF_IDLE.indication
RF_OCC.indication

2.5.2.1 **Busy.** RF_BUSY.indication is the service busy indication primitive for the channel sensing service. This primitive is received by the physical layer when the channel becomes occupied.

2.5.2.2 **Idle.** RF_IDLE.indication is the service idle indication primitive for the channel sensing service. This primitive is received by the physical layer when the channel becomes idle.

2.5.2.3 **Channel occupancy.** RF_OCC.indication is the service idle indication primitive for the channel occupancy service. This primitive is received by the physical layer and is a measurement of the channel occupancy.

2.6 SDL DESCRIPTION

The SDL description for the physical layer is in Figure I-1-2.

2.7 STATES

The physical layer is stateless.

Chapter 3

LINK LAYER PROTOCOLS AND SERVICES

3.1 GENERAL INFORMATION

3.1.1 The link layer is responsible for transferring information from one network entity to another, for announcing errors encountered during transmission and for providing the following services:

- a) assembly and disassembly of frames;
- b) establishment of frame synchronization;
- c) rejection of non-standard frames;
- d) detection and control of frame errors;
- e) selection of RF channels;
- f) recognition of addresses;
- g) initiation of receiver muting; and
- h) generation of the frame check sequence.

3.1.2 The link layer provides the basic bit transmission service over the RF channel. Data at the link layer is transmitted as a bit stream in a series of frames exchanged between the aircraft transceiver and the ground-based radio elements.

3.2 MEDIA ACCESS CONTROL (MAC) SUB-LAYER

3.2.1 MAC functions

3.2.1.1 **P-Persistent CSMA.** While the channel is idle, a station with a packet to send transmits with probability p , and waits for $TM1$ seconds before trying again with probability $1 - p$. If the channel becomes busy during the wait, the $TM1$ timer is cleared and the system again waits for the transmission to terminate.

3.2.1.2 **Maximum wait time.** In order to ensure a finite wait time, a maximum number of access attempts will be made. For a given value of p and the desired cumulative probability, v , $M1$ can be computed by $M1 = \lceil \log(1 - v) / \log(1 - p) \rceil$. The default values for $M1$ have been chosen so that $v = 0.999$, or that 99.9 per cent of all transmissions will occur before $M1$ attempts have been made.

3.2.1.3 **Inter-access delay.** The value of $TM1$ is set to the interval between when one station decides to transmit and every other station can detect that transmission. Therefore, this value is constructed by summing the receive-

transmit turnaround time, the transmitter attack time, the maximum propagation delay time and the idle-busy channel sense detect time.

3.2.1.4 **Timers.** Table I-3-1 summarizes the timers used in the MAC sub-layer.

Table I-3-1. MAC sub-layer timers

Timer	Started	Cancelled or restarted	Action upon expiration
TM1	By random backoff algorithm after access failure	Cancelled when channel becomes busy	Attempt to gain access to the channel
TM2	On request to transmit	Cancelled upon transmission	Begin frequency recovery LME function

3.2.1.4.1 Figure I-3-1 provides an overview of the VDL Mode 2 MAC timers as well as the MAC processes which are executed when a station is attempting to access the VHF channel.

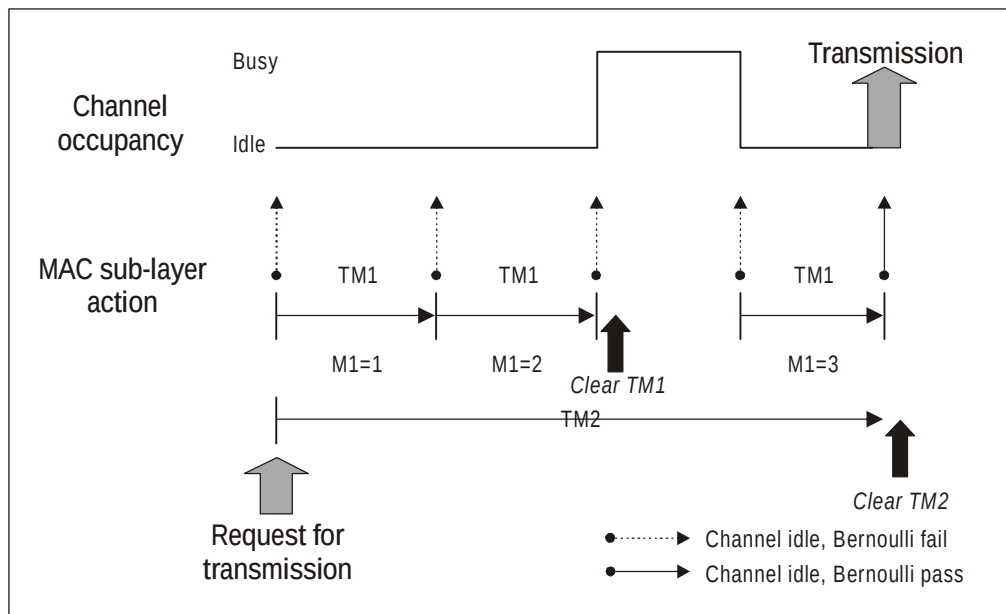


Figure I-3-1. MAC process

3.2.2 Interface to the upper layers

Note.— The primitives defined for the MAC layer are detailed in 3.2.2.1 to 3.2.2.2. Note that primitives to control MAC parameters negotiable via exchange identifications (XIDs) are not included.

3.2.2.1 **Transmission authorization.** Two primitives are passed between the MAC sub-layer and the DLS sub-layer to support the transmission of frames:

MA_RTS.request
MA_CTS.indication

3.2.2.1.1 *Request to send.* MA_RTS.request is the service request primitive for the transmission authorization service. This primitive is generated by the DLS sub-layer and passed to the MAC sub-layer to request permission to activate the physical transmission channel.

3.2.2.1.2 *Clear to send.* MA_CTS.indication is the service indication primitive for the transmission authorization service. This primitive is generated by the MAC sub-layer and passed to the DLS sub-layer to grant authorization for a single transmission.

3.2.2.2 **Channel congestion.** One primitive is used by the channel congestion service to indicate that the channel has become congested and that recovery mechanisms should be invoked:

MA_EVENT_TM2.indication

3.2.2.2.1 *Busy channel indication.* The MA_EVENT_TM2.indication is the service primitive for the channel congestion service. This primitive is sent by the MAC sub-layer to the DLS and logic link control - Type 1 (LLC_1) sub-layer when the TM2 timer expires indicating a busy channel.

3.2.3 Specification and description (SDL) language

Note.— The SDL description for the MAC sub-layer is in Figure I-1-2.

3.2.3.1 **States.** There are four states in the MAC sub-layer and these are shown in Figure I-3-2.

3.2.3.1.1 *Idle.* The MAC sub-layer is in the **idle** state when the RF channel is clear and there are no outstanding requests to transmit.

3.2.3.1.2 *Busy.* The MAC sub-layer is in the **busy** state when the RF channel is busy and there are no outstanding requests to transmit.

3.2.3.1.3 *Pending.* The MAC sub-layer is in the **pending** state when the RF channel is clear and there are outstanding requests to transmit.

3.2.3.1.4 *Waiting.* The MAC sub-layer is in the **waiting** state when the RF channel is busy and there are outstanding requests to transmit.

3.3 DATA LINK SUB-LAYER

3.3.1 Architecture

3.3.1.1 The data link entities (DLE), which provide connection-oriented point-to-point links with peer DLEs, exist within the data link sub-layer. The DLE in effect is the data link state machine which implements the aviation VHF link control (AVLC) protocol (i.e. connection-oriented and connection-less functions) as well as the transmit queue functions.

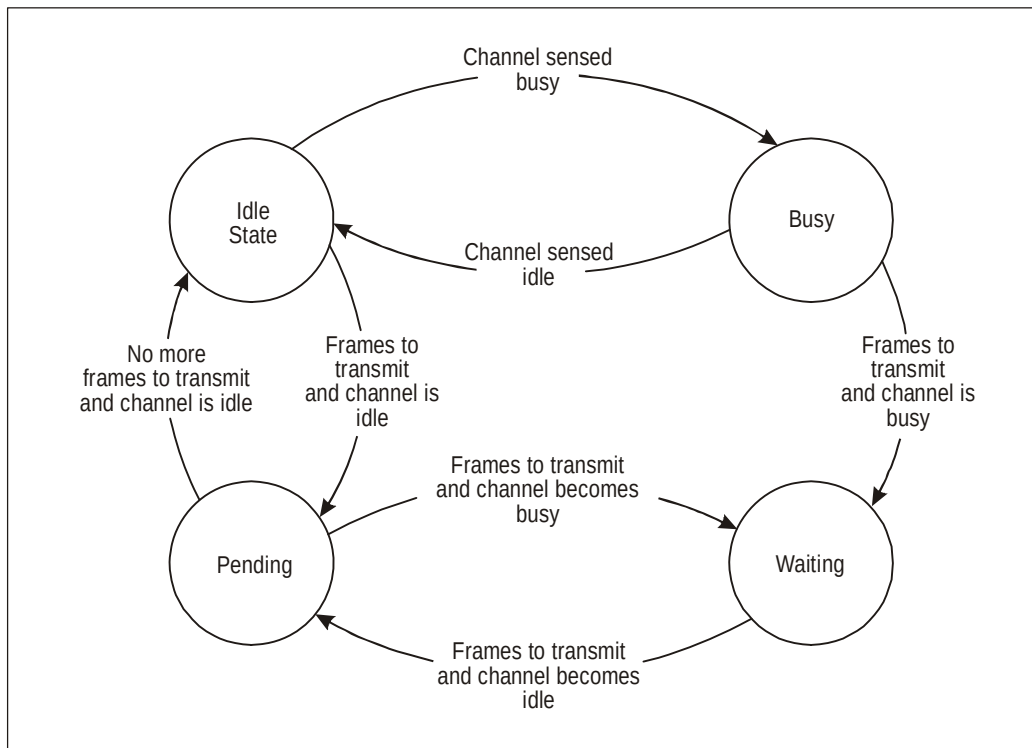


Figure I-3-2. MAC state diagram

3.3.1.2 The link management entity (LME), which acquires, establishes and maintains a link connection with its peer LME, exists within the VHF management entity (VME). One VME exists for each airborne and ground system. Figure I-3-3 provides an overview of the data link layer with its related sub-layers and entities.

3.3.1.3 A ground system is composed of, but not limited to, VHF ground stations, a ground network providing connectivity with the ATN routers and a VME which manages the VDL Mode 2 aircraft having link connections with the ground system. The ground VME will create one LME for every aircraft that is “logged-on” to the VDL Mode 2 ground system and similarly, the airborne VME will create one LME for each ground system with which it is communicating. These peer LMEs will use the information provided by the received XIDs (e.g. lat/long position parameter, airport destination, acceptable alternate ground stations, etc.) and other information sources (e.g. transceiver’s signal quality/strength of received frames) to establish and maintain reliable links between the aircraft and the VDL Mode 2 ground system.

3.3.1.4 In Figure I-3-4, the two aircraft have each one link with the same ground station which also supports broadcast services. The station LLC-1 entity also exists within the respective DLS and is responsible for processing the connection-less datagrams received from a peer broadcast entity.

3.3.1.5 In a one ground system scenario (i.e. the aircraft is in the coverage area of one VDL Mode 2 data link service provider) the aircraft station will have at most two active DLEs at any one time. This will only occur when the aircraft is in the process of performing a handoff between the existing ground station and a new ground station. The handoff procedures are outlined in section 5.2.3.

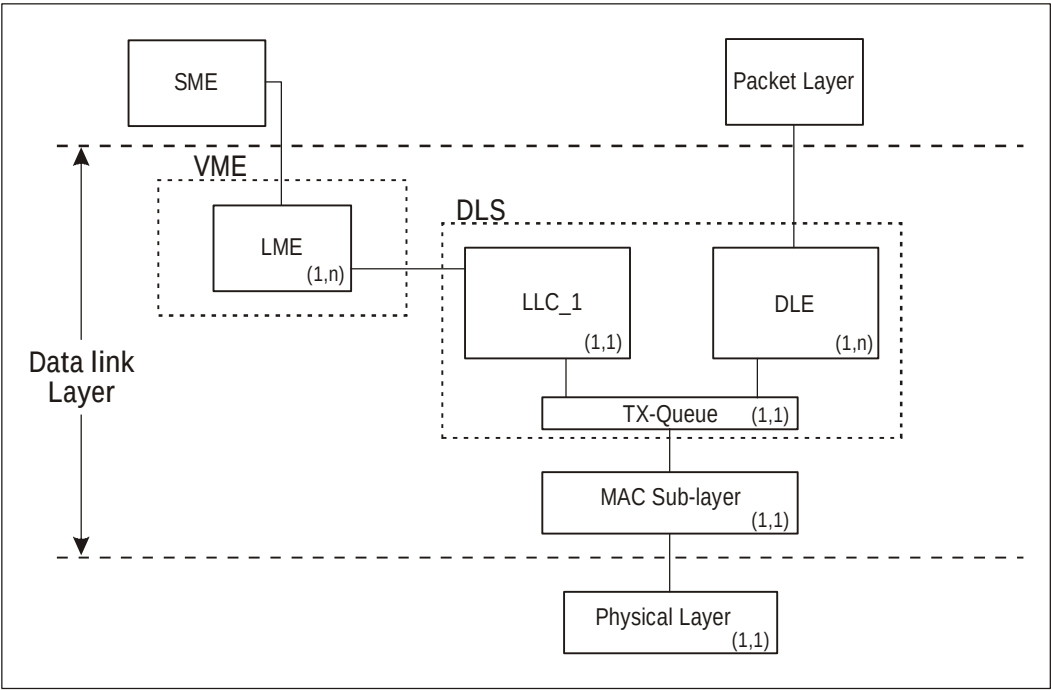


Figure I-3-3. Data link layer overview

3.3.1.6 Figure I-3-5 provides a system overview of the VME, LME and DLS concept by using an aircraft that has link connections with two different VDL Mode 2 ground systems. The ground infrastructure depicted below may be viewed as showing that link #1 using service provider #1 provides concurrent subnetwork connectivity to both an ATC and AOC routers, whereas link #2 over service provider #2 provides subnetwork connectivity to only one router.

3.3.1.7 Using the example in Figure I-3-5, the following link management entities have been created in the airborne and ground systems in order to support this specific ground infrastructure:

NUMBER OF VMEs	airborne: 1 ground: 1 each (total of 2)
COMMENTS: The airborne and ground systems have only one VME each to manage all VDL links.	
NUMBER OF LMEs	airborne: 2 ground: 1 each (total of 2)

COMMENTS: Two LMEs exist within the airborne VME and have been created to manage the VDL Mode 2 links #1 and #2. Subsequently, ground systems #1 and #2 have also created one LME each to control and manage this aircraft.	
NUMBER OF DLEs	airborne: 2 ground: 1 each (total of 2)
COMMENTS: For each LME there exists one DLE (except during handoffs). Airborne DLEs #1 and #2 support the AVLC protocol with ground DLEs #1 and #2. Ground DLE #1 exists within the ground station with which the aircraft has established a link (ground system #1). Similarly, ground DLE #2 exists within the ground station with which the aircraft has established a link (ground system #2).	
TOTAL NUMBER OF SWITCHED VIRTUAL CIRCUITS (SVCs)	Between airborne DTE and ground ATN routers: 3
COMMENTS: There are two subnetwork connections established between the airborne DTE and the ATN routers 1A and 1B over the pair of DLE #1. In addition, there is one subnetwork connection residing over the pair of DLE #2 which provides a subnetwork connection between the aircraft and the ATN router 2.	

3.3.2 Functions

3.3.2.1 Retransmission algorithm. The link layer uses an adaptive retransmission algorithm. This algorithm is comprised of two elements: measuring the transmission delay (which can be used to determine the minimum retransmission time) and an exponential backoff (which provides damping when the channel becomes congested and reduces the effects of miscomputed transmission delay measurements).

3.3.2.1.1 Transmission delay measurement. The transmission delay is measured from two input events: the channel utilization measurement provided by the physical layer (which will be used to calculate the 99th percentile of successfully accessing the channel) and the time to receive an acknowledgement for an unretransmitted frame (i.e. the time for the peer entity to access the channel). This algorithm, based on the algorithm used in the transport control protocol/internetworking protocol (TCP/IP), uses two registers to compute a likely upper bound for the transmission delay, *avg_est* (estimate of the average) and *mdev_est* (estimate of the mean deviation). Note that *avg_est* and *mdev_est* are scaled versions of the actual values and that only integer computations are needed. The C code for the algorithm is as follows:

```
measurement -= (avg_est >> 3);  
avg_est += measurement;  
if ( measurement < 0)  
measurement = -measurement;  
measurement -= (mdev_est >> 2);  
mdev_est += measurement;  
trans_delay = ((avg_est >> 2) + mdev_est) >> 1.
```

Note.— This algorithm is documented in Jacobson, Van, "Congestion Avoidance and Control", ACM Sigcomm '88, August 1988, pages 314-329. Mean deviation is used instead of the standard deviation because it is much quicker to compute but gives very similar results.

3.3.2.2 **Acknowledgement process and transmission queue management.** In order to improve the VDL Mode 2 acknowledgement process as well as to minimize the retransmission period which ultimately affects the protocol recovery period, special considerations were given to the frame rejection and T1 timer processes.

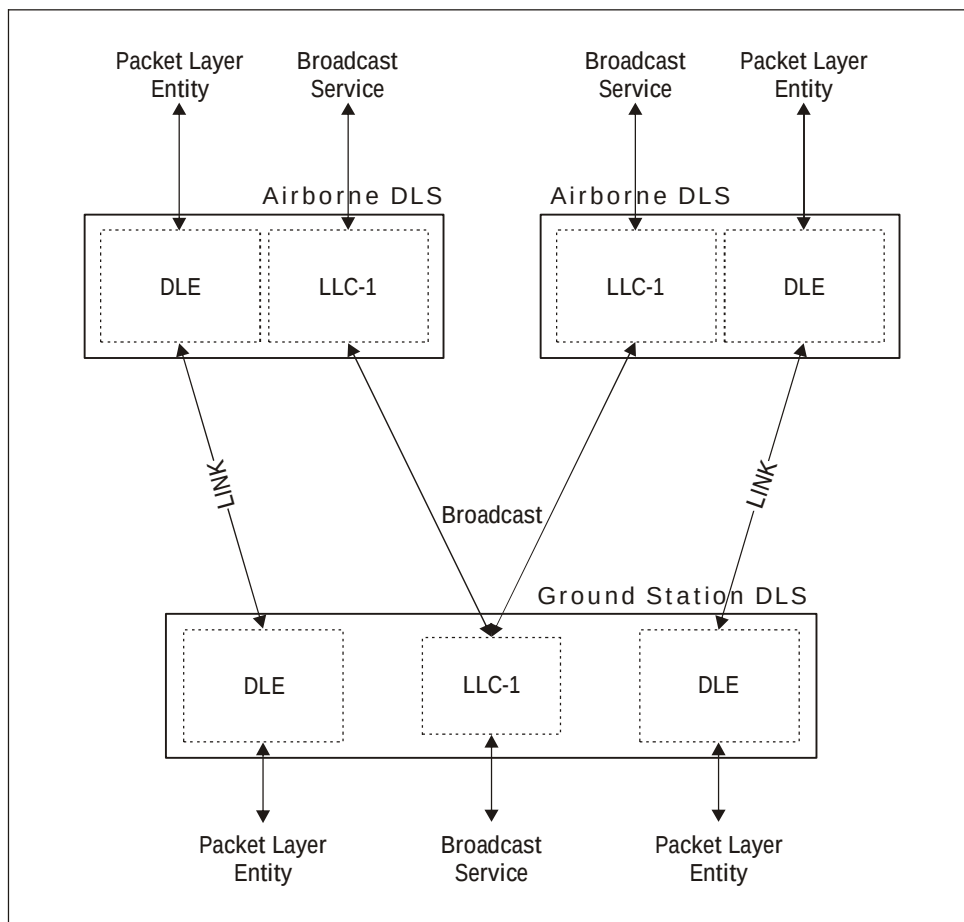


Figure I-3-4. DLS sub-layer architecture

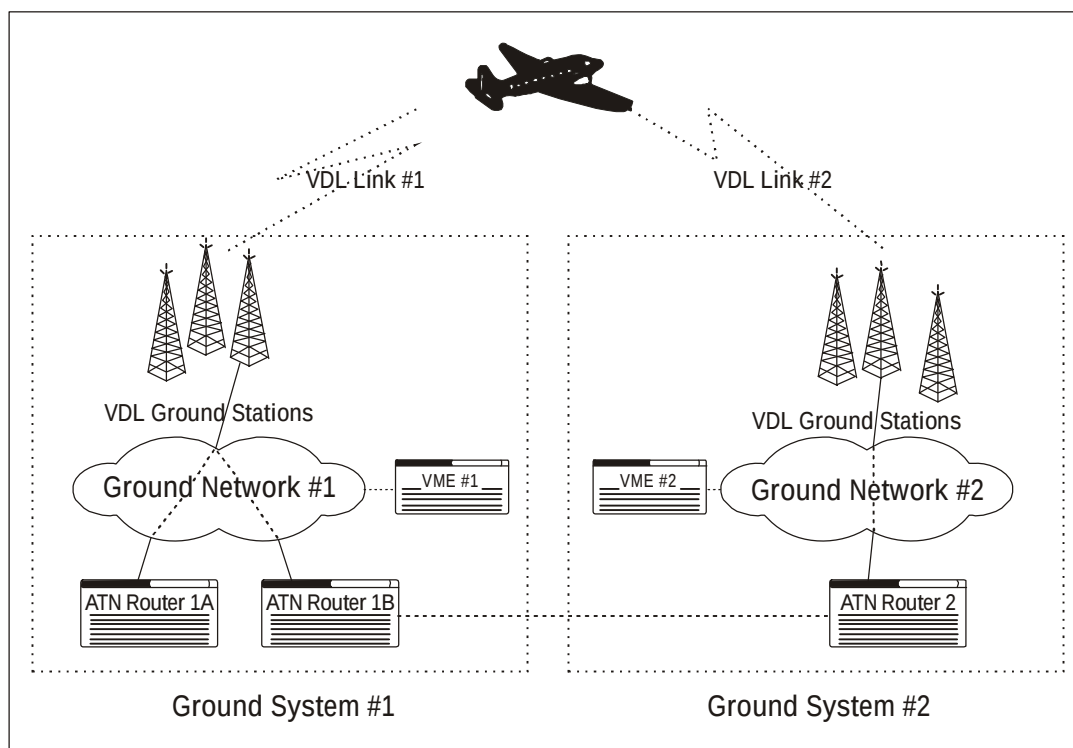


Figure I-3-5. System overview of VME, LME and DLS

3.3.2.3 In VDL Mode 2, multi-selective reject (SREJ) option is used. However, the format and SREJ process have departed from the standard HDLC protocol. The following is a summary of these changes:

SREJ Format	bit 1 of the control field (in the Information portion) will be set to 1 to indicate frames (identified in bits 6-8) that have been correctly received by the peer DLE (i.e. deviation from the standard HDLC protocol), and set to 0 to indicate frames that need to be retransmitted (i.e. same process as in the standard HDLC protocol)
--------------------	---

SREJ Process	- the P bit will always be set to 0 except when T4 expires or when checkpoint procedures have been invoked by the peer DLE. An SREJ with P bit set to 0 will indicate that all frames N(r)-1 have been acknowledged. - SREJ (P=0) will not be retransmitted after T1 expiration if there is no explicit response from the peer DLE (i.e. the peer DLE will end up retransmitting all outstanding frames after the T1 expiration). The SREJ (P=1) will be retransmitted only upon T1 expiration.
---------------------	--

3.3.2.4 In order to reduce the protocol recovery period, the T1 timer is reset based on the time of the oldest queued frame and not based on the current time. In addition, only those frames that have been queued (i.e. DLE entity has passed the frames to the transmission queue for transmission) for at least $T1_{min} + 2TD$ will be retransmitted upon T1 expiration. In this manner, frames will not be re-queued prematurely without providing the peer station sufficient time to respond. Figure I-3-6 outlines three examples of the SREJ and T1 processes.

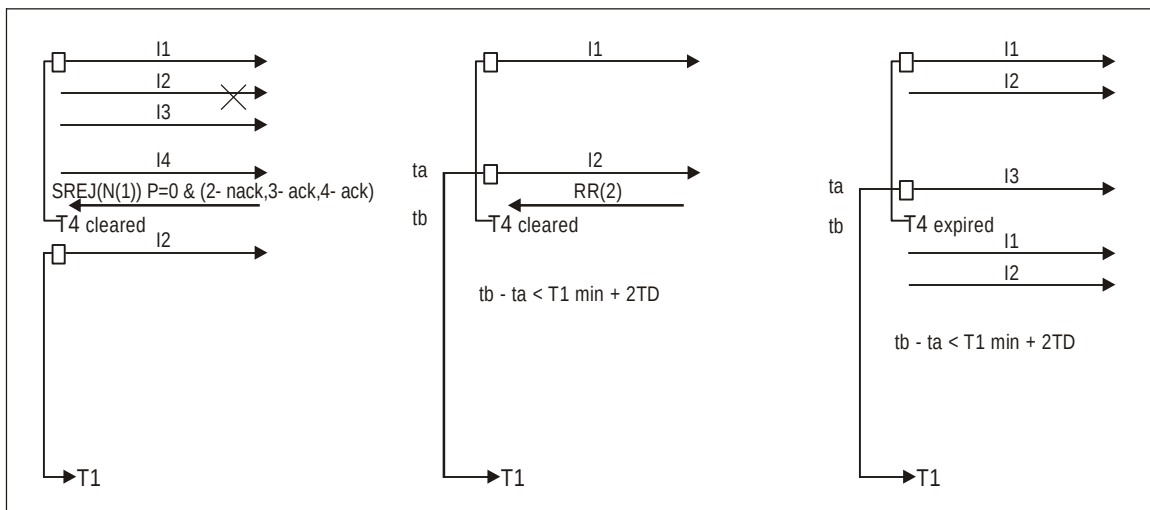


Figure I-3-6. SREJ and T1 flow diagrams

3.3.2.5 **FRMR/UA process.** The frame reject (FRMR) mode frame is always sent as a command (CMD) frame with the poll/final (P/F) bit set and is meant to signal the resetting of the link in situations where a reset may be necessary to resolve a transitory problem. The following situations will cause an FRMR frame to be issued:

- a frame with a bad or unknown control field;
- a frame with an invalid size;
- a frame with an invalid acknowledgement number;

- d) a frame received with an invalid command/ response (C/R) bit and/or P/F bit combination (for instance, an unnumbered acknowledgement (UA) frame received as a command, or a response frame with the P/F bit set when a response frame is not expected);
- e) a T1 timeout when the station is in FRMR mode; and
- f) an information frame or XID frame that is more than N1 bytes in length.

Note.— Frames without control fields and frames with unknown addresses are ignored.

3.3.2.5.1 Three bytes of information will follow the AVLC header. These bytes will correspond, as per ISO 4335, to the information fields of an FRMR frame in modulo 8 operation. Bits w, x, y and z will be coded as per ISO 4335.

3.3.2.5.2 The sender of the FRMR frame will remain in the reset state until a UA frame response frame is received back from the remote, or a disconnect (DISC) frame is received from the remote station which would result in the termination of the link as well as the associated packet level entity.

3.3.2.6 **TEST frame process.** The TEST command will be used to cause the addressed station to respond at the first response opportunity. An information field is optional with the TEST command; however, if present, the receiving information field will be returned in the TEST response. The TEST frame process can be executed by any station in any operational or non-operational state. For example, even if the aircraft has not executed a link establishment with a ground system, a ground station transmitting a TEST command will expect a response from that aircraft. The TEST command will have no effect on the mode or sequence variables maintained by the transmitting and responding stations.

3.3.2.7 **SABM/UA frame process.** The set asynchronous balanced mode (SABM) command is not used in VDL because the link is established by the exchange of XID_CMD and XID_RSP frames.

3.3.3 Interface to the peer entity

3.3.3.1 **Addresses.** The current address space allows a single radio address per aircraft. Each ground station radio should have a different address so that radios on different frequencies which are attached to the same ground station will have different addresses. This is done to mitigate the effect of RF spurs and intermodulation products which corrupt peer entity contact table (PECT) maintenance (see LME section for use of the PECT). The combination of spurs and intermods will occasionally cause a station to be intelligible on other frequencies. The use of different addresses for different frequencies can reduce the problem.

3.3.3.1.1 *Air-ground status bit.* The air-ground status bit should be set by all aircraft which have that information available. This bit may be used by service providers to decide whether to retune an aircraft and to which frequency it should be retuned, during takeoff and landing.

3.3.3.1.2 *Command/response (C/R) status bit.* Normal ISO 4335 procedures use the address field to distinguish command and response frames. However, in a broadcast medium, this procedure does not work properly, consequently an explicit bit is used to specify the type of frame.

3.3.3.1.3 *Data link service (DLS) parameters*

3.3.3.1.3.1 N1 Computation. The N1 parameter (i.e. maximum number of bits in any frame) is computed as follows:

Mode 2 (default): $N1 = [11 \text{ (link layer)} + 4 \text{ (packet layer)} + 1 \text{ 024}] \times 8 = 8 \text{ 312}$

Mode 2 (Max): $N1 = [11 \text{ (link layer)} + 4 \text{ (packet layer)} + 2 \text{ 048}] \times 8 = 16 \text{ 504}$

As per ISO standards, the flag is not counted in the above calculations.

3.3.3.1.3.2 **T2 Parameter.** The VDL Mode 2 station that receives a frame that requires a response has to be able to process this frame within T2 time. That is, if the MAC p value is set to 1 and there is no other traffic on the channel, then the VDL Mode 2 station has to produce a transmission within the T2 interval.

3.3.3.2 **Receive not ready (RNR).** The standard HDLC frame to denote a temporary inability to communicate, the RNR protocol data unit (PDU), is not used in AVLIC. This is primarily because sending an RNR requires a second frame to clear the condition. It is more efficient to occasionally ignore a frame or two so that the potential for large outages while trying to clear the RNR condition is avoided.

3.3.3.3 **Timers.** Table I-3-2 summarizes the operation of the DLS sub-layer timers.

3.3.3.3.1 **Values prior to link establishment.** Prior to establishing a link with a ground station, an aircraft should use the default values for the MAC and DLS parameters unless a ground station information frame (GSIF) setting new values is received from the ground station with which the aircraft is attempting to establish a link.

Table I-3-2. DLS sub-layer timers

<i>Timer</i>	<i>Started</i>	<i>Cancelled or restarted</i>	<i>Action upon expiration</i>
T1	Upon queuing a frame to the transmit queue, and when T1 timer not running	Cancelled upon receipt of an acknowledgement	Retransmit frames which have been enqueued for at least $T1m + 2T1int + 2TD$
T3	Upon queuing XID_CMD to the transmit queue	Cancelled upon receipt of XID_RSP	Retransmit XID_CMD
T4	Upon receipt of any frame	Restarted upon receipt of any frame	Send an RR command (P = 1) or FRMR (P=1) or SREJ (P=1) depending on the state, for up to N2 times

3.3.4 Interface to the upper layers

ISO 8886, *Data Link Service Definition for Open Systems Interconnection*, is the basis for the DLS sub-layer design. This service definition has extra primitives to resolve that exposed interface.

3.3.4.1 **Data transfer.** Two primitives are passed between the DLS sub-layer and the subnetwork layer to support the connection-oriented transfer of data. This is an unconfirmed service.

DL_DATA.request.
DL_DATA.indication.

3.3.4.1.1 **Request.** DL_DATA.request is the service request primitive for the connection-oriented transfer of data. This primitive is generated by the subnetwork layer and passed to the DLS sub-layer to request the transfer of data over a specific link.

Parameters: Link ID (M)
 User data (M)

3.3.4.1.2 *Indication.* DL_DATA.indication is the service indication primitive for the connection-oriented transfer of data. This primitive is generated by the DLS sub-layer and passed to the subnetwork layer to indicate the receipt of valid data over a specific link.

Parameters: Link ID (M)
 User data (M)

3.3.4.2 **Unitdata transfer.** Two primitives are passed between the LLC_1 sub-layer and the network layer to support the connection-less transfer of data. This is an unconfirmed service.

DL_UNITDATA.request.
 DL_UNITDATA.indication.

3.3.4.2.1 *Request.* DL_UNITDATA.request is the service request primitive for the connection-less transfer of data. This primitive is generated by the network layer and passed to the LLC_1 sub-layer to request the broadcast transfer of data.

Parameters: Destination address (M)
 User unitdata (M)

3.3.4.2.2 *Indication.* DL_UNITDATA.indication is the service indication primitive for the connection-less transfer of data. This primitive is generated by the LLC_1 sub-layer and passed to the network layer to indicate the receipt of a valid broadcast data.

Parameters: Source address (M)
 User unitdata (M)

3.3.4.3 **XID transfer.** Two primitives are passed between the LLC_1 sub-layer and the LME sub-layer to support the transfer of XIDs. This is an unconfirmed service.

DL_XID.request.
 DL_XID.indication.

3.3.4.3.1 *Request.* DL_XID.request is the service request primitive for the transfer of XIDs. This primitive is generated by the LME sub-layer and passed to the DLS sub-layer to request the transfer of an XID to a specific address.

Parameters: Destination address (M)
 Link ID (Optional (O))

3.3.4.3.2 *Indication.* DL_XID.indication is the service indication primitive for the transfer of XIDs. This primitive is generated by the DLS sub-layer and passed to the LME sub-layer to indicate the receipt of a valid XID from a specified address.

Parameters: Source address (M)

3.3.4.4 **DM transfer.** Two primitives are passed between the LLC_1 sub-layer and the LME sub-layer to support the transfer of DM frames. This is an unconfirmed service.

DL_DM.request.

DL_DM.indication.

3.3.4.4.1 *Request.* DL_DM.request is the service request primitive for the transfer of a DM frame. This primitive is generated by the LME sub-layer and passed to the LLC_1 sub-layer to request the transfer of a DM frame to a specific address.

Parameters: Destination address (M)
 Link ID (O)

3.3.4.4.2 *Indication.* DL_DM.indication is the service indication primitive for the transfer of received DM frames, unicasted frame except for an XID, that are not associated with any existing links. This primitive is generated by the LLC_1 sub-layer and passed to the LME sub-layer indicating the source address.

Parameters: Source address (M)

3.3.4.5 **State management.** Two primitives are passed between the DLS sub-layer and the LME sub-layer to support the link maintenance service.

DL_BLOCK.request
DL_UNBLOCK.request

3.3.4.5.1 *Block.* DL_BLOCK.request is the service request primitive for the link outage service. This primitive is passed from the LME sub-layer to the DLS sub-layer when a link is temporarily unavailable and the LME sub-layer is attempting to restore it. The receipt of this primitive informs the DLS sub-layer that a remote entity is temporarily unavailable for the transfer of data.

Parameters: Link ID (M)

3.3.4.5.2 *Unblock.* DL_UNBLOCK.request is the service request primitive for the link operational service. This primitive is passed from the LME sub-layer to the DLS sub-layer when a link is viable. The receipt of this primitive informs the DLS sub-layer that a remote entity is available for the transfer of data. If the new address is 0, then a quiet disconnect (delete the entity and all associated information, but do not send a DISC) should occur.

Parameters: Link ID (M)
 Address (M)

3.3.4.6 **Reset.** Three primitives are passed from the DLS/LLC_1 sub-layer to the LME sub-layer in the provider-initiated reset service.

DL_RESET_N2.indication
DL_RESET_TM2.indication
DL_RESET_FRMR.indication

3.3.4.6.1 *No response.* DL_RESET_N2.indication is the service indication primitive for a no response. This primitive is passed from the DLS or LLC_1 sub-layers to the LME sub-layer when no response is received from a remote entity. The receipt of this primitive causes the LME sub-layer to initiate site recovery procedures.

Parameter: Link ID (M)

3.3.4.6.2 *Congested channel.* DL_RESET_TM2. indication is the service indication primitive for a congested channel-caused, provider-initiated reset. This primitive is passed from the DLS or LLC_1 sub-layer to the LME sub-layer when the channel is detected as congested. The receipt of this primitive causes the LME sub-layer to initiate frequency recovery procedures, hopefully shielding the upper layers from the temporary loss of service.

3.3.4.6.3 **Protocol error.** DL_RESET_FRMR. indication is the service indication primitive for a protocol error-caused, provider-initiated reset. This primitive is passed from the DLS sub-layer to the LME sub-layer when a protocol error is detected either in the local or remote DLS sub-layer. The receipt of this primitive informs the LME sub-layer that the link is cleared and that upper layer data may have been lost.

Parameter: Link ID (M)
 Cause (O)

3.3.4.7 **Disconnect.** Either LME sub-layer (ground or avionics) can initiate a disconnect. Disconnection is not subject to the response of a higher layer but is treated as an automatic sequence once initiated. The primitives associated with the connection termination service are:

DL_DISC.request
DL_DISC.indication

3.3.4.7.1 **Request.** DL_DISC.request is the service request primitive for the connection termination service. This primitive is generated by the LME sub-layer and passed to the DLS sub-layer when the LME sub-layer wishes to terminate a connection. Receipt of this primitive causes the DLS sub-layer to immediately terminate the specified link.

Parameter: Link ID (M)
 Reason (O)

3.3.4.7.2 **Indication.** DL_DISC.indication is the service indication primitive for the connection termination service. This primitive is generated by the DLS sub-layer and passed to the LME sub-layer to signal an immediate disconnect. Receipt of this primitive means that the LME sub-layer may no longer use this link.

Parameter: Link ID (M)
 Reason (M)

3.3.5 SDL description

Note.— The SDL description of the DLS sub-layer is in Figure I-1-2.

3.3.5.1 **States.** There are five states in the DLS state machine, with one entity per connection. A state diagram of the DLS sub-layer is outlined in Figure I-3-7.

3.3.5.1.1 **Idle.** The DLS entity is in the disconnected mode. It can accept an XID from the remote DLS entity or generate an XID to initiate a link based on a request from the local LME sub-layer.

3.3.5.1.2 **Data transfer ready.** A data link connection exists between the local DLS entity and the remote DLS entity. Sending and receiving of information and supervisory PDUs can be performed.

3.3.5.1.3 **Blocked.** A data link connection exists between the local DLS entity and the remote DLS entity, however, sending of information and supervisory PDUs cannot be performed until some temporary loss of service is resolved. Note that receiving of PDUs is still possible.

3.3.5.1.4 **FRMR state.** A data link connection exists between the local DLS entity and the remote DLS entity, however, sending of information and supervisory PDUs cannot be performed until a UA frame is received or a DISC frame which would result in the termination of the link.

3.3.5.1.5 **Disconnect state.** A data link connection has been disconnected between the local DLS entity and the remote DLS entity, and the local DLS is waiting for the LME to kill this instance of the DLS process.

3.3.6 DLS test scripts

A set of airborne and ground system DLS test scripts have been developed to guide the implementation of the respective DLEs. These test scripts are outlined in the Appendix to Part 1 of this manual.

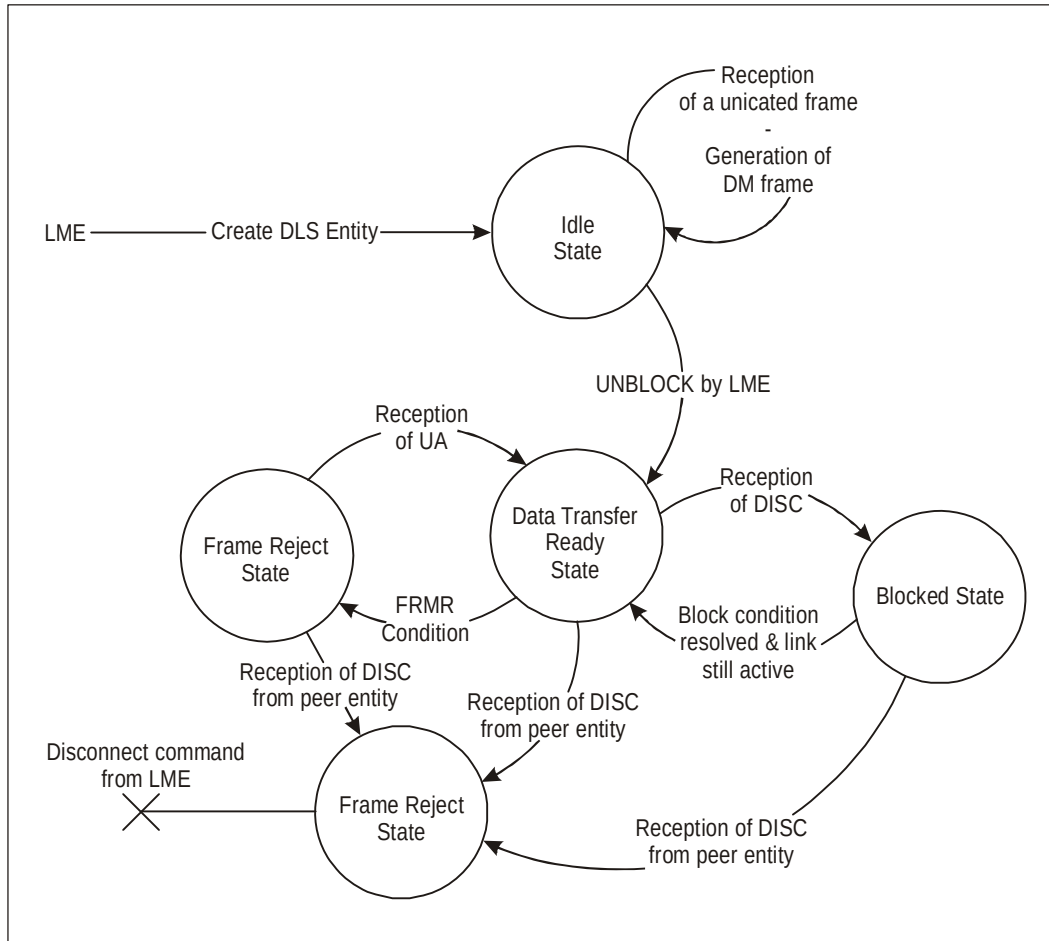


Figure I-3-7. DLS state diagram

3.4 LINK MANAGEMENT ENTITY (LME)

3.4.1 Functions

3.4.1.1 **Initialization.** The system management entity should start operation of the LME. The LME is then responsible for establishing a link layer connection. This could occur either by use of a common signalling channel or by a frequency search function.

Note.— The system management entity is an ATN entity that is beyond the scope of this document and that controls the operation of the router and the subnetwork selection algorithm.

3.4.1.2 Common signalling channel. The common signalling channel (CSC) (136.975 MHz) is used wherever service providers want to annunciate the VDL availability of CNS services over VHF carriers using the VDL Mode 2 physical and MAC layers (i.e. D8PSK and CSMA). By guaranteeing one common frequency, the problem of the aircraft in trying to locate a valid frequency is minimized. Also, aircraft tuned to frequencies other than the CSC do not need the frequency list XID parameter to be aware of an alternate frequency to use in the frequency recovery function.

3.4.1.2.1 Invocation. The LME should use the CSC to establish a link level connection when commanded startup or other search algorithms have failed and an aircraft is equipped for VDL Mode 2 and is in a service area that offers VDL Mode 2. The aircraft LME tunes the radio to the CSC and attempts to establish a link. After a link is established, the ground station may send an autotune command to the aircraft to have it switch to a different frequency.

3.4.1.2.2 Failure. If no link can be established using the CSC, then the LME may optionally use the frequency search function. Otherwise, the CSC function remains active.

3.4.1.3 Frequency search. The frequency search function attempts to establish a data link connection with any station on any frequency. Frequencies known a priori to be available for data service are scanned, and upon detection of an appropriate/usable signal, a link is established.

3.4.1.3.1 Invocation. The LME should perform the frequency search function upon commanded startup or failure of other search algorithms, and either the aircraft cannot use VDL Mode 2 or is not in a service area that offers VDL Mode 2 service.

3.4.1.3.2 Failure. If the frequency search function fails, the LME may use the CSC or remain in the frequency search function.

3.4.1.3.3 Timer TG1 (maximum frequency dwell time). This timer is implementation-dependent and is included as an example of what parameter(s) an implementation may include in the frequency search table. The frequency search table is a static table located in the aircraft LME that lists possible frequencies on which to attempt to make a link, the provider(s) available on that frequency, and whatever other pertinent information is required by the specific LME implementation in the selection of an optimal frequency.

3.4.1.4 Idle peer detection. There are two timers, T4 and TG2, which are used by the VDL Mode 2 to detect an idle/missing peer entity. In the aircraft, TG2 is set relatively short (to a multiple of TG3) and is reset when the ground station transmits to any aircraft. This allows an aircraft to quickly detect when a ground station cannot be received (either because the aircraft is no longer within range of the ground station or the ground station failed). The airborne T4 timer is used as a minimum traffic generator so that the ground system can determine that the aircraft is still around. The ground T4 timer is used to detect when an aircraft has departed from the region. The ground TG2 timer, however, is set much longer so that basic information about the location of the aircraft will survive even though the link is torn down and the resources used elsewhere.

3.4.1.5 Link establishment. When the airborne LME establishes a link layer connection with the ground system, it will inform the subnetwork dependent convergence function (SNDCF) or the intermediate system-system management entity (IS-SME) of the ATN router network entity titles (NETs) information received and the link ID for the new link. The SNDCF will indicate this link ID in all CALL REQUEST primitives that apply to that link.

Note.— The link identifier will differentiate between two state machines in the same radio and two state machines in different radios.

3.4.1.6 Timers. Table I-3-3 summarizes the timers in the LME sub-layer.

Table I-3-3. LME timers

<i>Timer</i>	<i>Started</i>	<i>Cancelled or restarted</i>	<i>Action upon expiration</i>
TG1 (aircraft only)	Initially tuning to a frequency during frequency search	Receiving any uplink on frequency	Retune to new frequency in frequency search table
TG2	Upon receipt of transmission from a station	Restarted upon receipt of transmission from a station	Remove entry from PECT; if link exists with that entity, perform recovery operation
TG3 (ground only)	Upon tx of any frame	Restarted upon tx of any frame	Transmit a GSIF
TG4 (ground only)	Upon tx of any GSIF	Restarted upon tx of any GSIF	Transmit a GSIF
TG5 (air only)	Opening a second link with a ground station operator	Should never be restarted	Consider old link disconnected

3.4.2 Interface to the peer entity

3.4.2.1 Exchange identity (XID) format. An XID frame may consist of public parameters, private parameters and user data. The public and private parameters used in XIDs frames are listed in Tables II-5-47 a), b) and c) in Part II, Detailed Technical Specifications. The group identifiers in this document are encoded in the reverse manner to ISO 8885.

3.4.2.1.1 Handoff request. The process by which a ground station requests an aircraft to initiate a ground station change (e.g. an autotune to a new frequency) involves the exchange of three XIDs between the ground system and the aircraft. The ground system will continue to retransmit the XID_CMD_HO (P=0) on the old frequency, until the XID_CMD_HO (P=1) from the aircraft is received on the new frequency to resolve a lost XID_CMD_HO (P=0). The aircraft will continue to transmit the XID_CMD_HO (P=1) on the new frequency until the XID_RSP_HO (P=1) from the ground system is received to resolve a lost XID_CMD_HO (P=1). This uses the minimum number of frames to ensure a reliable handoff. This process has been generalized where one entity wants the other to begin the handoff process.

Note.— When a VDL handoff takes place between ground stations connected to different air-ground routers, the aircraft system is recommended to use the new air-ground router. However, both Routes may have equal merit and the IDRP protocol, as currently specified by ATN standards, cannot be expected to select the most appropriate route.

3.4.2.1.2 Ground station information frames. Ground stations will periodically transmit ground station information frames broadcasting certain information for the aircraft LMEs to use. (The GSIFs are broadcast in a randomized window so that two transmitters hidden from each other will not synchronize and their signals collide.)

3.4.2.1.2.1 Destination airport identifier. The GSIF identifies the airport at which the ground station is located or, if the ground station is not located at an airport, the airport closest to the ground station is identified. An aircraft may, at its discretion, choose to connect to the station located at the flight's destination, so that the number of ground station changes is minimized and the aircraft does not suddenly drop below the radio horizon of the ground station while it is descending.

3.4.2.1.2.2 Supported facilities. The GSIF identifies all frequencies and protocols that the ground station supports. It may also identify other available ground stations. The aircraft LME stores this information to be used when trying to contact the stations during ground station changes. This allows the LME to retune the radio and know information about ground stations on that frequency without having to wait for several GSIFs to be transmitted. All GSIF transmissions will also include the HDLC and AVLC options parameters to also factor into any handoff decisions. When an aircraft establishes a link with the ground system, it will provide a list of the facilities that it supports. The ground system LME stores this information to be used when deciding what type of service to provide the aircraft.

3.4.2.1.2.3 Operational parameters. The service provider operating the ground station is responsible for management of the channel. It may become necessary for the ground service provider to adjust certain parameters throughout the area for better overall throughput on the channel. For channel management, the GSIF may broadcast new values of MAC persistence, M1, TM2, T4, TG5, k, and N2 for use by all aircraft connected to it. After the ground transmits an XID_RSP_LE to establish a link with an aircraft, a GSIF may be transmitted to set the operational parameters for that aircraft. The operational parameters are usually transmitted in a GSIF, so that all aircraft in the vicinity may receive the update.

3.4.2.1.2.4 Ground station location. All GSIF transmissions will include either the airport identifier or the nearest airport identifier.

3.4.2.1.3 *Ground to air connection-oriented XID parameters.* The ground-air connection-oriented XID transmissions contain various parameters used for maintaining the link.

3.4.2.1.3.1 Mandatory parameters. All connection-oriented XID frames will include the XID sequencing parameter. Connection-oriented XID frames will include the connection management parameter when establishing or handing over a link.

3.4.2.1.3.2 Connection management. The connection management parameter identifies the type and function of the XID. This parameter is not included in GSIFs or when operational parameters are being modified without resetting connection. For instance, an XID exchange to change the protocol options in use would not include the connection management parameter.

3.4.2.1.3.3 Autotune. The autotune frequency parameter allows the ground station to manage multiple frequencies in a congested area. The ground station may request that an aircraft retune to a different frequency and initiate a handoff on the new frequency. The replacement ground station parameter will be included to inform the aircraft of which ground station to attempt to contact. Alternately, the Frequency Support List parameter may be used to manage multiple frequencies.

Note.— In order to properly implement make-before-break across two frequencies, the aircraft will need two VDL radios. With only one VDL radio, the system will operate with a break-before-make paradigm. The system will silently disconnect the link before retuning to the new frequency.

3.4.2.1.3.4 Replacement ground station. The replacement ground station parameter can be used without the autotune parameter when the ground stations are on the same frequency.

3.4.2.1.4 *Air to ground connection-oriented XID parameters.* The air-ground connection-oriented XIDs contain various parameters concerning the link.

3.4.2.1.4.1 Mandatory parameters. All connection-oriented XID frames will include the XID sequencing parameter. Connection-oriented XID frames will include the connection management parameter when establishing or handing over a link.

3.4.2.1.4.2 Connection management. The connection management parameter identifies the type and function of the XID. This parameter is not included in GSIFs or when operational parameters are being modified without affecting the connection. For instance, an XID exchange to change the protocol options in use would not include the connection management parameter.

3.4.2.1.4.3 Aircraft handoff. In general, the aircraft LME will monitor the signal quality parameter (SQP) values of all transmissions from ground stations. When it determines that a ground station change is needed, it will send an XID to the selected (new) ground station. The aircraft LME may include a list of alternate (acceptable) ground stations. The ground service provider may, at its discretion, reply from another ground station (usually in the alternate list). This allows, among other functions, a means of load-balancing the ground stations.

Note.— The Handoff may also result from frequency recovery, ground-requested aircraft-initiated handoff (GRAIHO) or other reasons.

3.4.2.1.4.4 Destination airport. The flight's destination airport is transmitted so that the ground service provider may use that information in selecting the ground station from which to send a reply.

3.4.2.1.4.5 Supported facilities. When first establishing a link, the aircraft informs the service provider of modulation schemes it is capable of supporting so that the service provider may use this information when performing frequency management. The connection-establishment XID also includes the HDLC and AVLC protocol options parameter.

3.4.2.1.4.6 SQP measurement transfer. Ground-air and air-ground XID frames may include the SQP of the other station's last received transmission. This is expected to be used for testing purposes only.

3.4.3 Interface to the upper layer

3.4.3.1 **Link availability.** Four primitives are passed between the LME and the system management entities (SME) and the VHF-SNDCF entity for the link availability service.

LM_STARTUP.request
LM_SHUTDOWN.request
LM_LINKUP.indication
LM_LINKDOWN.indication

3.4.3.1.1 *Startup.* LM_STARTUP.request is the primitive passed from the aircraft SME to the LME to request that a VDL link be set up. The receipt of this primitive causes the aircraft LME to begin attempting to establish a link with a ground link layer entity.

3.4.3.1.2 *Shut down.* LM_SHUTDOWN.request is the primitive passed from the SME to the LME to request that the VDL link shut down. The receipt of this primitive causes the LME to disconnect all currently established links and go to a halt state.

3.4.3.1.3 *Link up.* LINKUP.indication is the primitive passed from the LME to the SNDCF to indicate that the VDL link is available. The receipt of this primitive causes routing initiation procedures to be invoked.

Parameters: ATN router NETs (M)
 Link ID (M)

3.4.3.1.4 *Link down.* LINKDOWN.indication is the primitive passed from the LME to the SNDCF to indicate that the VDL link is currently unavailable. The receipt of this primitive causes routing termination procedures to be invoked.

Parameters: Link ID (M)

Note.— Additional LME primitives are outlined in Chapter 5 of this manual.

3.5 LME TEST SCRIPTS

A set of airborne and ground system LME test scripts have been developed to guide the implementation of the respective LMEs. These test scripts are outlined in the Appendix to Part 1 of this manual.

Chapter 4

SUBNETWORK LAYER PROTOCOLS AND SERVICES

4.1 ARCHITECTURE

When a received frame passes through the link layer, the layer 2 header and trailer used for processing are stripped off. The remaining data link service (DLS) user_data parameter is passed within a DLS primitive up to the subnetwork layer. This remainder is a subnetwork protocol data unit (SNPDU) or, informally, a **packet**.

4.2 FUNCTIONS

4.2.1 The subnetwork layer is responsible for controlling the data packet flow with respect to duplicate, lost or invalid packets. Data passing through the subnetwork layer for transmission is broken into segments, called SNPDU's, for control and error recovery.

4.2.2 The basic service of the subnetwork layer is to provide for the transfer of data across the subnetwork. The subnetwork protocol is responsible for internal routing and relay functions across the subnetwork, functions which are outside the scope of the level 1 and level 2 routing, as defined in the *ISO/IEC TR9575: 1990 (E) OSI Routing Framework*.

4.3 INTERFACE TO PEER ENTITIES

4.3.1 Acknowledgement window

Because typical 8208 implementations generate a receive ready (RR) frame for every data packet, the acknowledgement process has been modified by creating an explicit acknowledgement window and by replacing almost all timer-based functions with event-based functions, thereby reducing the load on the RF channel. By setting the window wider than one, the probability of an explicit acknowledgement is reduced (with A=7, an RR is sent around 1 per cent of the time).

4.3.2 Packet size

By modifying P and W, the packet size and transmit window size parameters, the system can control the amount of outstanding information, and consequently, the delay experienced by a packet in the network layer queue.

4.4 INTERFACE TO UPPER LAYER

ISO 8348, *Network Service Definition*, includes detailed definitions of the primitives interfacing with the upper layer.

Chapter 5

VDL MODE 2 SUBNETWORK CONNECTION MANAGEMENT

5.1 INTRODUCTION

5.1.1 The ATN Internet protocols consist of the Internetworking Protocol (ISO 8473) as well as other protocols such as inter-domain routing protocol (IDRP - ISO 10747) and end systems-intermediate systems (ES-IS) routing exchange protocol (ISO 9542). Given that VDL Mode 2 is a connection-mode subnetwork access protocol (SNAcP), an SNDCF (subnetwork dependent convergence function) is required to provide a transparent connection-less mode service to the ATN internetworking protocol. The VDL protocol stack and the associated ATN stack are shown in Figure I-5.1.

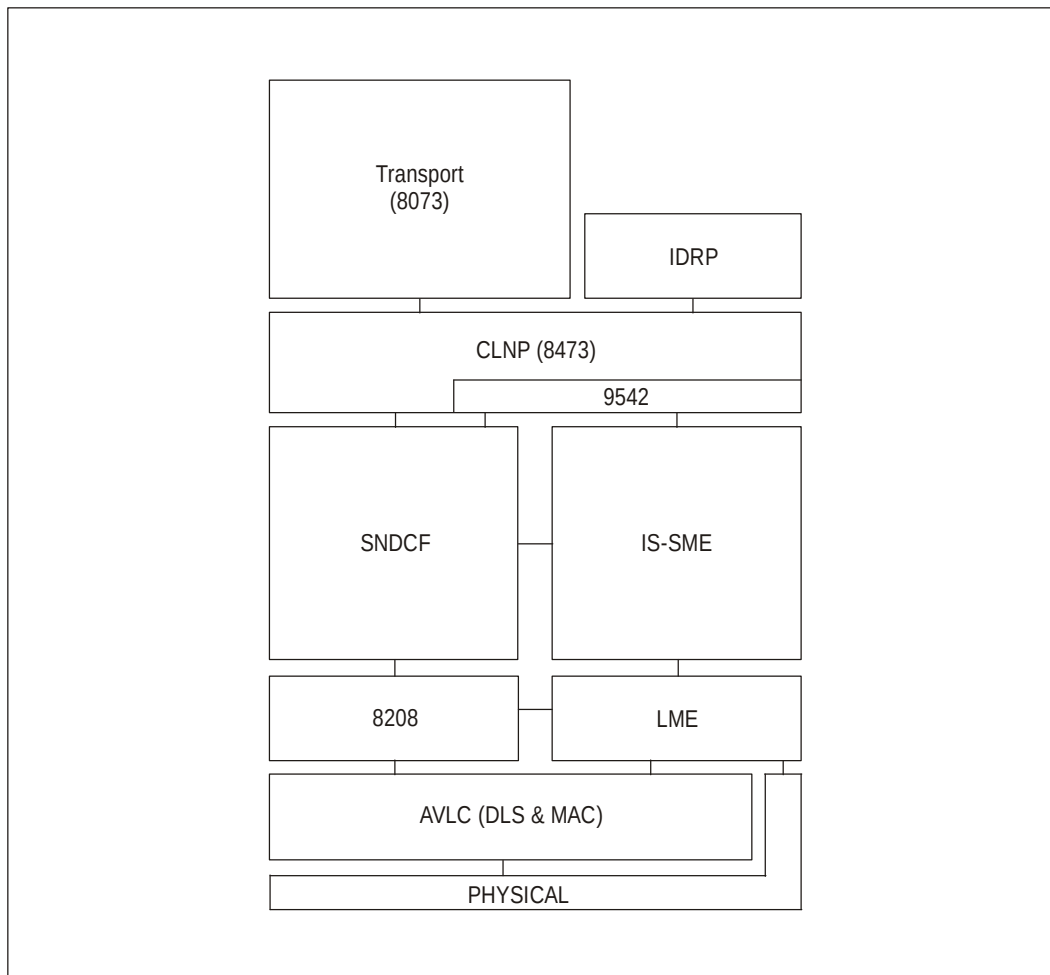


Figure I-5-1. VDL and associated ATN protocol stack

5.1.2 The VDL Mode 2 subnetwork consists of an airborne subsystem and a network of remote ground stations (RGS). The predominantly line-of-sight nature of VHF radio limits its use for air-ground communications to airspace that can be served by ground-based stations. The airborne subsystem functions as a mobile communication terminal, establishing and re-establishing link and subnetwork connections with ground stations that can provide reliable connectivity with ground data terminal equipment (DTEs) (or air-ground routers). An aircraft en route to its final destination will be required to re-establish connections (handovers) with numerous ground stations as the aircraft moves from one RGS coverage area to another. In view of these VHF characteristics, the VDL Mode 2 subnetwork initiation, handover and termination processes must be tailored appropriately so as to minimize the communication exchanges over the RF but at the same time provide a global baseline for the different implementation envisioned by the different States, airlines and service providers (SP).

5.2 VDL MODE 2 SUBNETWORK CONNECTION MANAGEMENT OVERVIEW

5.2.1 The VHF subnetwork connection management is primarily comprised of three phases:

- a) connection initiation;
- b) connection handoff (or handover); and
- c) connection termination.

5.2.2 Connection initiation

As per the VDL Mode 2 SARPs, the airborne VDL entity is responsible for initiating the link and subnetwork connection(s) with available VDL Mode 2 ground systems upon service start-up. The VHF airborne initiation mechanism is comprised of the following processes:

- a) a frequency search and acquisition process;
- b) a link establishment and parameter setting process; and
- c) a subnetwork establishment process.

The frequency search and acquisition is performed with the aid of the common signalling channel (CSC), the link establishment and parameter setting process is performed with the exchange of XID frames, and the subnetwork establishment process is performed with the exchange of 8208 CALL packets.

5.2.3 Connection handoff

5.2.3.1 As the aircraft moves from one RGS coverage region to another, handoffs will be required to maintain VDL Mode 2 communications. The airborne LME may wish to hand off (depending on signal quality, policy based, etc.) to a new RGS that may or may not have access to the same air-ground router as the current RGS.

5.2.3.2 The connection handoff process comprises the following phases:

- 1) link re-establishment and parameter setting process;
- 2) expedited or explicit subnetwork establishment process.

5.2.3.3 The VDL Mode 2 protocol provides a subnetwork maintenance facility that permits an aircraft to hand off from one RGS to another, without requiring the re-initialization of the “ATN contexts” (i.e. IDRP/SNDCF Local Reference Table) if both RGSs have access to the same ground DTE (i.e. air-ground router). This handoff process is to be executed by using the standard 8208 CALL procedures each time the airborne entity changes ground stations. Depending on whether the peer systems support expedited subnetwork connections, these CALL establishment packets will be part of the XID frames or will be sent as INFO frames (standard method). The expedited and explicit handover processes are outlined in detail below.

5.2.4 Connection termination

VDL Mode 2 connection termination may be initiated by either the airborne or ground entities. Some of the reasons for the airborne system terminating VDL Mode 2 connections are loss of VDL Mode 2 ground coverage, unrecoverable error or because the VDL Mode 2 ground service is no longer needed.

5.3 VDL MODE 2 SYSTEM MANAGEMENT ENTITIES

5.3.1 Link management entity (LME)

5.3.1.1 The functions of the LME are:

- a) ground station identification;
- b) aircraft frequency search;
- c) initial link establishment and parameter negotiation;
- d) link parameter modification; and
- e) aircraft and ground-initiated ground station handovers.

5.3.1.2 The ground station information frames (GSIFs) are transmitted periodically by the VDL Mode 2 ground stations so as to inform any aircraft (i.e. airborne LME) of the existence and of the operational parameters of the sending ground station. The LME may also use any uplink traffic from the ground stations to update its peer entity contact table (PECT) which is used by the aircraft to initiate air-ground link connections and handovers.

5.3.1.3 A common signalling channel has been reserved to facilitate the LME frequency acquisition process. All ground station service providers that are offering VDL Mode 2 services in a particular region will identify themselves (via GSIFs) on this channel. Included in the GSIF or Autotune XID frames will be the VDL Mode 2 frequency to which an airborne user may tune its VHF transceiver in order to access the necessary service. If more than one ground station Service Provider is supporting VDL Mode 2 services in a particular region, it is a higher layer (i.e. IS-SME) policy matter to decide with which ground network the aircraft will establish a connection. These policies are dictated by the respective user. The LME and the associated primitives are shown in Table I-5-1.

5.3.2 Subnetwork — system management entity (SN-SME)

The main role of the SN-SMEs is to generate events that advertise a change in the subnetwork connectivity. The SN-SME will trigger the LME to initiate the frequency acquisition process under certain conditions (e.g. avionics equipment power-up). By the same token, the SN-SME will also shut down the VHF service triggered by external events such as the termination of a flight.

5.3.3 Intermediate system — system management entity (IS-SME)

5.3.3.1 As per the *Manual of Technical Provisions for the Aeronautical Telecommunication Network (ATN)* (Doc 9705), a series of system management actions triggered by events will be used to establish and terminate communications between boundary intermediate systems (BIS). The IS-SME is located in all the air-ground and airborne routers. Its main role is to trigger the ISO 9542 ES-IS protocol for the ISH PDU transfer (peer discovery process) and to start up the ISO 10747 Routing Protocol.

5.3.3.2 The LME will pass to the IS-SME all the necessary information derived from the GSIFs and available VDL Mode 2 traffic, so that the IS-SME can determine which service is available to support the on-board applications. In the content of the GSIFs or XID connection management response frames, the VDL ground station will indicate the partial network entity titles (NETs) (i.e. ADM and ARS fields) of the air-ground routers that are accessible to the aircraft. Primarily there will be two categories of router: AOC and ATS. If an RGS indicates that it has accessibility to both ATS and AOC routers, the aircraft may decide to establish two subnetwork connections to each air-ground router for the exchange of AOC and ATS traffic, respectively. The IS-SME will be responsible for making the decision to which ground DTE a subnetwork connection is required to support the Internetworking protocol as well as the on-board applications.

5.3.3.3 For an airborne DTE to establish a subnetwork connection with a ground DTE (i.e. air-ground router), it requires a subnetwork point of attachment (SNPA). The VDL Mode 2 specification supports both specific VDL Mode 2 addresses and X.121 addresses as SNPAs. VDL Mode 2 specific addresses are coded addresses which reflect the SNPA of the air-ground ATN router with which the airborne DTE wishes to establish a subnetwork connection. As outlined above, the GSIFs will contain the partial NETs of the accessible air-ground routers, and depending on their transmitted order in the GSIF frame, a VDL specific DTE address can be derived. In addition, the ground station provider may also support exact addressing, that is, X.121 formatted DTE addresses. The IS-SME is responsible for the SNPA resolution process and for initiating the Call process with the VHF-SNDCF. The IS-SME and its associated primitives are shown in Table I-5-1.

5.3.4 VHF system management entity messages

Figure I-1-2 outlines the relationship between the sub-layers, including the primitives which are outlined in Table I-5-1.

5.4 VDL MODE 2 SUBNETWORK INITIATION PROCESS

As mentioned above, the VHF subnetwork initiation process is comprised of a frequency search and acquisition process, a link establishment and parameter setting process and a subnetwork establishment process. The message sequence chart (MSC) for the VHF subnetwork initiation process is shown at the end of this section.

Table I-5-1. System management entity messages

<i>From</i>	<i>To</i>	<i>Message/primitive</i>	<i>Information conveyed</i>
External Agents	IS-SME	ATC_Control	– indicates the transfer of tactical control to the next ATC/FIR centre
		APPS_Request	– on-board applications informing of their air-ground communications requirements
External Agents	SN-SME	VHF_SERVICEup.req	– request the initiation of a VDL Mode 2 subnetwork service (e.g. avionics power-up or at flight initiation)
		VHF_SERVICEdown.req	– request the termination of the VDL Mode 2 subnetwork service (e.g. flight termination)
SN-SME	LME	LM_STARTUP.req	– activation of LME (i.e. frequency acquisition, ground station identification, etc.)
		LM_SHUTDOWN.req	– de-activation of LME and associated air-ground link connections
IS-SME	LME	LM_SERVICE_startup.req	– requesting the LME to establish link connection with the specified service (provided by LM_SVCS_AVAIL.ind)
		LM_SERVICE_shutdown.req	– requesting the LME to tear down an existing link with a service
IS-SME	VHF-SNDCF	SC_SNPA.req	– specification of the SNPA to be used when constructing the CALL REQUEST packet (i.e. X.121 or VDL specific addresses)
IS-SME	ES-IS	IS_LINKUP.ind	– triggering event for the peer discovery mechanism (i.e. ISH PDU)
LME	IS-SME	LM_SVCS_AVAIL.ind	– list of services available (i.e. high speed/low speed VDL Mode 2 service, VDL Mode 2 service providers, accessible routers, VDL Mode 2 RGS operating parameters, etc.)
LME	VHF-SNDCF	LM_LINKUP.ind	– indication that the link has been successfully established with the requested service (from LM_SERVICE_startup.req)
		LM_LINKDOWN.ind	– indication that the link has been broken for a specified reason

<i>From</i>	<i>To</i>	<i>Message/primitive</i>	<i>Information conveyed</i>
		LM_NOEXP_CALL.ind LM_EXP_CALL.ind LM_SUBNET.ind	– indication that the ground system does not support expedited handoffs – indication that the ground system does support expedited handoffs – in the case of an expedited subnetwork establishment, these primitives will forward the CALL REQUEST or CALL CONFIRMATION packet to the VHF-SNDCF that was included in the XID frame
VHF-SNDCF	LME	LM_SUBNET.req	– in the case of an expedited subnetwork establishment, these primitives will forward the CALL REQUEST or CALL CONFIRMATION packet to the LME so that it can be included in the XID frame
VHF-SNDCF	IS-SME	SC_LINKUP.ind SC_SNPAAup.ind SC_SNPAdown.ind SC_NOEXP_CALL.ind	– indication that the link (i.e. first time) has been successfully established and a subnetwork connection may be initiated at this point – confirmation that a subnetwork connection (i.e. SNPA) has been successfully established or handed over (expedited or explicit) – indication that a subnetwork connection (i.e. SNPA) has been torn down for a particular reason – indication that an explicit handover is required (i.e. construction of CALL REQUEST) because the ground system does not support expedited subnetwork handoffs

5.4.1 Frequency acquisition and determination of available services

5.4.1.1 At VHF service start-up (i.e. SN_SME commanded), the LME may tune the VHF data radio (VDR) to the CSC (PHFREQ.req) in order to discover the available VDL Mode 2 services together with their associated frequencies. The type of services available in a particular region can span from one ground station provider connected to only one air-ground router, to multiple ground station providers connected to multiple routers with different operating parameters (i.e. low speed, high speed, redirected virtual circuits (RVCs), ATC routers, AOC routers). The annunciation of the services will be done by the RGSs via the periodic transmission of GSIFs.

5.4.1.2 The LME will use the GSIFs and uplink traffic (DL_XID.ind and PH_SQP.ind) to update its PECT. The LME will not only keep track of the type of services available but also of the ground stations that offer these services. It will take a maximum of TG1 time for the LME to acquire all the available services broadcasted on the CSC.

5.4.2 Link establishment

5.4.2.1 The LME will inform the IS-SME of the type of services available in the particular region (LM_SVCS_AVAIL.ind). The IS-SME will have prior knowledge of the airborne applications requiring air-ground communications (via the APPS_Request primitive) and will request the LME to establish a link connection with the appropriate service (LM_SERVICE_startup.req). For example, the airline may have AOC data to send to its central host, such as engine monitoring reports, in which case the IS-SME will request the LME to establish a connection with its preferred ground station provider who is able to deliver this type traffic to the airline's end-system.

5.4.2.2 The required service may not be available on the CSC and therefore before the LME can initiate the link establishment and parameter setting process it will have to retune the VDR to the appropriate service frequency (the broadcasted GSIF on the CSC will annunciate among other things the VHF service frequencies).

5.4.2.3 If the system does not support expedited subnetwork connections, the airborne LME will exchange XID frames as outlined in the VDL Mode 2 SARPs as part of the link establishment process (DL_XID.req and DL_XID.ind). Once the LME has successfully completed the link establishment and parameter negotiation processes, it will inform the VHF-SNDCF that a subnetwork connection can be initiated at this point (LM_LINKUP.ind). (The example given at the end of this section assumes that expedited subnetwork connections are not supported.)

5.4.3 Subnetwork establishment and routing initiation

5.4.3.1 Once a link connection has been established with a VDL Mode 2 ground station, the IS-SME is responsible for triggering the subnetwork connection as well as the peer discovery processes.

5.4.3.2 The VHF-SNDCF will require an SNPA and the intermediate system hello protocol data unit (ISH PDU) to construct the CALL REQUEST packet to be sent to the ground DTE (i.e. air-ground router) which can provide ATN connectivity to the desired end-system. As mentioned above, the VDL Mode 2 protocol supports both VDL Mode 2 specific and exact addressing. The IS-SME will determine with which ground DTE to establish a subnetwork connection and thereafter convey the appropriate SNPA to the VHF-SNDCF (SC_SNPA.req). Moreover, as a part of the peer discovery process, the ISH PDU will be included in the CALL REQUEST packet call user data field. The IS-SME will trigger the end systems/intermediate systems (ES-IS) entity to send the ISH PDU to the VHF-SNDCF in order to complete the construction of the CALL REQUEST packet (SC_ISH_PDU.req).

5.4.3.3 The 9542 process will pass the ISH PDU as well as the maintained/initialized bit set to 1 found in the SNDCF parameter block as per the VDL Mode 2 and ATN SARPs to the VHF-SNDCF. The VHF-SNDCF will build the CALL REQUEST packet, by placing the SNPA provided by the IS-SME in the *Called Address* field if the SNPA is an exact address, or will place the VDL Mode 2 specific address in the *Called Address Extension* facility and then place the ISH PDU provided by the 9542 process in the *User Data* field using the *Fast Select* 8208 facility. The *Calling Address* field will include the aircraft 24-bit address.

5.4.3.4 The VHF-SNDCF will then pass this CALL REQUEST packet to the 8208 entity for transmission over the link and physical layers (SN_CALL.req).

5.4.3.5 The air-ground router will accept the call by generating a *CALL ACCEPT* packet including the ISH PDU, as part of the user data field identifying the air-ground router's NET, and the SNDCF parameter block, indicating that the router cannot maintain subnetwork connections.

Note.— It is assumed that this is the first subnetwork connection that the air-ground router has with this aircraft.

5.4.3.6 Once the aircraft receives the CALL ACCEPT packet from the called air-ground router, the VHF-SNDCF will convey this information to the ES-IS entity and will inform the IS-SME that the subnetwork connection has been successfully completed (SC_SNPAup.ind). The 9542 process will then:

- a) activate the forwarding information base (FIB); and
- b) initiate the inter-domain routing protocol (IDRP) process which is responsible for the exchange of routing information between the two entities.

5.4.4 The airborne IDRP entity will then generate the appropriate OPEN and UPDATE PDUs with its peer entity.

5.4.5 VDL Mode 2 handoff process

5.4.5.1 The handover scenario that will be covered in this section is a handoff from one VDL Mode 2 RGS to another that has accessibility to the **same** air-ground router. The case of a handoff from one VDL Mode 2 RGS to another which does not have accessibility to the same air-ground router is similar to the subnetwork initiation process outlined in section 5.4.3 and will not be covered in this section. As mentioned above, the VDL Mode 2 protocol supports both an *expedited* and *explicit* handoff for subnetwork connection maintenance. The VDL Mode 2 handoff MSCs are shown at the end of this section.

5.4.5.2 **Explicit handoff protocol overview.** If an aircraft DTE wishes to *explicitly* request a subnetwork connection to a ground DTE, it will send a CALL REQUEST packet to the ground DTE with the fast select user data field containing the ISO 9542 ISH PDU, after link establishment.

5.4.5.3 **Expedited subnetwork handoff protocol overview.** If both the air and the ground system supports expedited subnetwork connection handoffs, the aircraft can include in the XID handoff frame the CALL REQUEST packet, thus reducing the number of transmissions over the RF.

5.4.6 VHF explicit handoff process

5.4.6.1 In order for subnetwork connections to be maintained across ground station changes, the aircraft LME will give preference in choosing a new ground station to a ground station indicating accessibility to the DTEs to which subnetwork connections already exist. In this manner the type of “service” will remain the same and it will require minimum intervention by the IS-SME. The MSC for the explicit handover case is shown at the end of this section.

5.4.6.2 Depending on the signal quality of the existing link relative to the signal quality of other neighboring ground stations, the LME will initiate a ground handover as to maintain the subnetwork connection with the ground DTE. Given that a new link would have to be established with the new ground station, it will be required to create a new 8208 Packet Level Entity over that link (creation of Subnet_Entity 2).

5.4.6.3 Once the aircraft LME has established a link with the new ground station that has access to the same ground DTE as the previous RGS, the LME will inform the VHF-SNDCF of the link change (LM_NOEXP_CALL.ind). The VHF-SNDCF in turn will initiate the subnetwork connection process (SC_NOEXP_CALL.ind) very similar to that of the subnetwork initiation process.

5.4.6.4 To support the above architecture, the VHF-SNDCF (both on the ground and in the aircraft) will have to be able to associate a single local reference with successive logical channels. That is, the VHF-SNDCF must be able to

map a remote SNPA with successive switched virtual circuits (SVCs) if the remote SNPA does not change. The mechanism that allows the aircraft entity to be explicitly notified that the “ATN contexts” have been maintained in the air-ground router, is via a Maintained/Initialized bit in the SNDCF parameter block sent between the peer entities via the CALL REQUEST/CONFIRM packet exchange. If the router does not have a subnetwork connection with that aircraft, or for any reason the router cannot maintain the “ATN contexts” for that aircraft, the router will respond with the Maintained/Initialized bit to 0 as part of the SNDCF parameter block. At this point, the IS-SME/9542 will have to re-initiate the IDRP and SNDCF Local Reference processes.

5.4.6.5 Therefore, if we assume that the air-ground router can maintain the subnetwork connection with the aircraft, the only adjustment that is required is for the VHF-SNDCF to map the new SVC to the local reference of the previous SVC. There is no need to update the FIB or activate the IDRP process. It is assumed that once the new subnetwork connection has been successfully completed, the air-ground router will send all traffic via the new path. However, given that there may still be data being queued-up via the old link, the aircraft will maintain the previous link for a maximum time of TG5. During this time the aircraft will continue to accept and acknowledge frames on the previous link.

5.4.6.6 After TG5 time, both the previous link and the associated 8208 packet level entity will be terminated (DL_DISC.req, LM_DISC.ind).

Appendix to Part I

DLS TEST SCRIPTS

Actions (A=):

A ']' implies a set of legal responses (that is, any one of the list is valid). A comma delimited list is a series of mandatory actions.

A1: If a ground IUT, discard frame. If an airborne IUT and sender is a ground station, send an XID_CMD_LE/P=1. If an airborne IUT and sender is an airborne station, discard frame.

A2: Disconnect the current connection and then perform A1.

A3: Perform other specified actions, then, if an airborne IUT and sender is a ground station, send an XID_CMD_LE/P=1.

A5: Send a DM/F=0, then perform A3.

DI: Discard frame

frame type: send specified frame type

Parameters (P=):**State (S=):**

ADM: asynchronous disconnected mode (force IUT into disconnected state before beginning test)

ABM: asynchronous balanced mode (force IUT into data transfer state before beginning test)

FRM: frame reject mode (force IUT to send FRMR from the ABM before beginning test)

SRM: sent selective reject mode (force IUT to send SREJ from the ABM before beginning test)

Underlined stimuli are illegal frames which should never be transmitted; however, the IUT is being tested for its response against said frames.

The response to any frame except for an XID (either transmitted or received) must be within T2 seconds. An XID response must be within T2 + 5 seconds.

Unless otherwise noted in a particular test case, the P0 set of parameter values will be used.

PARAMETER	UNITS	P0-SET	P1-SET	P2-SET
MAC p		1	1	1
MAC M1		1	1	1
DLS T1min	sec	2	120	10
DLS T1max	sec	10	10	10
DLS T1mult		0	1	1
DLS T1exp		2	2	2

PARAMETER	UNITS	P0-SET	P1-SET	P2-SET
DLS T2	msec	500	500	500
DLS T4	min	15	1	15
DLS N1	bits	2 168	2 168	2 168
DLS N2		3	3	3
DLS k	frames	4	4	4

The tests in this table do not test the ability to pass traffic (in the ABM and SRM), but the general responses to various frame types.

ROW	STIMULUS	PARAM SET	ADM	ABM	SRM	FRM
B1	<u>DISC/P=1</u>	P0	A=A1 S=ADM	A=A2 S=ADM		
B2	DISC/P=0					
B3	<u>DISC/F=1</u>					
B4	<u>DISC/F=0</u>					
B5	<u>DM/P=1</u>					
B6	<u>DM/P=0</u>					
B7	<u>DM/F=1</u>					
B8	DM/F=0					
B9	RR/P=1		A=A5 S=ADM	A=RR/F=1 S=ABM	A=SREJ/F=1 P=as last SREJ S=SRM	A=FRMR/P=1 P=as last FRMR S=FRM
B12	RR/F=0			A=DI S=same state		
B13	<u>UA/P=1</u>		A=DI A5 S=ADM	A=FRMR/P=1 P=W=1/X=Y=Z=0 S=FRM		
B14	<u>UA/P=0</u>					
B15	UA/F=1		A=A5 S=ADM	A=reset link S=ABM		
B16	<u>UA/F=0</u>		A=DI A5 S=ADM	A=FRMR/P=1 P=per last FRMR S=FRM		
B18	<u>DISC/P=0, w/ info field</u>		A=DI A1 S=ADM			
B24	<u>DM/F=0, w/ info field</u>					
B25	<u>RR/P=1, w/ info field</u>		A=DI A5 S=ADM			
B27	<u>RR/F=1, w/ info field</u>					
B28	<u>RR/F=0, w/ info field</u>					
B31	<u>UA/F=1, w/ info field</u>					

ROW	STIMULUS	PARM SET	ADM	ABM	SRM	FRM
B33	TEST/P=1		A=TEST/F=1, A3 P=copied from TEST command	A=TEST/F=1 P=copied from TEST command S=same state		
B34	<u>TEST/P=0</u>		A=DI A1	A=DI S=same state		
B35	TEST/F=1		A=A1			
B36	<u>TEST/F=0</u>		A=DI A1			
B37	<u>RNR/P=1</u>		A=DI A5	A=FRMR/P=1 P=W=X=1/Y=Z=0 S=FRM		A=FRMR/P=1 P=as last FRMR S=FRM
B38	<u>SABM/P=1</u>					
B39	<u>REJ/P=1</u>		A=DI A5			
B40	<u>RNR/P=0</u>					
B41	<u>RNR/F=1</u>					
B42	<u>RNR/F=0</u>					
B47	<u>REJ/P=0</u>					
B48	<u>REJ/F=1</u>					
B49	<u>REJ/F=0</u>					
B54	<u>SABM/P=0</u>					
B55	<u>SABM/F=1</u>					
B56	<u>SABM/F=0</u>					
B61	broadcast UI/P=0		A=process, A3 S=ADM	A=process S=same state		
B62	multicast UI/P=0 to all aircraft		A=process if IUT type is same as destination address, A3 S=ADM	A=process if IUT type is same as destination address S=same state		
B63	multicast UI/P=0 to all ground stations					
B64	multicast UI/P=0 to all ground stations of a different provider					
B65	multicast UI/P=0 to all ground stations of this provider					
B66	<u>broadcast UI/P=1</u>	A=A1 S=ADM	A=DI S=same state			
B67	<u>unicast UI/P=0</u>					
B68	FRMR/P=1 from a lower-numbered station	A=A5 S=ADM	A=UA/F=1, clear state S=ABM			
B69	<u>FRMR/F=1 from a lower-numbered station</u>		A=DI UA/F=1 S=ABM			
B70	<u>FRMR/P=0 from a lower-numbered station</u>					

ROW	STIMULUS	PARAM SET	ADM	ABM	SRM	FRM	
B71	FRMR/F=0 from a lower-numbered station						
B72	INFO/P=0 with bad FCS		A=DI S=same state				
B73	INFO/P=0 that is aborted						
B74	INFO/P=0 with valid FCS but non-integral number of octets		A=DI S=same state				
B82	SREJ/P=1		S=A5 S=ADM	A=RR/F=1 INFO/F=1 S=ABM	A=SREJ/F=1 S=SRM	A=FRMR/F=1 P=as last FRMR S=FRM	
B83	<u>SREJ/P=0</u>		A=DI A5 S=ADM	A=FRMR/P=1 P=W=1/X=Y=Z=0 S=FRM			A=FRMR/P=1 P=as last FRMR S=FRM
B85	<u>SREJ/F=0</u>						
B86	no stimulus for T4	P1	A=DI	A=RR/P=1 INFO/P=1 S=ABM (**verify that the exponential backoff works)	A=SREJ/P=1 S=SRM (**verify that the exponential backoff works)	A=FRMR/P=1 S=FRM (**verify that the exponential backoff works)	
B87	B86: no stimulus for T1						
B88	B87: no stimulus for T1						
B89	B88: no stimulus for T1			A=inform LME S=same state			
B90	<u>TEST/P=1 with right destination address, but no source address</u>	P0	A=DI S=same state				
B91	<u>broadcast UI/P=0 with no source address</u>						
B92	<u>broadcast UI/P=0 from an unknown type</u>		A=DI process S=same state				
B94	INFO/P=0 with unknown source address		A=A5	A=DM/F=0 (to second tester address) S=same state (first tester address), ADM (second tester address)			
B95	<u>INFO/P=0 with modulo 128 format</u>		A=DI A5	S=FRMR/P=1 P=W=1/X=Y=X=0 S=FRM			
B96	<u>INFO/P=0 with missing leading flag</u>		A=DI S=same state				
B97	<u>broadcast UI/P=0 with source address as broadcast address</u>						
B98	unicast UI/P=1		A=DI S=ADM	A=FRMR/P=1 P=W=X=1/Y=Z=0 S=FRM		A=FRMR/P=1 P=as last FRMR S=FRM	
B99	FRMR/P=1 from a higher numbered station		A=A5 S=ADM	A=UA/F=1, clear state S=ABM		A=DI S=FRM	
B100	<u>FRMR/P=0 from a higher numbered station</u>	A=DI UA/F=1, clear state S=ABM					
B101	<u>FRMR/F=1 from a higher numbered station</u>						

ROW	STIMULUS	PARM SET	ADM	ABM	SRM	FRM
B102	<u>FRMR/F=0 from a higher numbered station</u>					

The tests in this table are intended to verify that the IUT can successfully pass traffic in both directions. All tests are to be performed with the IUT in the ABM state. Those rows marked with a '*' are also to be performed with the IUT starting in the SRM state (this is achieved by first sending the IUT an INFO/P=0 (N(s)=1, N(r)=0)).

With all tests, the V(s) and V(r) of the IUT shall be 0 (except as described in the next sentence). If the stimulus is a semi-colon-separated pair, the second stimulus should be presented after the IUT successfully passes the named first test. A comma-separated list of stimuli should be transmitted to the IUT in a single transmission, with a single flag between frames.

A "DATA" stimulus is a data packet causing the IUT to transmit an INFO frame with the indicated parameters.

Abbreviations:

S = N(s)

R = N(r)

1 (in SREJ) = a byte in the information field acknowledges sequence number 1

/2 (in SREJ) = a byte in the information field negative acknowledges (naks) sequence number 2

ROW	STIMULUS	PARM SET	RESPONSE	COMMENTS
C1	INFO/P=0 (S=0, R=0)	P0	A=RR/F=0 (R=1) S=ABM	receiving every sequence number
C2	INFO/P=0 (S=1, R=0)		A=SREJ/F=0 (R=0, 1) S=SRM	
C3	INFO/P=0 (S=2, R=0)		A=SREJ/F=0 (R=0, /1, 2) S=SRM	
C4	INFO/P=0 (S=3, R=0)		A=SREJ/F=0 (R=0, /1, /2, 3) S=SRM	
C5	INFO/P=0 (S=4, R=0)		A=RR/F=0 (R=0) S=ABM	
C6	INFO/P=0 (S=5, R=0)		A=RR/F=0 (R=0) S=ABM	
C7	INFO/P=0 (S=6, R=0)		A=RR/F=0 (R=0) S=ABM	
C8	INFO/P=0 (S=7, R=0)		A=RR/F=0 (R=0) S=ABM	
C9*	<u>INFO/P=0 (S=0, R=1)</u>		A=FRMR/P=1 P=Z=1/W=X=Y=1 S=FRM	illegal frame check

ROW	STIMULUS	PARM SET	RESPONSE	COMMENTS
C10	C1: INFO/P=0 (S=1, R=0)		A=RR/F=0 (R=2) S=ABM	rotate the receive window
C11	C10: INFO/P=0 (S=2, R=0)		A=RR/F=0 (R=3) S=ABM	
C12	C11: INFO/P=0 (S=3, R=0)		A=RR/F=0 (R=4) S=ABM	
C13	C12: INFO/P=0 (S=4, R=0)		A=RR/F=0 (R=5) S=ABM	
C14	C13: INFO/P=0 (S=5, R=0)		A=RR/F=0 (R=6) S=ABM	
C15	C14: INFO/P=0 (S=6, R=0)		A=RR/F=0 (R=7) S=ABM	
C16	C15: INFO/P=0 (S=7, R=0)		A=RR/F=0 (R=0) S=ABM	
C17	INFO/P=0 (S=0, R=0), INFO/P=0 (S=1, R=0)		A=RR/F=0 (R=2) S=ABM	verify that can receive various numbers of frames with a single flag delimiter
C18	INFO/P=0 (S=0, R=0), INFO/P=0 (S=1, R=0), INFO/P=0 (S=2, R=0)		A=RR/F=0 (R=3) S=ABM	
C19	INFO/P=0 (S=0, R=0), INFO/P=0 (S=1, R=0), INFO/P=0 (S=2, R=0), INFO/P=0 (S=3, R=0)		A=RR/F=0 (R=4) S=ABM	
C21	C2:INFO/P=0 (S=0, R=0)		A=RR/F=0 (R=2) (two frames delivered in order) S=ABM	deliver out-of-order traffic correctly
C22*	DATA		A=INFO/P=0 (S=0, R=0) S=same state	can transmit traffic
C23*	C22: no stimulus for T1		A=INFO/P=0 (S=0, R=0) S=same state	retransmit OK
C24*	C23: no stimulus for T1		A=INFO/P=0 (S=0, R=0) S=same state	
C25*	C24: no stimulus for T1		A=inform LME S=same state	
C26*	DATA, DATA	P2	A=INFO/P=0 (S=0, R=0), INFO/P=0 (S=1, R=0) S=same state	

ROW	STIMULUS	PARM SET	RESPONSE	COMMENTS
C27*	C26: SREJ/F=0 (R=0, 1)		A=INFO/P=0 (S=0, R=0) S=same state	only retransmit negative acknowledged (nak'ed) traffic
C28*	C27: DATA (after T1/2 seconds)		A=INFO/P=0 (S=2, R=0) S=same state	
C29*	C28: no stimulus for T1 (since C26)		A=INFO/P=0 (S=0, R=0) S=same state	only transmit traffic sufficiently old
C30*	C29: no stimulus for T1		A=inform LME S=same state	properly count N1
C31*	DATA, DATA, DATA, DATA	P0	A=INFO/P=0 (S=0, R=0), INFO/P=0 (S=1, R=0), INFO/P=0 (S=2, R=0), INFO/P=0 (S=3, R=0) S=same state	can transmit 4 frames properly
C32*	C31: SREJ/F=0 (R=0, /1, /2, 3)		A=INFO/P=0 (S=0, R=0), INFO/P=0 (S=1, R=0), INFO/P=0 (S=2, R=0) S=same state	only transmit nak'ed frames
C33*	C32: SREJ/F=0 (R=1, /2, 3)		A=INFO/P=0 (S=1, R=0), INFO/P=0 (S=2, R=0) S=same state	
C34*	C33: DATA, DATA		A=INFO/P=0 (S=4, R=0) S=same state	respect send window
C35*	C34: RR/F=0 (R=5)		A=INFO/P=0 (S=5, R=0) S=same state	
C36	INFO/P=0 (S=3, R=0)		A=SREJ/F=0 (R=0, /1, /2, 3) S=SRM	send appropriate SREJ
C37	C36: INFO/P=0 (S=0, R=0)		A=SREJ/F=0 (R=1, /2, 3), (one frame delivered) S=SRM	
C38	C37: INFO/P=0 (S=4, R=0)		A=SREJ/F=0 (R=1, /2, 3, 4) S=SRM	
C39	<u>C38: INFO/P=0 (S=5, R=0)</u>		A=SREJ/F=0 (R=1, /2, 3, 4) (** link renegotiation should occur to reset k **) S=SRM	
C40	INFO/P=0 (S=0, R=0), INFO/P=0 (S=2, R=0)		A=SREJ/F=0 (R=1, 2) S=SRM	

ROW	STIMULUS	PARAM SET	RESPONSE	COMMENTS
C41*	C26: no stimulus for T1		A=INFO/P=0 (S=0, R=0), INFO/P=0 (S=1, R=0) S=same state	retransmit all outstanding frames
C42*	C26: SREJ/F=0 (R=0, 1), TEST/P=1		A=TEST/F=1, INFO/P=0 (S=0, R=0) S=same state	transmit supervisory frames before INFO frames
C43*	<u>C26: SREJ/F=0 (R=0, 1),</u> <u>SREJ/F=0 (R=0, 1)</u>		A=INFO/P=0 (S=0, R=0) S=same state	only queue one INFO regardless of number of SREJ
C44*	C22: DATA, RR/F=0 (R=1)		A=INFO/P=0 (S=1, R=0) S=same state	can transmit properly
C45*	C44: DATA, RR/F=0 (R=2)		A=INFO/P=0 (S=2, R=0) S=same state	
C46*	C45: DATA, RR/F=0 (R=3)		A=INFO/P=0 (S=3, R=0) S=same state	
C47*	C46: DATA, RR/F=0 (R=4)		A=INFO/P=0 (S=4, R=0) S=same state	
C48*	C47: DATA, RR/F=0 (R=5)		A=INFO/P=0 (S=5, R=0) S=same state	
C49*	C48: DATA, RR/F=0 (R=6)		A=INFO/P=0 (S=6, R=0) S=same state	
C50*	C49: DATA, RR/F=0 (R=7)		A=INFO/P=0 (S=7, R=0) S=same state	
C51*	C50: DATA, RR/F=0 (R=0)		A=INFO/P=0 (S=0, R=0) S=same state	
C52	INFO/P=1 (S=0, R=0)		A=RR/F=1 (R=1) S=ABM	sets F bit properly
C53*	<u>INFO/P=0 (S=0, R=1),</u> <u>INFO/P=0 (S=1, R=1)</u>		A=FRMR/P=1 P=Z=1/W=X=Y=1 S=FRM	sends only one FRMR per transmission
C54	INFO/P=0 (S=0, R=0) with no info field		A=RR/F=0 (R=1) S=ABM	accepts minimum sized INFO frame
C55	INFO/P=0 (S=0, R=0) with info field containing 8208 DATA packet of 256 octets		A=RR/F=0 (R=1) S=ABM	accepts maximum sized INFO frame
C56	INFO/P=0 (S=0, R=0) with info field containing 8208 DATA packet of 257 octets		A=FRMR/P=1 P=Y=1/W=X=Z=0 S=FRM	reject too large INFO frame

ROW	STIMULUS	PARAM SET	RESPONSE	COMMENTS
C57*	C31: SREJ/F=0 (R=0, /0, /1, /2, 3)		A=FRMR/P=1 P=Z=1/W=X=Y=0 S=FRM	rejects illegal SREJ
C58*	C31: SREJ/F=0 (R=0, 5)			
C59*	C31: SREJ/F=0 (R=6)			
C60*	C31: SREJ/F=0 (R=0, 3, /4)			
C61*	<u>C22: RR/F=1 (R=1) (unsolicited F=1)</u>		A=DI (note N(r) *not processed*)	discards illegal RR

Additional tests not specified in tabular form:

- D1 — Verify that a ground IUT always has the air-ground (A/G) bit set to 1.
- D2 — Verify that an aircraft IUT which cannot switch the A/G bit has it set to 1.
- D3 — Verify that an aircraft IUT which can switch the A/G bit sets it appropriately.
- D4 — Verify that an IUT, after having transmitted a FRMR, retransmits it according to the T1 procedures up to N2 times and then informs the LME.

— — — — —

LME TEST SCRIPTS

Aircraft LME

Explanations:

S=	State
A=	Action
GS-c=	Current ground station (either the only GS with which a link is established or the active link when in the process of handoff).
GS-n=	New ground station (just after a successful handoff this is the “freshly” established link).
GS-p=	Proposed ground station (during handoff this is the new GS with which the aircraft proposes to establish a link).
GS-o=	Old ground station (in a link overlap situation, this is the GS which was the current GS until the new link was established and for which the overlap timer TG5 has been started).
GS-x=	Other ground station, that is a GS which is not one of active stations as explained in “GS:x,y.”
GS-active=	One of the active stations as explained in “GS:x,y”.
DI=	Discard the received input
ADM=	Asynchronous Disconnect Mode
LE_pend=	Link establishment pending
ABM_single=	Link established with a single GS
ABM_mult=	Link established with two GSs at the same time. One link is with the current GS, the other is with the new GS. The link with GS-c will only be maintained for TG5 time interval.
HO_pend=	Handoff pending state. In this state the link with the current GS is maintained while the link with the proposed GS is in the process of being set up but is not established yet.
*n=	Reference number of an explanatory footnote
GS:x,y	List of GSs with which the a/c is communicating (and expecting semantically correct responses) in a particular state.

General comments:

1. This table represents the behaviour of the aircraft LME and only aircraft-initiated handoffs are considered.
2. All XID frames transmitted by a/c have C/R bit = 0 (command).
3. Handoffs are done between ground stations of the same operator.

Aircraft LME

ROW	Stimulus	ADM GS:none	LE_pend GS:p	ABM_single GS:o,n	ABM_mult GS:o,n	HO_init_pend GS:c,p	HO_req_pend GS:c,p
A1	VME command to establish a link	A=CMD_LE (GS-p)/P=1 S=LE_pend	A=DI S=LE_pend	A= DI S=ADM_single	A=DI S=ABM_mult	A=DI S=HO_init_pend	A=DI S=HO_req_pend
A2	DM (GS-x)/F=0 1	A=DI S=ADM	A=DI S=LE_pend	A= DI S=ABM_single	A= DI S=ABM_mult	A=DI S=HO_init_pend	A=DI S=HO_req_pend
A3	DM (GS-active)/F=0 1	A=DI S=ADM	A=DI S=LE_pend	A=inform VME =choose new GS- p & CMD_LE (P=1) S=LE_pend	if GS=o A= GS-c <= GS- n, cancel TG5 S=ABM_single if GS=n A= GS-c <= GS- o, cancel TG5 =choose new GS & CMD_HO(P=0 1) S=HO_init req_pe nd	if GS=p A=DI S=HO_init_pend if GS=c A=i choose new GS & CMD_LE(P=1) S=LE_pend	if GS=p A=DI S=HO_req_pend if GS=c A=choose new GS & CMD_LE(P=0) S=LE_pend
A4	DISC (GS-x)/P=0 1	A= DI S=ADM	A= DI S=LE_pend	A= DI S=ABM_single	A= DI S=ABM_mult	A=DI S=HO_init_pend	A=DI S=HO_req_pend
A5	DISC (GS-active)/P=0 1	A=DI S=ADM	A=DI S=LE_pend	A=choose new GS-p and & CMD_LE (P=1) S=LE_pend	A= GS-c <= GS- n, o cancel TG5 = delete relevant link S=ABM_single	if GS=p A=DI S=HO_init_pend if GS=c A=choose new GS & CMD_LE(P=1) S=LE_pend	if GS=p A=DI S=HO_req_pend if GS=c A=choose new GS & CMD_LE(P=1) S=LE_pend
A6	T3 expiration	A=DI S=ADM	A=CMD_LE (GS-p)/P=1 S=LE_pend (increment N2)	A=DI (*1) S=ABM_single	A=DI (*1) S=ABM_mult	A=CMD_HO (GS-p)/P=1 S=HO_init_pend (increment N2)	A=CMD_HO (GS-p)/P=0 S=HO_req_pend (increment N2)
A7	N2 exhausted (GS-active)	A=DI S=ADM	A=choose new GS-p & CMD_LE(P=1) S=LE_pend	A=CMD_HO (GS-p)/P=0 1 S=HO_init req_pe nd (*4)	if GS=o A= GS-c <= GS-n cancel TG5 S=ABM_single if GS=n A= GS-c <= GS-o = choose new GS-p & CMD_HO (P=0 1) S=HO_init req_pe nd	if GS=p A=choose new GS-p & CMD_HO(P=1) S=HO_init_pend if GS=c A= DI S=HO_init_pend	if GS=p A=choose new GS-p & CMD_HO(P=0) S=HO_req_pend if GS=c A= DI S=HO_req_pend

Aircraft LME

ROW	Stimulus	ADM GS:none	LE_pend GS:p	ABM_single GS:o,n	ABM_mult GS:o,n	HO_init_pend GS:c,p	HO_req_pend GS:c,p
A8	RSP_LCR F=0	A=DI S=ADM	A= CMD_LCR(P=0) - illegal S=ADM	A= CMD_LCR(P=0) - illegal S=ADM	A= CMD_LCR(P=0) - illegal S=ADM	A= CMD_LCR(P=0) - illegal S=ADM	A= CMD_LCR(P=0) - illegal S=ADM
A9	RSP_LCR (GS-active)/F=1	A=DI S=ADM	A=inform VME S=ADM or A= choose new GS-p & CMD_LE(P=1) S=LE_pend	A=XID_CMD_LC R (P=0) - unexpected S=ADM	A=XID_CMD_LC R (P=0) - unexpected S=ADM	A=inform VME S=ABM_single or A= choose new GS-p & CMD_HO(P=1) S=HO_init_pend	A=XID_CMD_LC R (P=0) - unexpected S=ADM
A10	RSP_LCR (GS-x)/F=1	A=DI S=ADM	A=inform VME S=ADM or A= choose new GS-p & CMD_LE(P=1) S=LE_pend	A=XID_CMD_LC R (P=0) - unexpected S=ADM	A=XID_CMD_LC R (P=0) - unexpected S=ADM	A=inform VME S=ABM_single or A= choose new GS-p & CMD_HO(P=1) S=HO_init_pend	A=XID_CMD_LC R (P=0) - unexpected S=ADM
A11	CMD_LCR P=0	A=DI S=ADM	A=DI S=LE_pend	A=XID_CMD_LC R (P=0) - unexpected S=ADM	A=XID_CMD_LC R (P=0) - unexpected S=ADM	A=XID_CMD_LC R (P=0) S=ADM	A=inform VME S=ABM_single
A12	CMD_LCR (P=1)	A=DI S=ADM	A=XID_CMD_LC R (P=0) - illegal S=ADM	A=XID_CMD_LC R (P=0) - illegal S=ADM	A=XID_CMD_LC R (P=0) S=ADM	A=XID_CMD_LC R (P=0) S=ADM	A=XID_CMD_LC R (P=0) S=ADM
A13	XID_CMD_LE	A=DI S=ADM	A=XID_RSP_LC R (F=1) - illegal S=ADM	A=XID_RSP_LC R (F=1) - illegal S=ADM	A=XID_RSP_LC R (F=1) - illegal S=ADM	A=XID_RSP_LC R (F=1) - illegal S=ADM	A=XID_RSP_LC R (F=1) - illegal S=ADM
A14	XID_RSP_HO (F=0)	A=DI S=ADM	A=XID_CMD_LC R (P=0) - illegal S=ADM	A=XID_CMD_LC R (P=0) - illegal S=ADM	A=XID_CMD_LC R (P=0) - illegal S=ADM	A=XID_CMD_LC R (P=0) - illegal S=ADM	A=XID_CMD_LC R (P=0) - illegal S=ADM
A15	XID_CMD_HO (P=1) gs-x acceptable	A=XID_CMD_LC R (P=0) - disconnected S=ADM	A=DI S=LE_pend	A=XID_RSP_HO (F=1) S=ABM_mult	A=XID_CMD_LC R (P=1) - unspecified = delay for TG5 remaining S=ABM_mult	A=DI S=HO_init_pend	A=XID_RSP_HO (F=1) S=ABM_mult
A16	XID_CMD_HO (P=1) gs-x unacceptable	A=XID_CMD_LC R (P=0) - disconnected S=ADM	A=DI S=LE_pend	A=XID_RSP_LC R (F=1) - bad parameter S=ABM_single	A=XID_CMD_LC R (P=1) - unspecified = delay for TG5 remaining S=ABM_mult	A=DI S=HO_init_pend	A=XID_RSP_LC R (F=1) S=ABM_single
A17	XID_CMD_HO (P=1) gs-active	A=XID_CMD_LC R (P=0) - disconnected S=ADM	A=DI S=LE_pend	A=XID_RSP_LC R (F=1) - max delay, unspecified reason S=ABM_single	A=XID_CMD_LC R (P=1) - unspecified = delay for TG5 remaining S=ABM_mult	A=DI S=HO_init_pend	A=XID_RSP_LC R (F=1) - max delay, unspecified reason S=ABM_single

Aircraft LME

ROW	Stimulus	ADM GS:none	LE_pend GS:p	ABM_single GS:o,n	ABM_mult GS:o,n	HO_init_pend GS:c,p	HO_req_pend GS:c,p
A18	RSP_LE F=1, parameters acceptable (*2)	A=XID_CMD_LC R(P=0) - disconnected S=ADM or A=CMD_LE (P=1) S=LE_pend	A= GS-c <= GS-x S=ABM_single	A=CMD_LCR (P=0) - unexpected S=ADM (*G2)	A=CMD_LCR (P=0) - unexpected S=ADM (*G2)	A=CMD_LCR (P=0) - unexpected S=ADM (*G2)	A=CMD_LCR (P=0) - unexpected S=ADM (*G2)
A19	RSP_LE F=1, parameters not acceptable (*2)	A=XID_CMD_LC R(P=0) - disconnected S=ADM or A=CMD_LE (P=1) S=LE_pend	A=DISC (GS-x)/P=0, inform LME S=ADM	A=CMD_LCR (P=0) - unexpected S=ADM (*G2)	A=CMD_LCR (P=0) - unexpected S=ADM (*G2)	A=CMD_LCR (P=0) - unexpected S=ADM (*G2)	A=CMD_LCR (P=0) - unexpected S=ADM (*G2)
A20	TG5 expiry on (GS-o)	A=DI S=ADM	A=DI S=LE_pend	A=DI S=ABM_single	A= GS-c <= GS-n S=ABM_single	A=DI S=ADM	A=DI S=ADM
A21	LME command to perform handoff	A=DI S=ADM	A=DI S=LE_pend	A=CMD_HO (GS-p)/P=0 1 S=HO_req pend	A=DI S=ABM_mult	A=DI S=HO_init_pend	A=DI S=HO_req_pend
A22	RSP_HO (GS-x)/F=1, parameters acceptable (*2)	A=XID_CMD_LC R(P=0) - disconnected S=ADM	A=DI S=LE_pend	A=XID_CMD_LC R(P=0) - unexpected S=ADM	A=XID_CMD_LC R(P=0) - unexpected S=ADM	A= start TG5, GS-n <= GS-x, GS-o <= GS-c S=ABM_mult	A=XID_CMD_LC R(P=0) - unexpected S=ADM
A23	RSP_HO (GS-x)/F=1, parameters not acceptable (*2)	A=XID_CMD_LC R(P=0) - disconnected S=ADM	A=DI S=LE_pend	A=CMD_LCR (P=0) - unexpected S=ADM (*G2)	A=CMD_LCR (P=0) - unexpected S=ADM (*G2)	A= DISC on GS-x =CMD_HO(P=1) S=HO_init_pend	A=XID_CMD_LC R(P=0) - unexpected S=ADM
A24	RSP_HO (GS-active)/F=1 parameters acceptable (*2)	A=XID_CMD_LC R(P=0) - disconnected S=ADM	A=DI S=LE_pend	A=CMD_LCR (P=0) - unexpected S=ADM (*G2)	A=CMD_LCR (P=0) - unexpected S=ADM (*G2)	if GS=c A= CMD_LCR (P=0) - unexpected, max delay S=ABM_single (*5) if GS=p A= start TG5, GS-o <= GS-c, GS-n <= GS-p S=ABM_mult	A=XID_CMD_LC R(P=0) - unexpected S=ADM

Aircraft LME

ROW	Stimulus	ADM GS:none	LE_pend GS:p	ABM_single GS:o,n	ABM_mult GS:o,n	HO_init_pend GS:c,p	HO_req_pend GS:c,p
A25	RSP_HO (GS-active)/F=1 parameters not acceptable (*2)	A=DI S=ADM	A=DISC (GS-p)/P=0, inform LME S=ADM	A= DM S=ABM_single	A=DM S=ABM_mult	if GS=c A= CMD_LCR (P=0) - unexpected, max delay S=ABM_single (*5) A= DISC on GS-x =CMD_HO(P=1) S=HO_init_pend	A=XID_CMD_LC R(P=0) - unexpected S=ADM
A26	INFO (GS-x)/F=1	A=DM (GS-x)/P=0 S=ADM	A=CMD_LE (GS-p)/P=1 S=LE_pend (increment N2)	A= DM (GS-x)/P=0 S=ABM_single	A= DM (GS-x)/P=0 S=ABM_mult	A=CMD_HO (GS-p)/P=1 S=HO_pend (Increment N2)	A=CMD_HO (GS-p)/P=1 S=HO_pend (Increment N2)
A27	INFO (GS-active)/P=0 1	A=DM GS-active S=ADM	A=CMD_LE (GS-p)/P=1 S=LE_pend (increment N2)	A=RR & send to appropriate DLE S=ABM_single	A=RR & send to appropriate DLE S=ABM_mult	If GS=c A=RR & and send to appropriate DLE S=HO_init_pend If GS=p A=CMD_HO (GS-p)/P=1 S=HO_init_pend	If GS=c A=RR & and send to appropriate DLE S=HO_req_pend If GS=p A=CMD_HO (GS-p)/P=1 S=HO_req_pend
A28	TEST GS-x (P=1)	A=TEST (F=1) S=ADM	A=TEST (F=1) S=LE_pend	A=TEST (F=1) S=ABM_single	A=TEST (F=1) S=ABM_mult	A=TEST (F=1) S=HO_init_pend	A=TEST (F=1) S=HO_req_pend
A29	TEST GS-active (P=1)	A=TEST (F=1) S=ADM	A=TEST (F=1) S=LE_pend	A=TEST (F=1) S=ABM_single	A=TEST (F=1) S=ABM_mult	A=TEST (F=1) S=HO_init_pend	A=TEST (F=1) S=HO_req_pend
A30	TEST (GS-x)/F=1	A=DI S=ADM	A= DI S=LE_pend	A= DI S=ABM_single	A= DI S=ABM_mult	A= DI S=HO_init_pend	A=DI S=HO_req_pend
A31	TEST (GS-active)/F=1	A=DI S=ADM	A= DI S=LE_pend	A= DI S=ABM_single	A= DI S=ABM_mult	A= DI S=HO_init_pend	A=DI S=HO_req_pend
A32	any other frame (GS-active)/P=0 1			A=process signal quality S= remain in same state			

Aircraft LME

ROW	Stimulus	ADM GS:none	LE_pend GS:p	ABM_single GS:o,n	ABM_mult GS:o,n	HO_init_pend GS:c,p	HO_req_pend GS:c,p
A33	XID_CMD_HO p=0 gs-x acceptable	A=CMD_LCR(P=0) - disconnected S=ADM	A=DI S=LE_pend	A=CMD_HO(P=1) to best GS-p S=HO_init_pend	A=CMD_LCR(P=0) - unspecified = delay of TG5 S=ABM_mult	A=DI S=HO_init_pend	A=DI S=HO_req_pend
A34	XID_CMD_HO p=0 gs-x unacceptable	A=CMD_LCR(P=0) - disconnect S=ADM	A=DI S=LE_pend	A=CMD_LCR(P=0) - bad parameter S=ABM_single	A=CMD_LCR(P=0) - unspecified = delay of TG5 S=ABM_mult	A=DI S=HO_init_pend	A=DI S=HO_req_pend
A35	XID_CMD_HO p=0 gs-active acceptable	A=CMD_LCR(P=0) - disconnected S=ADM	A=DI S=LE_pend	A=CMD_HO(P=1) to best GS-p S=Ho_init_pend	A=CMD_LCR(P=0) - unspecified = delay TG5 S=ABM_mult	A=DI S=HO_init_pend	A=DI S=HO_req_pend
A36	XID_CMD_HO p=0 gs-active unacceptable	A=CMD_LCR(P=0) - disconnected S=ADM	A=DI S=LE_pend	A=CMD_LCR(P=0) - bad parameter S=ADM	A=CMD_LCR(P=0) - unspecified = delay TG5 S=ABM_mult	A=DI S=HO_init_pend	A=DI S=HO_req_pend
A37	XID_CMD_LPM p=1 gs-x	A=RSP_LCR(F=1) - disconnected S=ADM	A=DI S=LE_pend	A=RSP_LCR(F=1) - unexpected S=ADM	A=RSP_LCR(F=1) - unexpected S=ADM	A=DI S=HO_init_pend	A=RSP_LCR(F=1) - unexpected S=ADM
A38	XID_CMD_LPM p=1 gs-active	A=RSP_LCR(F=1) - disconnected S=ADM	A=DI S=LE_pend	A=XID_RSP_LPM(F=1') (change operating parameters) S=ABM_single	A=XID_RSP_LPM(F=1') (change operating parameters) S=ABM_mult	A=DI S=HO_init_pend	If GS-p A=RSP_LCR(F=1) - unexpected S=ADM If GS-c A=XID_RSP_LPM(F=1') (change operating parameters) S=HO_req_pend
A39	XID_CMD_LPM p=0 gs-x	A=CMD_LCR(P=0) - illegal S=ADM	A=DI S=LE_pend	A=CMD_LCR(P=0) - illegal S=ADM	A=CMD_LCR(P=0) - illegal S=ADM	A=DI S=HO_init_pend	A=DI S=HO_req_pend
A40	XID_CMD_LPM p=0 gs-active	A=CMD_LCR(P=0) - illegal S=ADM	A=DI S=LE_pend	A=CMD_LCR(P=0) - illegal S=ADM	A=CMD_LCR(P=0) - illegal S=ADM	A=DI S=HO_init_pend	A=DI S=HO_req_pend
A41	XID_RSP_LPM f=1 gs-x	A=CMD_LCR(P=0) - illegal S=ADM	A=DI S=LE_pend	A=CMD_LCR(P=0) - illegal S=ADM	A=CMD_LCR(P=0) - illegal S=ADM	A=CMD_LCR(P=0) - illegal S=ADM	A=DI S=HO_req_pend

Aircraft LME

ROW	Stimulus	ADM GS:none	LE_pend GS:p	ABM_single GS:o,n	ABM_mult GS:o,n	HO_init_pend GS:c,p	HO_req_pend GS:c,p
A42	XID_RSP_LPM f=1 gs-active	A=CMD_LCR(P=0) - illegal S=ADM	A=DI S=LE_pend	A=CMD_LCR(P=0) - illegal S=ADM	A=CMD_LCR(P=0) - illegal S=ADM	A=CMD_LCR(P=0) - illegal S=ADM	A=DI S=HO_req_pend
A43	XID_RSP_LPM f=0 gs-x	A=CMD_LCR(P=0) - illegal S=ADM	A=DI S=LE_pend	A=CMD_LCR(P=0) - illegal S=ADM	A=CMD_LCR(P=0) - illegal S=ADM	A=CMD_LCR(P=0) - illegal S=ADM	A=DI S=HO_req_pend
A44	XID_RSP_LPM f=0 gs-active	A=CMD_LCR(P=0) - illegal S=ADM	A=DI S=LE_pend	A=CMD_LCR(P=0) - illegal S=ADM	A=CMD_LCR(P=0) - illegal S=ADM	A=CMD_LCR(P=0) - illegal S=ADM	A=DI S=HO_req_pend
A45	XID_CMD_BCS p=0 gs-x gsaf=gs-active, no svcs, link only	A=CMD_LCR(P=0) - disconnected S=ADM	A=CMD_LE(P=1) (N2 equal 0) S=LE_pend	A= GS-c <-GS-x -do explicit subnetwork connection S= ABM_single	if GS-o A=GS-o die GS-c <- GS-n GS-n <- GS-x do explicit subnetwork connection -restart TG5 S= ABM_mult if GS-n A=GS-n die GS-n <- GS-x do explicit subnetwork connection S= ABM_mult	A= GS-c <-GS-x -do explicit subnetwork connection S= ABM_single	A= GS-c <-GS-x -do explicit subnetwork connection S= ABM_single
A46	XID_CMD_BCS p=0 gs-x or c gsaf=gs-active, svcs maintained	A=CMD_LCR(P=0) - disconnected S=ADM	A=CMD_LE(P=1) (N2 equal 0) S=Le_pend	A= GS-c <-GS-x S= ABM_single	if GS-o A=GS-o die GS-c <- GS-n GS-n <- GS-x -restart TG5 S= ABM_mult if GS-n A=GS-n die GS-n <- GS-x S= ABM_mult	A= GS-c <-GS-x - S= ABM_single	A= GS-c <-GS-x - S= ABM_single
A47	XID_CMD_BCS p=0 gs-x gsaf=gs-x, don't care for svcs	A=DI S=ADM	A=CMD_LE(P=1) (N2 equal 0) S=Le_pend	A=DI S=ABM_single	A=DI S=ABM_mult	A=DI S=HO_init_pend	A=DI S=HO_req_pend

Aircraft LME

ROW	Stimulus	ADM GS:none	LE_pend GS:p	ABM_single GS:o,n	ABM_mult GS:o,n	HO_init_pend GS:c,p	HO_req_pend GS:c,p
A48	XID_CMD_BCS p=0 gs-x gsaf=gs-active, new svcs	A=CMD_LCR(P=0) - disconnected S=ADM	A=CMD_LE(P=1) (N2 equal 0) S=Le_pend	A=GS-c <-GS-x -do explicit subnetwork connection - clear unknown SVC S=ABM_single	if GS-o A=GS-o die GS-c <- GS-n GS-n <- GS-x do explicit subnetwork connection - clear unknown SVC -restart TG5 S=ABM_mult if GS-n A=GS-n die GS-n <- GS-x do explicit subnetwork connection S=ABM_mult	A=GS-c <-GS-x -do explicit subnetwork connection S=ABM_single	A=GS-c <-GS-x -do explicit subnetwork connection S=ABM_single
A49	VME instructs an LME to die	A=DI S=ADM	A= once RSP to CMD_LE is received - send DISC S=ADM	A=DISC on c S=ADM	A=DISC on o,n S=ADM	A=DISC on c S=ADM	A=DISC on c S=ADM

*1: Once a link is established, T3 should be cancelled and therefore it should not generate any stimuli.

*2: The decision as to what constitutes acceptable or unacceptable parameters is a matter of policy of the aircraft's operator.

*3: The assumption here is that since we are only considering operation with a single provider the stimulus to establish a new link when one is already established is interpreted as a handoff command.

*4: This is a "make-before-break" principle. The consideration here is that if N2 has been exhausted we should establish a new link before disconnecting the old one.

*5: We interpret this case to mean that the ground system is telling the aircraft to abandon the handoff process and return to current ground station.

Ground LME

Explanations:

S=	State
A=	Action
GS-c=	Current ground station (either the only GS with which a link is established or the active link when in the process of handoff)
GS-n=	New ground station (just after a successful handoff this is the “freshly” established link)
GS-p=	Proposed ground station (during handoff this is the new GS with which the aircraft proposes to establish a link)
GS-o=	Old ground station (in a link overlap situation, this is the GS which was the current GS until the new link was established and for which the overlap timer TG5 has been started)
GS-x=	Other ground station, that is a GS which is not one of the active stations as explained in “GS:x,y”.
GS-active=	One of the active stations as explained in “GS:x,y”.
DI=	Discard the received input
ADM=	Asynchronous Disconnect Mode
LE_pend=	Link establishment pending
LPM_pend	Link parameter modification pending
ABM_single=	Link established with a single GS
ABM_mult=	Link established with two GSs at the same time. One link is with the current GS, the other is with the new GS. The link with GS-c will only be maintained for TG5 time interval.
HO_init_pend=	Initiated handoff pending state. In this state the link with the current GS is maintained while the link with the proposed GS is in the process of being set up but is not established yet.
HO_req_pend=	Requested handoff pending state. In this state the link with the current GS is maintained while the LME waits for the peer to initiate a handoff.
*n=	Reference number of an explanatory footnote
GS:x,y	List of GSs with which the a/c is communicating (and expecting semantically correct responses) in a particular state.

New stimulus for aircraft: VME indicates that link was successfully established via other system and that this LME should go into ADM. The LME shall inform the VME when it transitions from LE_pend to ABM_single. The a/c needs another state (the ABM-> ADM) to send a DISC when TG5 expires. The LME must also inform the VME whenever an autotune is being done so that the other LMEs “using this radio” can send a DISC immediately. Need other test cases for autotune during handoff as well.

Ground LME

Row	Stimulus	ADM GS:none	LPM_pend GS:p	ABM_single GS:c	ABM_mult GS:o,n	HO_init_pend GS:c,p	HO_req_pend GS:c,p
1	DM (GS-x)/F=0 1	A=DI S=same state					
2	DM (GS-active)/F=0 1	A=DI S=ADM	A=delete link S=ADM		A=delete relevant link, cancel TG5 S=ABM_single if DM sent on GS- n then send CMD_HO	if GS=p A=DI S=HO_init_pend if GS=c A=delete link S=ADM	if GS=p A=DI S=HO_req_pend if GS=c A=delete link S=ADM
3	DISC (GS-x)/P=0 1		A=DI S=LPM_pend	A= DI S=ABM_single	A= DI S=ABM_mult	A=DI S=HO_init_pend	A=DI S=HO_req_pend
4	DISC (GS-active)/P=0 1		A=delete link S=ADM	A=delete link S=ADM	A=delete relevant link, cancel TG5 S=ABM_single	if GS=p A=DI S=HO_init_pend if GS=c A=delete link S=ADM	if GS=p A=DI S=HO_req_pend if GS=c A=delete link S=ADM
5	T3 expiry		A=CMD_LPM (GS-c)/P=1 (increment N2) S=LPM_pend	A=DI (*1) S=ABM_single	A=DI (*1) S=ABM_mult	A=CMD_HO (GS-p)/P=1 (increment N2) S=HO_init_pend	A=CMD_HO (GS-p)/P=0 (increment N2) S=HO_req_pend
6	N2 exhausted (GS-active)		A=CMD_HO (GS-p) S=HO_???_pend (*G2)		if GS=o A= delete old link -cancel TG5 S=ABM_single if GS=n A= CMD_HO (GS-p) (*G2) S=HO_???_pend	if GS=p A=CMD_HO (GS- p2)/P=1 S=HO_init_pend A=DISC GS-c - delete current link S=ADM if GS=c A= DI S=HO_init_pend	if GS=p A=CMD_HO (GS- p2)/P=0 S=HO_req_pend A=DISC GS-c - delete link S=ADM if GS=c A=DI S=HO_req_pend
7	RSP_LCR /F=0		A=CMD_LCR (P=0), delete link(s), cancel TG5 if necessary P=illegal S=ADM				

Ground LME

Row	Stimulus	ADM GS:none	LPM_pend GS:p	ABM_single GS:c	ABM_mult GS:o,n	HO_init_pend GS:c,p	HO_req_pend GS:c,p
8	RSP_LCR (GS-active)/F=1		A=CMD_LPM S=LPM A=DI S=ABM_single A=DISC (P=0), delete link S=ADM	A=CMD_LCR (P=0), delete link(s), cancel TG5 if necessary P=unexpected S=ADM (*G1)		A=CMD_HO (P=1) S=HO_init_pend A=CMD_HO (P=0) S=HO_req_pend A=process code S=ABM_single A=DISC (P=0), delete link S=ADM	A=CMD_LCR (P=0), delete link, cancel T3 P=unexpected S=ADM (*G1)
9	RSP_LCR (GS-x)/F=1		A=CMD_LCR (P=0), delete link(s), cancel TG5 if necessary P=unexpected S=ADM (*G1)				
10	CMD_LCR (GS-x)/p=0 **more cases needed		A=process S=as required			A=DI S=HO_init_pend	A=process S=as required
11	CMD_LCR /p=1		A=RSP_LCR (F=1), delete link(s), cancel TG5 if necessary P=illegal S=ADM				
12	XID_CMD_LE (P=1) acceptable	A=RSP_LE, delete old link(s), create new link, cancel TG5 if necessary S=ABM_single					
13	XID_CMD_LE (P=1) unacceptable	A=RSP_LCR, delete link(s) , cancel TG5 if necessary P=bad parameter S=ADM					
14	XID_CMD_LE (P=0)	A=DI RSP_LCR P=illegal S=ADM	A=RSP_LCR, delete link(s) P=illegal S=ADM			A=DI S=HO_init_pend	
15	XID_RSP_HO (F=0)		A=DI CMD_LCR(P=0) - illegal				
16	XID_CMD_HO (P=1) gs-x acceptable	A=RSP_LCR P=disconnected S=ADM	A=RSP_HO, create link S=ABM_mult		A=RSP_LCR P=unspecified system reason (delay for remaining TG5) S=ABM_mult	A=RSP_HO, create link S=ABM_mult	

Ground LME

Row	Stimulus	ADM GS:none	LPM_pend GS:p	ABM_single GS:c	ABM_mult GS:o,n	HO_init_pend GS:c,p	HO_req_pend GS:c,p
17	XID_CMD_HO (P=1) gs-x unacceptable		A=RSP_LCR P=bad param S=ABM_single			A=RSP_LCR P=bad param S=ABM_single	
18	XID_CMD_HO (P=1) gs-active acceptable		A=RSP_LCR P=unspecified local reason (max delay) S=ABM_single			A=RSP_LCR P=unspecified local reason (max delay) S=ABM_single	
19	XID_CMD_HO (P=1) gs-active unacceptable						
20	RSP_LE	A=RSP_LCR, delete links(s), cancel TG5 if necessary P=illegal S=ADM					
21	TG5 expiry on (GS-o)	A=DI S=ADM	A=DI S=same state	A=delete old link S=ABM_single	A=DI S=same state		
22	LME command to perform handoff		A=CMD_HO (GS-p) S=HO_???_pend (*G2)	A=DI S=ABM_mult	A=DI S=HO_init_pend	A=DI S=HO_req_pend	
23	RSP_HO (GS-x)/F=1, parameters acceptable (*2)	A=CMD_LCR P=disconnected S=ADM	A=CMD_LCR, delete links(s), cancel TG5 if necessary P=unexpected S=ADM (*G1)			A=start TG5, create new link S=ABM_mult	A=CMD_LCR, delete link P=unexpected S=ADM (*G1)
24	RSP_HO (GS-x)/F=1, parameters not acceptable (*2)					A= DISC GS-x CMD_HO(P=1) GS-p2 S=HO_init_pend	
25	RSP_HO (GS-active)/F=1 parameters acceptable (*2)		A=CMD_LCR, delete links(s), cancel TG5 if necessary P=unexpected S=ADM (*G1)			if GS=c A=CMD_LCR P=unspecified local reason (max delay) S=ABM_single if GS=p A= create link, start TG5 S=ABM_mult	

Ground LME

Row	Stimulus	ADM GS:none	LPM_pend GS:p	ABM_single GS:c	ABM_mult GS:o,n	HO_init_pend GS:c,p	HO_req_pend GS:c,p
26	RSP_HO (GS-active)/F=1 parameters not acceptable					if GS=c A=CMD_LCR P=unspecified local reason (max delay) S=ABM_single A= DISC GS-x CMD_HO(P=1) GS-p2 S=HO_init_pend	
27	INFO (GS-x)/P=0 1	A=DM/F=0 S=same state				A=CMD_HO (GS-p)/P=1 S=HO_init_pend (increment N2)	A=CMD_HO (GS-p)/P=0, (increment N2) S=HO_req_pend
28	INFO (GS-active)/P=0 1		A=RR(by appropriate DLE) S=same state			If GS=c A=RR(by DLE) S=HO_init_pend If GS=p A=CMD_HO (GS-p)/P=1, (increment N2) S=HO_init_pend (increment N2)	If GS=c A=RR (by DLE) S=HO_req_pend If GS=p A=CMD_HO (GS-p)/P=1, (increment N2) S=HO_req_pend
29	TEST (GS-x)/P=1	A=TEST/F=1 S=same state					
30	TEST (GS-active)/P=1						
31	TEST (GS-x)/F=1	A=DI S=same state					
32	TEST (GS-active)/F=1						
33	all downlinks	A=process signal quality analysis S=same state					
34	XID_CMD_HO p=0 gs-x acceptable	A=CMD_LCR P=disconnected S=ADM	A=CMD_HO P=1 S=HO_init_pend		A=CMD_LCR P=unspecified system reason (delay for TG5) S=ABM_mult	A=DI S=HO_init_pend	A=CMD_HO P=1 S= HO_init_pend

Ground LME

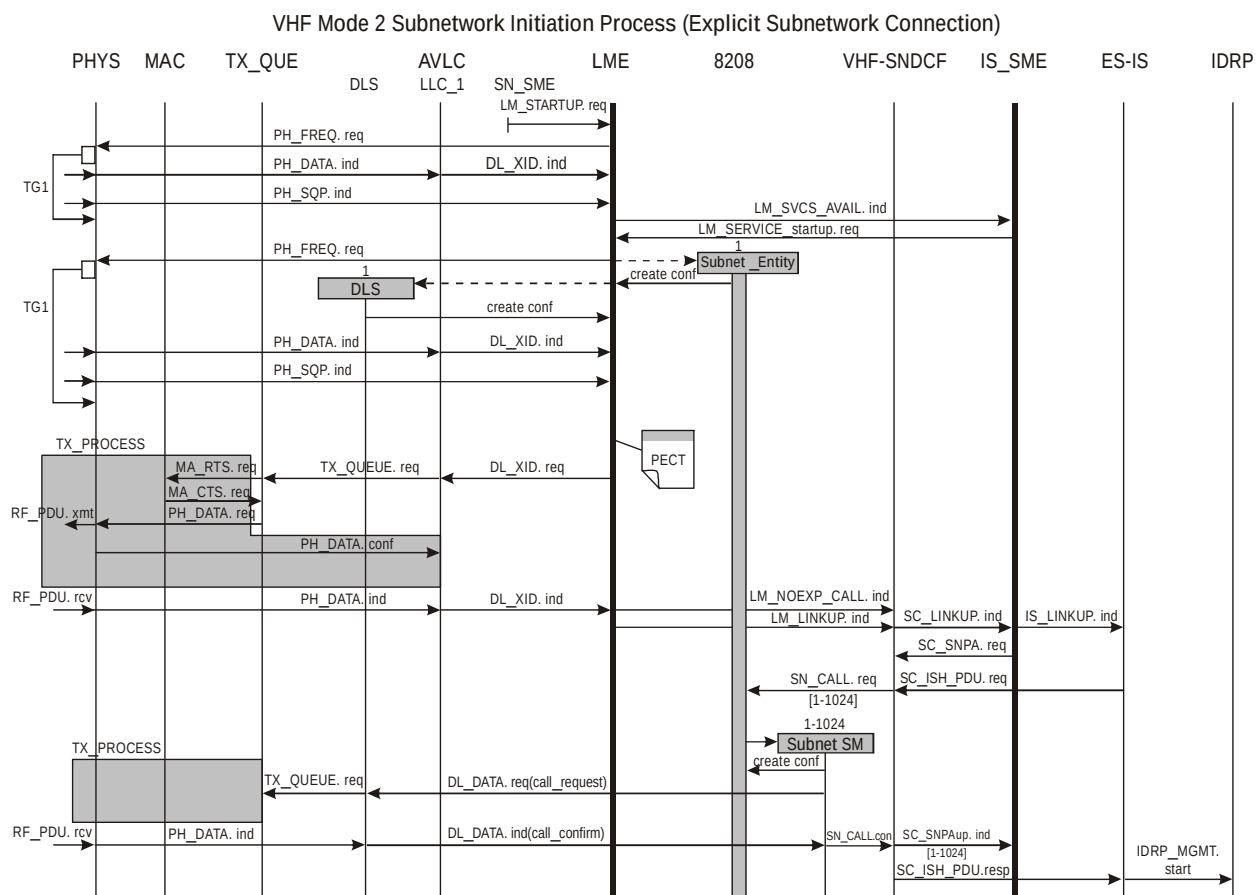
Row	Stimulus	ADM GS:none	LPM_pend GS:p	ABM_single GS:c	ABM_mult GS:o,n	HO_init_pend GS:c,p	HO_req_pend GS:c,p
35	XID_CMD_HO p=0 gs-x unacceptable		A=CMD_LCR P=bad param S=ABM_single				A=CMD_LCR P=bad param S=ABM_single
36	XID_CMD_HO p=0 gs-active acceptable		A=CMD_LCR P=unspecified local reason (max delay) S=ABM_single A=CMD_HO P=1 S=HO_init_pend				A=CMD_HO P=1 S=HO_init_pend A=CMD_LCR P=bad param S=ABM_single
37	XID_CMD_HO p=0 gs-active unacceptable		A=CMD_HO P=1 S=HO_init_pend				
38	XID_CMD_LPM p=1 gs-x	A=DI RSP_LCR P=illegal S=ADM	A=RSP_LCR, delete links(s), cancel TG5 if necessary P=illegal S=ADM				
39	XID_CMD_LPM p=1 gs-active	DI or illegal				A= DI S=HO_init_pend	
40	XID_CMD_LPM p=0 gs-x						
41	XID_CMD_LPM p=0 gs-active						
42	XID_RSP_LPM f=1 gs-x	A=CMD_LCR P=disconnected S=ADM	A=CMD_LCR, delete links(s), cancel TG5 if necessary P=unexpected S=ADM (*G1)				
43	XID_RSP_LPM f=1 gs-active		A=process S=ABM_single	A=CMD_LCR, delete links(s), cancel TG5 if necessary P=unexpected S=ADM (*G1)			
44	XID_RSP_LPM f=0		A=CMD_LCR, delete links(s), cancel TG5 if necessary P=illegal S=ADM				
45	XID_CMD_BCS p=0						

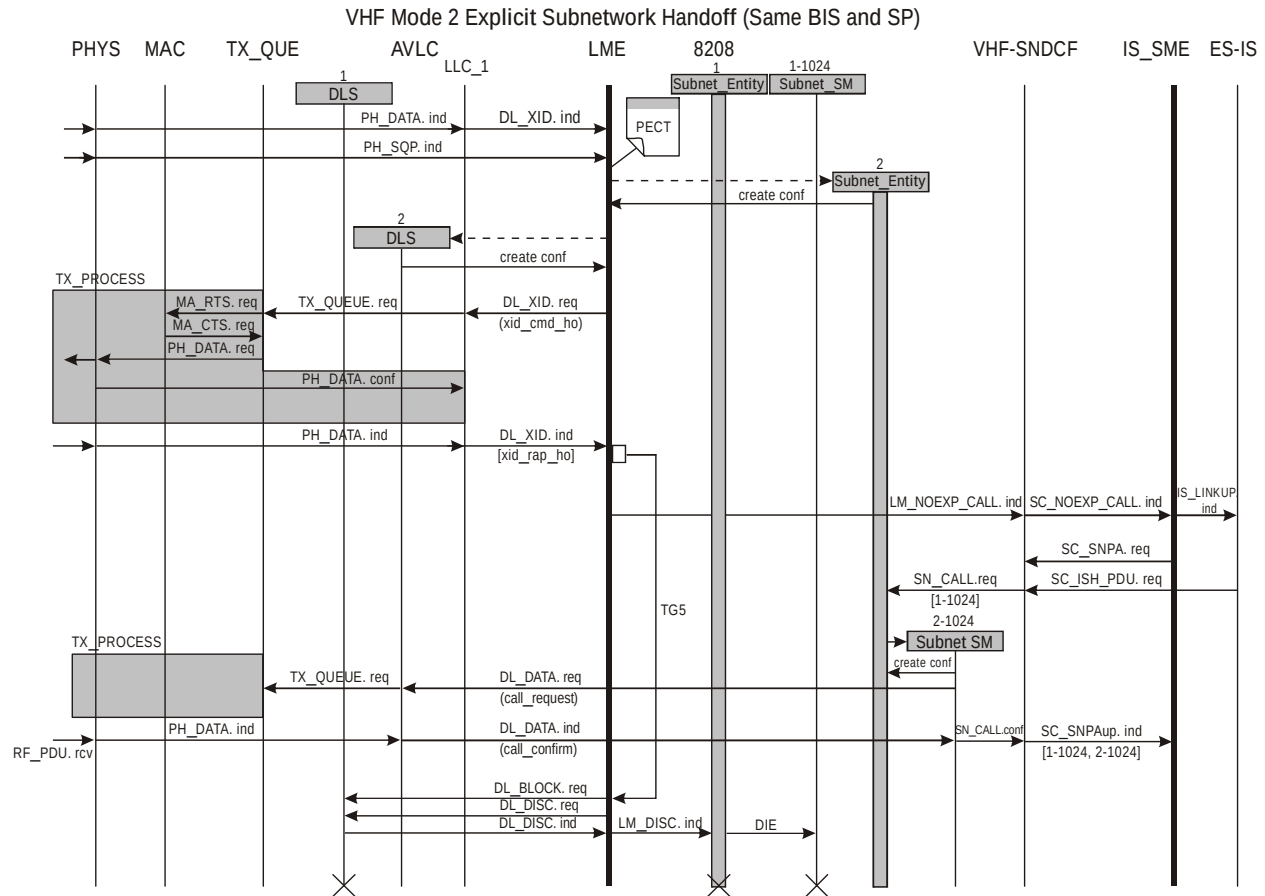
Ground LME

- *1: Once a link is established, T3 should be cancelled and therefore it should not generate any stimuli.
- *2: The decision as to what constitutes acceptable or unacceptable parameters is a matter of policy of the system's operator.
- *3: The assumption here is that since we are only considering operation with a single provider the stimulus to establish a new link when one is already established is interpreted as a handoff command.
- *4: This is a "make-before-break" principle. The consideration here is that if N2 has been exhausted we should establish a new link before disconnecting the old one.
- *5: We interpret this case to mean that the ground system is telling the aircraft to abandon the handoff process and return to current ground station.
- * G1: If the sequence number is identical to the most recently received XID, which is identical to this sequence number, then the XID shall be discarded instead of the indicated action occurring.
- G2: If the LME supports initiating handoffs, then the action is an XID_CMD_HO (P=1) and the next state is HO_init_pend; otherwise, the action is an XID_CMD_HO (P=0) and the next state is HO_req_pend.
- ** : If the LME deletes all links or if a DLE deletes the remaining link, the LME will enter the ADM state (e.g. in response to an error); when the link is torn down, the packet layer will fail, which will take down the SNDCF context, and finally the routing protocol will update the FIB. An aircraft LME will immediately try to re-establish communications by sending an XID_CMD_LE. A ground LME will do nothing and just wait for the aircraft to send the XID_CMD_LE.
- ** : Illegal, unexpected, disconnected, and bad parameter LCRs shall be sent with maximum delay.
- ** : Deleting the link cancels the T3 timer if it was running on that link.

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VDL MODE 2 MSCs



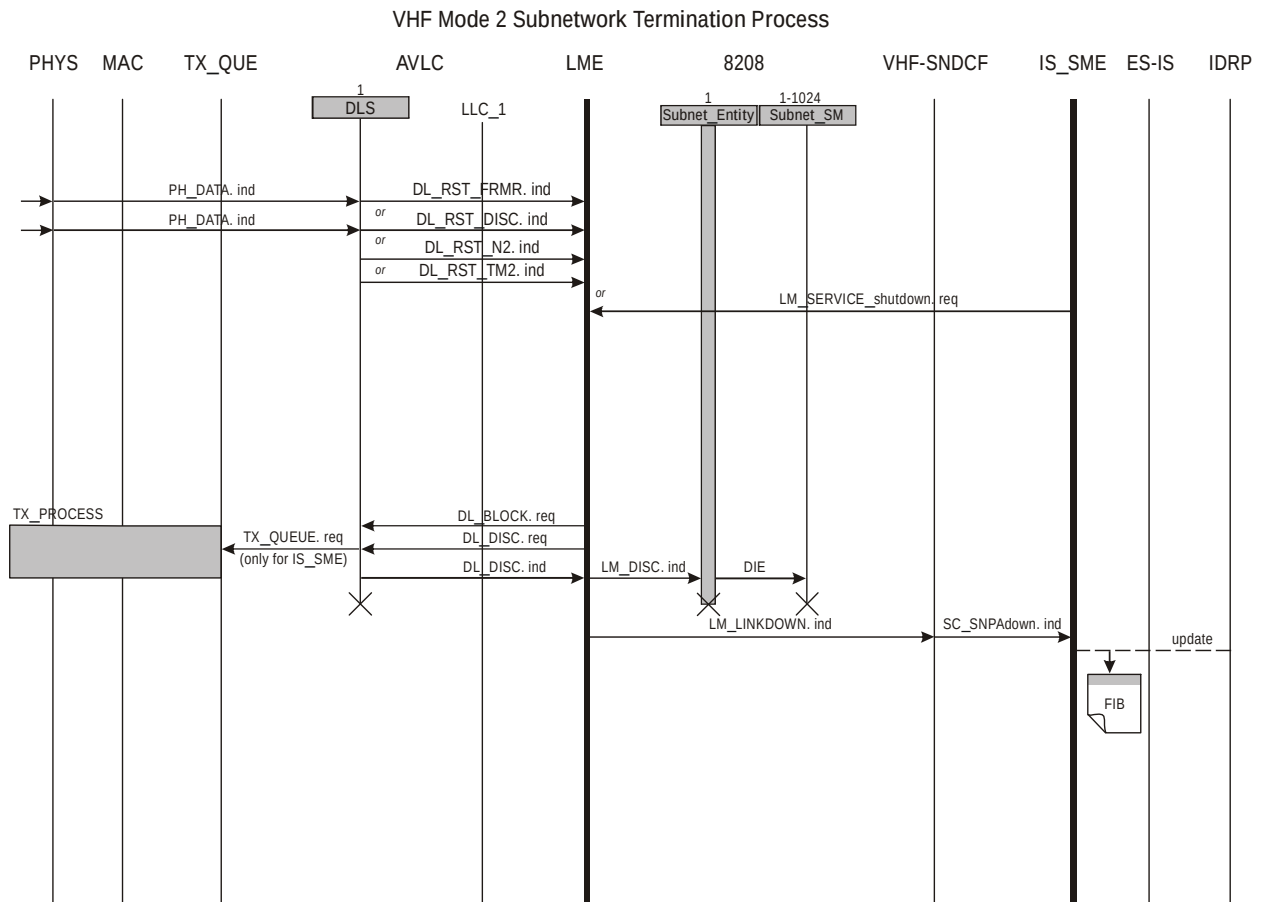


The diagram illustrates the sequence of events for a packet transmission and error handling across several protocol layers:

- PHY, MAC, TX_QUEUE:**
 - TX_QUEUE receives **MA_RTS.req**, **MA_CTS.req**, and **PH_DATA.req** from MAC.
 - TX_QUEUE sends **TX_QUEUE.req** to LLC_1.
 - TX_QUEUE processes **PH_DATA.conf** and sends **PH_DATA.ind** to LLC_1.
- LLC_1:**
 - LLC_1 receives **PH_DATA.ind** and **PH_SQP.ind** from TX_QUEUE.
 - LLC_1 sends **DL_XID.ind** to LME.
 - LLC_1 receives **DL_XID.req** from LME.
 - LLC_1 sends **DL_XID.conf** to TX_QUEUE.
 - LLC_1 receives **DL_BLOCK.req**, **DL_DISC.req**, and **DL_DISC.ind** from LME.
- LME:**
 - LME receives **DL_XID.ind** from LLC_1.
 - LME sends **DL_XID.req** to 8208.
 - LME receives **LM_SUBNET.req** from 8208.
 - LME sends **LM_SUBNET.ind** to 8208.
 - LME receives **LM_DISC.ind** from 8208.
 - LME sends **DL_BLOCK.req**, **DL_DISC.req**, and **DL_DISC.ind** to LLC_1.
- 8208:**
 - 8208 contains **Subnet Entity** and **Subnet SM** (1-1024).
 - 8208 sends **create conf** to **Subnet Entity**.
 - 8208 receives **LM_NOEXP_CALL.ind** from VHF-SNDCP.
 - 8208 sends **LM_NOEXP_CALL.ind** to VHF-SNDCP.
 - 8208 receives **SN_CALL.req [1-1024]** from VHF-SNDCP.
 - 8208 sends **LM_SUBNET.req** to LME.
 - 8208 receives **LM_SUBNET.ind** from LME.
 - 8208 sends **SN_CALL.conf** to VHF-SNDCP.
 - 8208 receives **LM_DISC.ind** from LME.
 - 8208 sends **DIE** to VHF-SNDCP.
- VHF-SNDCP:**
 - VHF-SNDCP receives **SC_SNPA.req** and **SC_ISH_PDU.req** from IS_SME ES-IS.
 - VHF-SNDCP sends **LM_NOEXP_CALL.ind** to 8208.
 - VHF-SNDCP receives **SN_CALL.req [1-1024]** from 8208.
 - VHF-SNDCP sends **SN_CALL.conf** to 8208.
 - VHF-SNDCP receives **SC_SNPAup.ind** from IS_SME ES-IS.
- IS_SME ES-IS:**
 - IS_SME ES-IS sends **IS_LINKUP.ind** to VHF-SNDCP.
 - IS_SME ES-IS sends **SC_SNPA.req** and **SC_ISH_PDU.req** to VHF-SNDCP.
 - IS_SME ES-IS receives **SC_SNPAup.ind** from VHF-SNDCP.

Additional details from the diagram:

- TX_PROCESS:** A block in the PHY/MAC layer that receives **MA_RTS.req**, **MA_CTS.req**, and **PH_DATA.req**.
- DL_XID.ind:** A signal that is sent from LLC_1 to LME and from LME to 8208.
- DL_XID.req:** A request sent from LME to LLC_1.
- DL_XID.conf:** A configuration sent from LLC_1 to TX_QUEUE.
- DL_BLOCK.req:** A request sent from LME to LLC_1.
- DL_DISC.req:** A request sent from LME to LLC_1.
- DL_DISC.ind:** An indication sent from LME to LLC_1.
- LM_NOEXP_CALL.ind:** An indication sent from VHF-SNDCP to 8208.
- LM_SUBNET.req:** A request sent from 8208 to LME.
- LM_SUBNET.ind:** An indication sent from LME to 8208.
- SN_CALL.req [1-1024]:** A request sent from VHF-SNDCP to 8208.
- SN_CALL.conf:** A configuration sent from 8208 to VHF-SNDCP.
- SC_SNPA.req:** A request sent from IS_SME ES-IS to VHF-SNDCP.
- SC_ISH_PDU.req:** A request sent from IS_SME ES-IS to VHF-SNDCP.
- SC_SNPAup.ind:** An indication sent from IS_SME ES-IS to VHF-SNDCP.
- IS_LINKUP.ind:** An indication sent from IS_SME ES-IS to VHF-SNDCP.
- DIE:** A signal sent from 8208 to VHF-SNDCP.



PART II

Detailed technical specifications

1. DEFINITIONS AND SYSTEM CAPABILITIES

The very high frequency (VHF) digital link (VDL) provides both voice and data service capability. The data capability is a constituent mobile subnetwork of the aeronautical telecommunication network (ATN). In addition, the VDL may provide non-ATN functions. The Standards and Recommended Practices (SARPs) for the VDL are defined in Annex 10, Volume III, Part I, Chapter 6. The SARPs contain introductory and general regulatory information. Additionally, the SARPs include detailed standards of the physical layer protocols and services. This manual contains detailed specifications of link layer protocols and services, subnetwork layer protocols and services and VDL mobile subnetwork dependent convergence function (SND CF).

Note.— Where appropriate, references to Annex 10, Volume III, Part I, Chapter 6, have been included in this manual.

1.1 Definitions

Aeronautical telecommunication network. An internetwork architecture that allows ground, air-ground, and aircraft data subnetworks to interoperate by adopting common interface services and protocols based on the International Organization for Standardization (ISO) Open Systems Interconnection (OSI) Reference Model.

Aircraft address. A unique combination of 24 bits available for assignment to an aircraft for the purpose of air-ground communications, navigation and surveillance.

Asynchronous balanced mode. A balanced operational mode in which a data link connection has been established between two service access points. Either data link entity can send commands at any time and initiate responses without receiving permission from the peer data link entity on the connection.

Asynchronous disconnected mode. A balanced non-operational mode in which no logical data link connection exists between two link layer entities. A connection must be established before data can be sent.

ATN router. An intermediate system used to interconnect subnetworks conforming to the lower three layers of the OSI reference model.

Autotune function. The function, performed by the link management entity, allows a ground station to command an aircraft to change frequencies.

Broadcast. A transmission intended to be received by all stations.

Broadcast handoff. The process by which a ground LME commands certain aircraft to execute a link handoff and optionally maintain its current subnetwork connections, without the need to explicitly confirm the link handoff or optionally the subnetwork connection maintenance.

Broadcast link handoff. The process by which a ground LME commands certain aircraft to execute a link handoff to a specific ground station without the need to explicitly confirm the link handoff.

Broadcast subnetwork connection handoff. The process by which a ground LME commands certain aircraft to execute a link handoff to a specific ground station and maintain its current subnetwork connections without the need to explicitly confirm the link handoff or the subnetwork connection maintenance.

Current link (or current ground station). Either the ground-to-aircraft link or the active link when in the process of a handoff.

Data circuit-terminating equipment (DCE). A DCE is a network provider equipment used to facilitate communications between DTEs.

Data link entity (DLE). A protocol state machine capable of setting up and managing a single data link connection.

Data link service (DLS) sub-layer. The sub-layer that resides above the MAC sub-layer. The DLS manages the transmit queue, creates and destroys DLEs for connection-oriented communications, provides facilities for the LME to manage the DLS, and provides facilities for connectionless communications.

Data terminal equipment (DTE). A DTE is an endpoint of a subnetwork connection.

Effective data rate. The actual instantaneous data throughput realized after overheads imposed by bit stuffing and by any forward error correction encoding, but not retransmissions.

Expedited subnetwork connection establishment. The process by which an aircraft DTE establishes a subnetwork connection with a ground DTE with which it does not have a subnetwork connection during link establishment (or aircraft-initiated handoff) by inserting the CALL REQUEST packet and its response in the link establishment (or aircraft-initiated handoff) frame and its response.

Expedited subnetwork connection maintenance. The process by which an aircraft DTE maintains a subnetwork connection with a DTE with which it has a subnetwork connection during link handoff by inserting the CALL REQUEST packet and its response in the link handoff frame and its response.

Explicit subnetwork connection establishment. The process by which an aircraft DTE establishes a subnetwork connection with a ground DTE with which it does not have a subnetwork connection only after completing the link establishment (or handoff).

Explicit subnetwork connection maintenance. The process by which an aircraft DTE maintains a subnetwork connection with a ground DTE with which it has a subnetwork connection only after completing the link handoff.

Frame. The link layer frame is composed of a sequence of address, control, FCS and information fields. For VDL Mode 2, these fields are bracketed by opening and closing flag sequences, and a frame may or may not include a variable-length information field.

Initiated handoff. The transmission process by which a station initiates link handoff.

Internetworking protocol. A protocol that transfers data packets between intermediate systems (IS) and end systems (ES) interconnected by subnetworks and that is supported by the routing protocols and addressing plan.

Link. A link connects an aircraft DLE and a ground DLE and is uniquely specified by the combination of aircraft DLS address and the ground DLS address. A different subnetwork entity resides above every link endpoint.

Link establishment. The process by which an aircraft and a ground LME discover each other, determine to communicate with each other, decide upon the communication parameters, create a link and initialize its state before beginning communications.

Link handoff. The process by which peer LMEs, already in communication with each other, create a link between an aircraft and a new ground station before disconnecting the old link between the aircraft and the current ground station.

Link layer. The layer that lies immediately above the physical layer in the Open Systems Interconnection protocol model. The link layer provides for the reliable transfer of information across the physical media. It is subdivided into the data link sub-layer and the media access control sub-layer.

Link management entity (LME). A protocol state machine capable of acquiring, establishing and maintaining a connection to a single peer system. An LME establishes data link and subnetwork connections, “hands-off” those connections, and manages the media access control sub-layer and physical layer. An aircraft LME tracks how well it can communicate with the ground stations of a single ground system. An aircraft VME instantiates an LME for each ground station that it monitors. Similarly, the ground VME instantiates an LME for each aircraft that it monitors. An LME is deleted when communication with the peer system is no longer viable.

Media access control (MAC). The sub-layer that acquires the data path and controls the movement of bits over the data path.

Multicast. A transmission intended to be received by multiple stations.

Network layer. The layer that provides the upper layers with independence from the data transmission and routing functions used to connect systems. The network layer is responsible for routing and relaying functions both within any subnetwork and throughout the aeronautical internetworking domain.

New link (or new ground station). After successful completion of handoff (or link establishment), the new “current” link.

N(r). The receive sequence number at the link layer, which indicates the sequence number of the next expected frame (and explicitly acknowledges all lesser numbered frames).

N(s). The send sequence number at the link layer, which indicates the sequence number associated with a transmitted frame.

Old link (or old ground station). Following link establishment during a handoff, the link that was previously the “current” link becomes the “old” link.

Physical layer. The lowest level layer in the Open Systems Interconnection protocol model. The physical layer is concerned with the transmission of binary information over the physical medium (e.g. VHF radio).

Private parameters. The parameters that are contained in exchange identity (XID) frames and that are unique to the VHF digital link environment.

Proposed link (or proposed ground station). The link being negotiated (in a handoff) to replace the current link.

Quality of service. The information relating to data transfer characteristics used by various communication protocols to achieve various levels of performance for network users.

Requested handoff. The one-transmission process by which a station requests its peer entity to initiate a link handoff.

Service primitives. The status and control information that must be available to the receiving entity to properly process incoming information. A service primitive may contain parameters. If parameters exist, they describe information that is defined either as mandatory (M) or optional (O) for conformance to a particular communications standard.

Service provider. An entity at a layer that provides services to the layer above. These services are provided at service access points through the use of service primitives.

Service user. An entity at a layer that makes use of the services that are provided at service access points by the layer below through the use of service primitives.

Subnetwork connection. A long-term association between an aircraft DTE and a ground DTE using successive virtual calls to maintain context across link handoffs.

Subnetwork connection maintenance. The process by which the VDL SNDCF maintains subnetwork context from one subnetwork connection to the next during handoffs.

Subnetwork connection management. The process by which the VDL SNDCF initially establishes a connection and then maintains it during handoffs.

Subnetwork dependent convergence function(SNDCF). A function that matches the characteristics and services of a particular subnetwork to those characteristics and services required by the internetwork facility.

Subnetwork entity. In this document, the phrase “ground DCE” will be used for the subnetwork entity in a ground station communicating with an aircraft; the phrase “ground DTE” will be used for the subnetwork entity in a ground router communicating with an aircraft station; and, the phrase “aircraft DTE” will be used for the subnetwork entity in an aircraft communicating with the station. A subnetwork entity is a packet layer entity as defined in ISO 8208.

Subnetwork layer. The layer that establishes, manages and terminates connections across a subnetwork.

System. A VDL-capable entity. A system comprises one or more stations and the associated VDL management entity. A system may either be an aircraft system or a ground system.

T. The baud period or 1/baud rate.

Unicast. A transmission addressed to a single station.

VDL management entity (VME). A VDL-specific entity that provides the quality of service requested by the ATN-defined SN_SME. A VME uses the LMEs (that it creates and destroys) to enquire the quality of service available from peer systems.

VDL station. A VDL-capable entity. A VDL station may either be an aircraft station or a ground station. A VDL station is a physical entity that transmits and receives frames over the air-ground interface and comprises, at a minimum: a physical layer, media access control sub-layer, and a unique DLS address. The particular initiating process (i.e. DLE or LME) in the VDL station cannot be determined by the source DLS address. The particular destination process cannot be determined by the destination DLS address. These can only be determined by the context of these frames as well as the current operational state of the DLEs.

1.2 Radio channels and functional channels

Note.— The radio frequency range for the aircraft station and ground station is contained in the VDL SARPs, Annex 10, Volume III, Part I, Chapter 6. The common signalling channel frequency for VDL Mode 2 is specified in Annex 10, Volume V, Part I, Chapter 6.

1.3 System capabilities

Note.— The VDL communication functions shall meet the general requirements standardized in the VDL SARPs, Annex 10, Volume III, Part I, Chapter 6. Guidance material for the VDL is included as an attachment to this manual.

1.4 Air-ground VHF digital link communications system characteristics

Note.— The characteristics of the air-ground VDL communications system used in the international aeronautical mobile service shall be in conformity with the standards of the VDL SARPs, Annex 10, Volume III, Part I, Chapter 6. This specification includes the definition of radio frequency bands, channel spacing and emissions polarization.

2. SYSTEM CHARACTERISTICS OF THE GROUND INSTALLATION

Note.— Annex 10, Volume III, Part I, Chapter 6, contains the SARPs relating to:

- the radio frequency stability of VDL ground station equipment;*
- the recommended effective radiated power of the VDL ground station equipment;*
- spurious emissions standards for the VDL ground station equipment; and*
- adjacent channel emissions standards for the VDL ground installation.*

3. SYSTEM CHARACTERISTICS OF THE AIRCRAFT INSTALLATION

Note.— Annex 10, Volume III, Part I, Chapter 6, contains the SARPs relating to:

- the radio frequency stability of VDL aircraft station equipment;*
- the effective radiated power of the VDL aircraft station equipment;*
- spurious emissions standards for the VDL aircraft station equipment;*
- adjacent channel emissions standards for the VDL aircraft installation; and*
- specified error rates, receiving function sensitivity, undesired signal rejection, and interference immunity standards for the VDL aircraft station.*

4. PHYSICAL LAYER PROTOCOLS AND SERVICES

4.1 Functions

Note.— The general functions provided by the VDL physical layer are contained in Annex 10, Volume III, Part I, Chapter 6.

4.1.1 Detailed notification services specification for Mode 2

As standardized in the VDL SARPs, Annex 10, Volume III, Part I, Chapter 6, the operational parameters of the equipment shall be monitored at the physical layer. Signal quality analysis shall be performed on the demodulator evaluation process and on the receive evaluation process; this analysis shall be normalized between a scale of 0 and 15, where 0 to 3 is considered poor, 4 to 12 is adequate, and 13 to 15 is excellent.

Note.— Processes that may be evaluated in the demodulator include BER, SNR and timing jitter. Processes that may be evaluated in the receiver include received signal level and group delay.

4.1.1.1 Recommendation.— *The signal quality analysis should be based on received signal strength.*

4.2 Mode 2 physical layer

Note.— The standards of the VDL Mode 2 physical layer are provided in the VDL SARPs, Annex 10, Volume III, Part I, Chapter 6.

5. LINK LAYER PROTOCOLS AND SERVICES

5.1 General information

Note.— General information regarding the link layer protocols including functionality and services is standardized in the VDL SARPs, Annex 10, Volume III, Part I, Chapter 6. The MAC sub-layer for Mode 2 is specified in section 5.2 of this manual. The data link service sub-layer for Mode 2 is specified in section 5.3 of this manual and the VDL management entity for VDL Mode 2 is specified in section 5.4.

5.2 Mode 2 MAC sub-layer

5.2.1 General description

Note 1.— A general description of the VDL Mode 2 MAC sub-layer is standardized in the VDL SARPs, Annex 10, Volume III, Part I, Chapter 6.

Note 2.— The service specification for the MAC sub-layer is modeled on the MAC Service Definition (ISO DP 10039).

5.2.2 MAC services for Mode 2

5.2.2.1 **Multiple access.** The MAC sub-layer shall implement a non-adaptive p-persistent CSMA algorithm to equitably allow all stations the opportunity to transmit while maximizing system throughput, minimizing transit delays, and minimizing collisions.

5.2.2.2 **Channel congestion.** The MAC sub-layer shall notify the VME sub-layer whenever channel congestion is detected (see 5.2.3.2).

5.2.3 MAC service system parameters for Mode 2

The MAC service shall implement the system parameters defined in Table II-5-1.¹

5.2.3.1 **Timer TM1 (inter-access delay timer).** Timer TM1 shall be set to the time (TM1) that a MAC sub-layer will wait between consecutive access attempts (see 5.2.4.2). This timer shall be started if it is not already running and the channel is idle after an unsuccessful access attempt. The timer shall be cancelled if the channel becomes busy. When the timer expires another access attempt shall be made.

5.2.3.2 **Timer TM2 (channel busy timer).** Timer TM2 shall be set to the maximum time (TM2) that a MAC sub-layer will wait after receiving a request to transmit. This timer shall be started if it is not already running, when the MAC sub-layer receives a request for transmission. The timer shall be cancelled upon a successful access attempt. When the timer expires, the VME shall be informed that the channel is congested.

5.2.3.3 **Parameter p (persistence).** The parameter p ($0 < p \leq 1$) shall be the probability that the MAC sub-layer will transmit on any access attempt (see 5.2.4.2).

5.2.3.4 **Counter M1 (access attempts counter).** M1 defines the maximum number of attempts that a MAC sub-layer will make for any transmission request. The Counter M1 shall be cleared upon: system initialization, Timer TM2 expiring, or a successful access attempt. The counter shall be incremented after every unsuccessful access attempt. When the counter reaches the maximum number of attempts (M1), authorization to transmit shall be granted as soon as the channel is idle.

5.2.4 Description of procedures for Mode 2

5.2.4.1 **Channel sensing.** Before performing an access attempt (see section 5.2.4.2), the MAC sub-layer shall verify that the channel is idle.

5.2.4.2 **Access attempt.** An access attempt is defined as the MAC layer determining whether the transmitter should be immediately enabled, with probability p . The result of an access attempt will be either *successful* or *unsuccessful*. If the access attempt is successful then the transmission shall begin immediately. An access attempt shall be made when Timer TM1 expires and the channel is idle or when a transmission request arrives from the DLS while the channel is idle or if the channel is determined to become idle while a message is queued for transmission.

1. All tables in Part II are located at the end of this manual.

5.3 Mode 2 data link service sub-layer

5.3.1 General information for Mode 2

The DLS shall support bit-oriented simplex air-ground communications using the aviation VHF link control (AVLC) protocol specified in this section.

Note.— The DLS for Mode 2 is derived from HDLC, as specified by ISO 3309, ISO 4335, ISO 7809, and ISO 8885. Any definitions of service are derived from the OSI Data Link Service Definition ISO 8886.3. AVLC is a variant of HDLC and derived from, but is not fully specified by, options 1, 3.2, 4, 7, and 12 of ISO 7809. Explicit references to these documents are made later in this section.

5.3.2 Services for Mode 2

Note.— In this section, the specific functions of the DLS are described with no reference to service primitives used for these functions. The link layer service primitives and protocol state machine are described in the VDL Guidance Material for Mode 2.

5.3.2.1 Frame sequencing. The receiving DLS sub-layer shall ensure that duplicated frames are discarded and all frames are delivered exactly once over a point-to-point connection.

Note.— Sequence numbers are included in the frame format to facilitate this service.

5.3.2.2 Error detection. The DLS sub-layer shall ensure that all frames corrupted during transmission are detected and discarded.

Note.— FCS is included in the frame format to facilitate this service.

5.3.2.3 Station identification. The DLS sub-layer shall accept over a point-to-point connection only frames that are addressed to it.

Note.— Unique source and destination addresses are included in the frame format to facilitate this service.

5.3.2.4 Broadcast addressing. The VDL shall support broadcast addresses that shall be recognized and acted upon by all appropriate receivers.

5.3.2.5 Data transfer. Data shall be transferred in the information fields of VDL INFO, UI and XID frames, per ISO 7809. The link layer shall process the largest packet size, specified in section 6.4 of this document, without segmenting. Only one data link user packet shall be contained in an INFO or UI.

5.3.3 AVLC data link service protocol specification for Mode 2

5.3.3.1 Frame format. AVLC frames shall conform to ISO 3309 frame structure except as specified in Table II-5-2.

5.3.3.2 Address structure. The address field shall consist of eight octets. As described in ISO 3309, option 7, the least significant (first transmitted) bit of each octet shall be reserved for address extension. When set to binary 0 it shall indicate that the rest of the following octet is an extension of the address field. The presence of binary 1 in the first transmitted bit of the address octet shall indicate that the octet is the final octet of the address field.

5.3.3.3 **Address fields.** The address field shall contain a destination address field and a source address field. The destination address field shall contain a destination DLS address or a broadcast address. The source address field shall contain a DLS address. There is a status bit in the source address and a status bit in the destination address field, which shall be set by the transmitting station to reflect status information. The status bits and address details are defined in 5.3.3.3.1 to 5.3.3.3.7.

Note.— See Part I of this manual for information on address field.

5.3.3.3.1 **Air-ground status bit.** The status bit in the destination address field (bit 2, octet 1) shall be the air-ground bit. The air-ground bit shall be set to 0 to indicate that the transmitting station is airborne. It shall be set to 1 to indicate that the transmitting station, either fixed or mobile, is on the ground. The default value for the air-ground bit shall be 0 for aircraft that do not provide this information at the link level; the value shall be 1 for ground stations.

5.3.3.3.2 **Command/response status bit.** The status bit in the source address field (bit 2, octet 5) shall be the command/response (C/R) bit. The C/R bit shall be set to 0 to indicate a command frame and set to 1 to indicate a response frame.

5.3.3.3.3 **Data link service addresses.** The DLS address shall be 27 bits, divided into a 3-bit type field and a 24-bit specific address field.

5.3.3.3.4 **Address type.** The address type field is described in Table II-5-3.

5.3.3.3.5 **Aircraft specific addresses.** The aircraft specific address field shall be the 24-bit ICAO aircraft address.

5.3.3.3.6 **ICAO-administered ground station specific addresses.** The ICAO-administered ground station specific address shall consist of a variable-length country code prefix (using the same country code assignment defined in Annex 10, Volume III, Chapter 9, Appendix 1, Table 1) and a suffix. The appropriate authority shall assign the bits in the suffix.

5.3.3.3.7 **ICAO-delegated ground station specific addresses.** The ICAO-delegated ground station specific address shall be determined by the organization to which the address space is delegated.

5.3.3.4 **Broadcast address.** The broadcast address shall be used only as a destination address for unnumbered information (UI) frames or for XID frames broadcasting ground station information.

5.3.3.4.1 **Encoding.** The broadcast addresses shall be encoded as in Table II-5-4.

5.3.3.4.2 **Erroneous transmission.** The aircraft station shall not transmit VDL frames if the 24-bit ICAO aircraft address is configured with the all-ones broadcast address.

5.3.3.4.3 **Erroneous reception.** The ground station shall discard without response any received frames containing a 24-bit source address of all ones.

5.3.3.5 **Link control field.** The basic repertoire of commands and responses for AVLC shall be as detailed in Table II-5-5 and shall be encoded as per ISO 4335.

5.3.3.6 **Information field.** The information field of an SREJ shall be as defined in 5.3.11.2, an XID shall be as defined in 5.4.2, and all other frames shall be as defined in ISO 4335.

5.3.4 Data link service system parameters for Mode 2

Note.— The parameters needed by the DLS sub-layer shall be as listed in Table II-5-6 and detailed in 5.3.4.1 through 5.3.4.7. DLS parameters shall be set using XID frames.

5.3.4.1 Timer T1 (delay before retransmission). Timer T1 shall be set to the time that a DLE will wait for an acknowledgement before retransmitting an INFO, RR (P=1), SREJ (P=1) or a FRMR frame. The value of Timer T1 shall be computed by the following formula:

$$\text{Timer T1} = T1_{\min} + 2T1_{\text{int}} + 2TD_{99} + \min(U(x), T1_{\max})$$

where

$U(x)$ is a uniform random number generated between 0 and x ;

$$x = T1_{\text{mult}} * TD_{99} * T1_{\text{exp}}^{\text{retrans}}$$

$TD_{99} = (TM1 * M1) / (1 - u)$ and is the running estimate for the 99th percentile transmission delay (between the time at which the frame is sent to the MAC sub-layer and the time at which its transmission is completed);

u is a measurement of channel utilization with a range of value from 0 to 0.99, with 0.99 corresponding to a channel that is 99 per cent or higher occupied;

$T1_{\text{int}}$ is the propagation delay between the VDL mode components in the CMU and VDR. If $T1_{\min}$ is set to a small value and the channel loading is very light, it is possible to calculate a T1 value that is smaller than the propagation delays between the CMU and VDR. $T1_{\text{int}}$ includes the estimated ARINC 429 access delay, file transfer time and ARINC 429 receive processing delay. $T1_{\text{int}}$ is set to 0.5 second.

retrans is the largest retransmission count of all the outstanding frames.

5.3.4.1.1 Timer T1 shall be started after any INFO, RR (P=1), SREJ (P=1) or FRMR frame is queued for transmission unless it is already running. If the timer expires, all outstanding INFO, RR (P=1), SREJ (P=1) or FRMR frames that have been queued for at least $T1_{\min} + 2T1_{\text{int}} + 2TD$ shall be retransmitted. The timer shall be cancelled upon receipt of an acknowledgement.

5.3.4.1.2 After processing an acknowledgement or Timer T1 expires, Timer T1 shall be restarted if there are still frames outstanding. Whenever Timer T1 is restarted, the timer shall be set as if it had been started when the oldest outstanding frame was queued.

Note.— There is one Timer T1 per DLE.

5.3.4.2 Parameter T2 (delay before acknowledgement). Parameter T2 defines the maximum time allowed for the DLE to respond to any received frame (other than an XID) in order to ensure the response is received before the peer DLE's Timer T1 expires.

5.3.4.2.1 A station shall respond to any received frame (other than an XID) within parameter T2 time in order to ensure the response is received before the peer DLE's Timer T1 expires.

Note.— The period T2 should be a delay (shorter than the $T1_{\min}$ value of the peer DLE) to permit the acknowledging DLE to schedule the response as an event in normal data processing and to allow sufficient time for an acknowledgement while maximizing the likelihood that an INFO frame will be transmitted and eliminate the need for an explicit acknowledgement.

5.3.4.3 Timer T3 (link initialization time). T3min is the acknowledgement delay for XID commands. Upon receiving an XID command, a station will transmit the XID response within the time T3min. Timer T3 shall be set to the time that a DLE waits for an XID response before retransmitting an exchange identification command (XID_CMD). The period of Timer T3 shall be computed by using a similar algorithm and parameters of Timer T1 with appropriate substitutions for T3min, T3max, T3multi and T3exp, except that T3min shall be separately negotiated. The timer component T1int should also be applicable to timer T3. XID_COMMANDs (except for ground station information frames) shall be retransmitted using the procedures defined in 5.3.4.1.

Note 1.— There is one Timer T3 per a DLE.

Note 2.— T3min shall be greater than T1min to allow the responding entity time to coordinate the response and perform any additional initialization processing.

5.3.4.4 Timer T4 (maximum delay between transmissions). Timer T4 shall be set to the maximum delay between transmissions (T4). Timer T4 shall be started or restarted on en-queuing a frame for transmission. Timer T4 shall never be cancelled. If a DLE does not receive a frame before Timer T4 expires, it shall send a command frame (P=1) to ensure a response from the peer DLE. When in the asynchronous balanced mode (ABM), the DLE shall send an RR; when in the sent selective reject mode (SRM), the DLE shall send an SREJ; when in the frame reject mode (FRM), the DLE shall send an FRMR. The value of Timer T4 shall be at least two minutes longer for a ground DLE than for the peer aircraft DLE. The command frame shall be transmitted using normal Timer T1 procedures up to N2 times. If no response is received, the DLE shall assume that the link is disconnected and that link recovery procedures shall be invoked.

Note 1.— Timer T4 is used to verify the continued existence of the link.

Note 2.— There is one Timer T4 per a DLE.

5.3.4.4.1 Recommendation. — A DLE in the ABM or SRM should send any outstanding frames with the P bit of the last INFO frame set to 1.

5.3.4.5 Parameter N1 (maximum number of bits of any frame). The parameter N1 defines the maximum number of bits in any frame (excluding flags and zero bits inserted for transparency) that a DLS shall accept.

5.3.4.6 Counter N2 (maximum number of transmissions). Counter N2 defines the maximum number of transmissions that the DLS shall attempt to transmit any outstanding AVLC frame that requires acknowledgement. A Counter N2 shall be set to zero when a new frame is ready for transmission. Counter N2 shall be incremented after each transmission of the frame. The counter shall be cleared after its associated frame is acknowledged. When Timer T1 expires, a DLE shall invoke the retransmission procedures of 5.3.4.1 up to N2 - 1 times. When Timer T3 expires, a DLE shall invoke the retransmission procedures of 5.3.4.3 up to N2 - 1 times. When Counter N2 reaches the maximum number of attempts (value of parameter N2) the LME shall be informed and the frame shall not be transmitted.

Note 1.— There is one Counter N2 per unacknowledged frame which requires an acknowledgement.

Note 2.— The value of the ground N2 parameter may be different from the value of the aircraft N2 parameter.

5.3.4.7 Parameter k (window size). Parameter k shall be set to the maximum number of outstanding sequentially numbered INFO frames that may be transmitted before an acknowledgement is required.

Note.— The value of the ground k parameter may be different from the value of the aircraft k parameter.

5.3.5 Description of procedures

Except as noted in 5.3.6 through 5.3.11.6, the standard procedures described in ISO 4335 and ISO 7809 shall be followed.

5.3.6 Modes of operation

Note.— The only modes of operation that a DLE shall support are those detailed below.

5.3.6.1 **Operational mode.** The operational mode shall be asynchronous balanced mode (ABM).

5.3.6.2 **Non-operational mode.** The non-operational mode shall be asynchronous disconnected mode (ADM).

Note.— Among the reasons why a DLE or LME enters non-operational mode are the issuing or receiving of any of the following frames: DISC, XID_CMD_LCR, DM or XID_RSP_LCR (abbreviated frame names are defined in Tables II-5-5 and II-5-13).

5.3.6.2.1 **DISC frame.** If a DLE is unable to continue to receive, it shall transmit a DISC to terminate the current link. The P bit shall be set to 0 in DISC commands. A DLE shall treat all received DISCs (regardless of the P bit) as a DISC (P=0).

Note.— The use of a DISC command may result in the loss of unacknowledged data.

5.3.6.2.2 **DM frame.** If a DLS receives any valid unicasted frame, except for an XID or TEST frame, from a DLS with which it does not have a link, it shall respond with a DM frame. All DM frames shall be transmitted with the F bit set to 0. An aircraft transmitting or receiving a DM frame shall initiate link establishment on one LME if no links remain. A DLE shall treat all received DMs (regardless of the F bit) as a DM (F=0).

Note 1.— If an LME is in the process of executing a handoff, it will retransmit the XID_CMD_HO (P=1) and wait for Timer T3 to expire.

Note 2.— A station receiving an invalid frame may choose to discard the frame instead of responding with a DM.

Note 3.— The procedures for an LME receiving a unicasted XID from an LME with which it does not have a link are found in 5.4.4.

5.3.6.3 **Frame reject mode.** When in ABM or SRM, and after transmitting a FRMR command, the DLE shall enter the frame reject mode (FRM). The DLE shall re-enter the ABM only after it receives a UA (F=1) frame.

5.3.6.4 **Sent selective reject mode.** When in ABM, and after transmitting a SREJ, the DLE shall enter the sent selective reject mode (SRM). The DLE shall re-enter the ABM only after it receives the missing INFO frames.

5.3.7 Use of the P/F bit for Mode 2

The use of the P/F bit shall follow the procedures detailed in ISO 4335, except as modified by 5.3.7.1 through 5.3.7.4.

5.3.7.1 **General.** When a DLE receives a command frame with the P bit set to 1, the F bit shall be set to 1 in the corresponding response frame. The C/R bit in the address field shall be referenced to resolve the ambiguity between command and response frames.

5.3.7.2 **INFO frames.** After receiving an INFO frame, a DLE shall generate an acknowledgement within T2 seconds after detecting the end of transmission. If a valid INFO (P=1) is received, the response shall be either an RR (F=1) or SREJ (F=1). If a valid INFO (P=0) is received, the response shall be either an RR (F=0) or SREJ (F=0).

5.3.7.3 **Recommendation.**— *The only time that an RR or SREJ frame should be transmitted with P=1 is when T4 expires. The only times that an INFO frame should be transmitted with P=1 is either when T4 expires or the transmit window has closed.*

5.3.7.4 **Unnumbered frames.** The P bit shall be set to 0 for UI and DISC frames. The F bit shall be set to 0 for DM frames. Therefore, a response (e.g. UA) shall not be expected, and if received, shall be treated as an error.

5.3.8 Unnumbered command frames collisions for Mode 2

When a command frame collision occurs, the entity which has precedence shall discard the received frame from its peer entity and the peer entity shall respond as if it had never sent its command frame.

5.3.8.1 **DLE procedures.** While waiting for a response to an unnumbered command frame (i.e., FRMR), a DLE whose DLS address is lower than its peer DLE shall have precedence.

5.3.8.2 **LME procedures.** An LME receiving a Broadcast Handoff shall process it regardless of what XID_CMD it is waiting for a response. Otherwise, an LME sending an XID_CMD (P=1) shall have precedence over an LME sending an XID_CMD (P=0). Otherwise, an LME whose DLS address is lower than its peer LME shall have precedence.

5.3.9 XID frame

The XID frame shall be used for the LME to establish and maintain links as defined in section 5.4. The originator of an XID_CMD (P=1) frame shall retransmit the XID upon expiration of Timer T3 whenever no response has been received. The receiving LME shall use the XID sequence number and retransmission field to differentiate a retransmission from a new XID; however, no meaning shall be attached to a missing sequence number. An LME shall send the exact same XID_RSP to every retransmission of an XID_CMD, unless it intends to change the link status via an XID_CMD (_HO, or _LCR).

Note.— The procedure for retransmission for XID_CMD (P=0) is a local ground system implementation matter.

5.3.9.1 **Unrecognized parameters.** Receiving stations shall disregard any unrecognized XID parameters carried in an uplink XID frame. Receiving stations shall process the remainder of the frame as if the unrecognized parameters had not been present. This provision is to facilitate introduction of additional XID parameters which may be needed in the future, without disruption to existing avionics or ground systems.

5.3.9.2 **Missing parameters.** Receiving stations should continue to process an XID frame in the event that a parameter that is designated Mandatory, in accordance with Tables II-5-47 a), b) and c), for a particular message is not present in the frame. The aircraft (and ground stations) are likely to receive messages that do not contain “Mandated” parameters due to variations in the ground system (and avionic) implementations that evolve over time. This may occur because the implementations are based on different versions of this standard. While it is expected that eventually these inconsistencies will be eliminated, in the interim it is necessary that the avionics (and ground systems) accept messages with “missing data”.

Note.— It is recognized that the lack of key information in a parameter may limit the processing of an XID frame.

5.3.10 Broadcast

Only XID_COMMANDS or UIs shall be broadcast. The P bit shall be set to 0 (no acknowledgement) for broadcast frames.

5.3.11 Information transfer for Mode 2

Except as noted below, the procedures for information transfer shall be specified by ISO 4335 and ISO 7809.

5.3.11.1 **Transmit queue management.** When the DLS sub-layer has frames to transmit, it shall wait for the MAC sub-layer to authorize transmission. Two transmit queues shall be maintained, one for supervisory and unnumbered (XID, FRMR, TEST, DISC, DM, RR, SREJ) frames and the other for information (INFO and UI). While waiting for authorization to transmit, the DLS sub-layer shall update the transmit queue, eliminating certain frames as specified in 5.3.11.1.1 through 5.3.11.1.7. If all of the frames on the DLS transmit queue are eliminated, then the authorization to transmit shall be ignored.

5.3.11.1.1 **Eliminate redundant frames.** At most one RR, SREJ, DM, FRMR or retransmitted INFO (of a given sequence number) shall be queued in response to a transmission.

5.3.11.1.2 **Recommendation.**— *To eliminate redundant frames, superseded frames in the transmit queue should be deleted (e.g. an INFO queued in response to a T1 timeout and then an SREJ).*

5.3.11.1.3 **Recommendation.** — *If any INFO frame is received from a peer DLE, the DLS sub-layer should update the N(r) of all numbered frames addressed to that DLE in the transmit queue, thus improving the probability of the acknowledgement arriving.*

5.3.11.1.4 **Recommendation.** — *To eliminate unnecessary retransmissions, if any numbered frame is received from a peer DLE, all frames in the transmit queue that it acknowledges should be deleted. If an XID_COMMAND from a peer LME with a lower DLS address or an XID_RSP is received from a peer LME, any XID_COMMANDS in the transmit queue for that LME should be deleted.*

5.3.11.1.5 **Procedures for transmission.** Supervisory frames have higher priority than the information frames, and so supervisory and unnumbered (XID, FRMR, TEST, DISC, DM) frames shall be transmitted in preference to information frames.

5.3.11.1.6 **Recommendation.** — *On transmission of an INFO frame, the DLE should also transmit any queued RR so as to avoid transmitting the RR as a separate frame.*

5.3.11.1.7 **Recommendation.** — *A station receiving a FRMR, DISC, or DM frame should delete all outstanding traffic for the transmitting DLE as it would not be accepted if transmitted.*

5.3.11.1.8 **Recommendation.** — *All unicast frames in the transmit queue should be deleted after the radio supporting this transmit queue is returned as the intended station cannot receive the transmission.*

5.3.11.2 **SREJ frame.** The multi-selective reject option in ISO 4335 shall be used to request the retransmission of more than one INFO frame. The SREJ (F=0) frame shall be generated only after receipt of an out-of-order INFO (P=0). The SREJ (F=1) shall be generated only after receipt of an INFO (P=1), RR (P=1) or SREJ (P=1). The SREJ (P=1) frame shall be generated only in accordance with the procedures of 5.3.4.4. A DLE shall acknowledge those frames which were received correctly but out of order by including in the SREJ information field an octet with bits 6-8 set to the INFO frame's sequence number and bit 1 set to 1. Although the F bit may be set to 0, the SREJ frame shall always acknowledge INFO frames up to N(r)-1 (where N(r) is the value in the control field).

Note.— AVLC has extended the standard ISO 4335 SREJ functionality to selectively acknowledge frames. In ISO 4335, the octets in the information field which were requesting retransmission of frames had bit position 1 set by default to 0.

5.3.11.3 **FRMR frame.** If a DLE receives an illegal frame (as defined by ISO 4335), it shall transmit a FRMR (P=1) to reset the link (e.g. state variables, timers and queues). A DLE, on receiving or transmitting a UA (F=1), shall reset the link (no XID exchange required). A DLE shall use the normal T1 and N2 procedures during the FRMR/UA exchange. A DLE transmitting the FRMR shall also retransmit the FRMR either upon expiration of Timer T4 or upon receipt of any frame other than a UA (F=1). A DLE receiving an illegal FRMR shall either discard the frame or treat it as a valid FRMR.

5.3.11.4 **UA frame.** The UA frame shall be used only to acknowledge a FRMR.

5.3.11.5 **UI frame.** UI frames shall be used solely to support connectionless data transfer required to provide broadcast services.

5.3.11.6 **TEST frame.**

Note.— The TEST command/response exchange has been included in AVLC to allow a station to perform a loopback test using logic that is isolated from the normal frame processing.

5.4 Mode 2 VDL management entity

5.4.1 Services

The services of the VME shall be as follows:

- a) link provision; and
- b) link change notifications.

5.4.1.1 **Link provision.** A VME shall have an LME for each peer LME. Hence, a ground VME shall have an LME per aircraft and an aircraft VME shall have an LME per ground system. An LME shall establish a link between a local DLE and a remote DLE associated with its peer LME. A ground LME shall determine if an aircraft station is associated with its peer aircraft LME by comparing the aircraft address; two aircraft stations with identical aircraft addresses are associated with the same LME. An aircraft LME shall determine if a ground station is associated with its peer ground LME by bit-wise logical ANDing the DLS address with the station ground system mask provided by the peer ground LME; two ground stations with identical masked DLS addresses are associated with the same LME. Each aircraft and ground LME shall monitor all transmissions from its peer's stations to maintain a reliable link between some ground station and the aircraft while the aircraft is in coverage of an acceptable ground station in the ground system.

Note.— If an aircraft receives a frame from a ground station, only one LME will process and react to that frame. Thus the qualifying phrase "from a ground station associated with its peer LME" will not be included and should be understood to be implied.

5.4.1.2 **Link change notifications.** The VME shall notify the intermediate-system system management entity (IS-SME) of changes in link connectivity supplying information contained in the XID frames received.

5.4.2 Exchange identity (XID) parameter formats for Mode 2

In the tables included in the subsections to this section, the following order is implied:

- a) bit order in each parameter value shall be indicated by subscript numbers. Bit 1 shall indicate the least significant bit; and
- b) bits shall be transmitted octet by octet, starting with the parameter id, and within each octet the rightmost bit (as shown in the tables) shall be transmitted first.

Note 1.— The tables are divided into three major columns that define the field name, the bit encoding and brief explanatory notes.

Note 2.— Requirements for the use of the parameters defined in the following sections are defined in 5.4.4.

5.4.2.1 **Encoding.** The XID information field shall be encoded per ISO 8885 and may include the parameters described in 5.4.2.2 to 5.4.2.7.

5.4.2.2 **Public parameters.** XID parameters shall be encoded as defined in ISO 8885, with the addition of the private parameter data link layer subfield as defined in ISO 8885. The format identifier (hexadecimal 82) shall be used (per ISO 4335.2, Annex C) to identify the public parameter list identified in ISO 8885. The VDL shall use the public parameter group ID of hexadecimal 80 to negotiate the common HDLC parameters. The public parameter set ID shall be included in XID frames if other public parameters are included; the public parameter set ID shall not be included in XID frames if other public parameters are not included.

Note.— ISO 8885 defines certain public parameters as receive and transmit which are referred to herein as uplink and downlink, respectively.

5.4.2.2.1 **HDLC public parameter set identifier.** The HDLC parameter set shall be identified by the ISO IA5 character string “8885:1993” encoded as per Table II-5-7. This parameter shall be included whenever any of the public parameters are sent. It shall be the first public parameter sent as per ISO 8885.

5.4.2.2.2 **Timer T1 parameter.** This parameter defines the value of the downlink Timer T1 that an aircraft DLE shall use. The values shall be defined in units of milliseconds for T1min and T1max and in hundredths for T1mult and T1exp. The timer values shall be encoded as 4 unsigned 16-bit integers as per Table II-5-8.

5.4.2.3 **VDL private parameters.** The parameter identifier field shall allow simple identification of the purpose of the parameter as defined in Table II-5-9.

5.4.2.4 **General purpose information private parameters.** Both aircraft and ground-based LMEs shall use general purpose information private parameters to transfer basic information to each other.

5.4.2.4.1 **VDL private parameter set identifier.** The VDL private parameter set identifier shall be the ISO IA5 character capital “V” encoded as per Table II-5-10. This parameter shall be included whenever any of the private parameters are sent. It shall be the first private parameter sent as per ISO 8885.

5.4.2.4.2 **Connection management parameter.** This parameter defines the type of XID sent and the connection options negotiated for that particular link. It shall be used in XID frames sent during link establishment and ground-based initiated ground station handoff and shall be encoded as per Tables II-5-11, II-5-12 and II-5-13. An LME shall set the reserved bits to 0 on transmission and shall ignore the value of these bits on receipt.

5.4.2.4.3 *Signal quality parameter (SQP)*. This parameter defines the received signal quality value of the last received transmission from the destination of the XID. It shall be encoded as a 4-bit integer as per Table II-5-14. If the transmitting LME included the SQP parameter in the XID_CMD (P=1) frame, then the responding LME shall also include it in the respective XID_RSP (F=1) frame.

Note.— This parameter will be used for testing purposes.

5.4.2.4.4 *XID sequencing parameter*. This parameter defines the XID sequence number (sss) and an XID retransmission number (rrrr). It shall be encoded as per Table II-5-15. An LME shall increment the sequence number for every new XID (setting the retransmission field to 0 on the first transmission) and shall increment the retransmission field after every retransmission. In an XID_RSP, the sequence number shall be set to the value of the XID_CMD sequence number generating the response (the retransmission field shall be ignored).

5.4.2.4.5 *AVLC specific options parameter*. This parameter defines which AVLC protocol options are supported by the transmitting station. It shall be encoded as per Tables II-5-16 and II-5-17. An LME shall set the reserved bits to 0 on transmission and shall ignore the value of these bits on receipt. When both this parameter and the Connection Management parameter are included in an XID, the bit values for those options which are included in both parameters shall be determined by the Connection Management parameter.

A ground station advertises the operational state of available services through the use of the AVLC Specific Options parameter and the ATN Router NETs parameter. Possible states for available services are:

- ATN VHF digital link Mode 2 (VDLM2) 8208 only
- non-VDLM2 8208 only
- ATN VDLM2 8208 plus non-VDLM2 8208
- No Service

The ATN VDLM2 8208 only state is indicated by setting bit 6 (“a” bit) of the AVLC Specific Options parameter to zero and encoding at least one non-zero parameter value in the ATN Router NETs parameter.

The non-VDLM2 8208 (e.g., ACARS over AVLC (AOA)) only state is indicated by setting bit 6 (“a” bit) of the AVLC Specific Options parameter to one and encoding one all-zeros parameter value in the ATN Router NETs parameter.

The ATN VDLM2 8208 plus non-VDLM2 8208 (e.g., AOA) state is indicated by setting Bit 6 (“a”) of the AVLC Specific Options parameter to one and encoding one non-zero parameter value in the ATN Router NETs parameter.

The No Service state is indicated by setting Bit 6 (“a”) of the AVLC Specific Options parameter to zero and encoding one all-zeros parameter value in the ATN Router NETs parameter.

If the ground station sets bit 6 of the AVLC specific options parameter to zero in its GSIF, it indicates that the ground station does not support non-VDLM2 8208 protocol over the VDL link. If the aircraft responds (via an XID frame) with bit 6 of the AVLC specific options parameter also set to 0, then AOA service is not available over the established link. In this case, if the aircraft responds (via an XID frame) with bit 6 of the AVLC specific options parameter set to 1, then the ground station may reject the aircraft-initiated link establishment or aircraft-initiated handoff.

If the ground station sets bit 7 ("gnd" bit) of the AVLC Specific Options parameter to one in its GSIF, it indicates that the frequency support list defined in the GSIF shall be used only by aircraft which are on the ground at the airport identified by the airport coverage parameter in the GSIF. If the ground station sets bit 7 ("gnd" bit) of the AVLC Specific Options parameter to zero in its GSIF, it indicates that the frequency support list defined in the GSIF shall be used when the aircraft is airborne.

Note.— Avionics designed prior to the introduction of the "gnd" bit may use the Frequency Support List (FSL) when airborne or on the ground regardless of the value of the "gnd" bit. It is recommended that the DSP not accept connection on the ground frequency by aircraft that are airborne.

5.4.2.4.6 Expedited subnetwork connection parameter. This parameter defines the expedited packets that the current XID contains. This parameter, which may be repeated, shall contain one and only one of the following subnetwork packets: CALL REQUEST, CALL CONFIRMATION, or a CLEAR REQUEST. It shall be encoded as Table II-5-18. The inclusion of this parameter shall invoke the expedited subnetwork connection procedures. This parameter shall only be included if the ground LME indicates that it supports expediting subnetwork connections. If, during link establishment, an aircraft LME has not received a ground station information frame (GSIF), it may assume expedited subnetwork connection is supported.

5.4.2.4.7 LCR cause parameter. This parameter defines the reason why the link connection request was refused. The parameter, which may be repeated, shall consist of a rejection cause code (c bits), backoff delay time in seconds (d-bits), and any additional data required by the various parameters. It is encoded as per Table II-5-19. Cause codes 00 hex to 7F hex shall apply to the responding station; cause codes 80 hex to FF hex shall apply to the responding system and shall be encoded as per Table II-5-20. At least one copy of this parameter shall be included whenever the "r" bit in the Connection Management parameter is set to 1; this parameter shall not be included if the "r" bit is set to 0. An LME receiving an LCR Cause parameter less than 80 hex shall not transmit another XID_CMD to that peer *station* for the duration of time designated in the LCR Cause parameter. An LME receiving an LCR Cause parameter greater than 7F hex shall not transmit another XID_CMD to that peer *system* for the duration of time designated in the LCR Cause parameter.

Note.— An aircraft LME receiving a station-based cause code from one ground station may immediately transmit the same XID_CMD to another ground station of the same ground system.

5.4.2.5 Aircraft-initiated information private parameters. An aircraft LME shall use aircraft-initiated information parameters to inform the ground about that aircraft's capabilities or desires. Ground LMEs shall not send these parameters.

5.4.2.5.1 Modulation support parameter. This parameter defines the modulation schemes supported. This parameter shall be sent on link establishment. It shall be encoded as shown in Tables II-5-21 and II-5-22.

5.4.2.5.2 Acceptable alternate ground station parameter. This parameter defines a list of ground stations in order of preference. This parameter shall be a list of DLS addresses encoded in 32-bit fields as per Table II-5-23. These shall be used by the ground LME during handoffs as possible alternate ground stations, if the proposed ground station is not acceptable to the ground LME.

5.4.2.5.3 Destination airport parameter. This parameter defines the aircraft's destination airport identifier. It shall be encoded as four 8-bit ISO IA5 characters per Table II-5-24.

5.4.2.5.4 Aircraft location parameter. This parameter defines the current position of the aircraft. It shall be encoded as shown in Tables II-5-25 and II-5-26.

5.4.2.6 **Ground-based initiated modification private parameters.** A ground LME shall use the ground-based initiated modification parameters to change the value of various parameters in one or more aircraft. Aircraft LMEs shall not send an XID with these Parameters.

5.4.2.6.1 *Autotune frequency parameter.* This parameter defines the frequency and modulation scheme that an aircraft LME shall use to reply to a ground station listed in the replacement ground station parameter. This parameter shall be sent by a ground LME when an autotune is required. The parameter shall be encoded as a 16-bit field as per Table II-5-27. The modulation subfield (m bits) shall be defined as per Table II-5-22. The frequency subfield (f bits) shall be the frequency encoded as:

$$\text{Integer}[(\text{frequency in MHz} * 100) - 10000].$$

Note.— As an example, for a frequency of 131.725 MHz, the encoded value is decimal 3172 or hexadecimal C64.

5.4.2.6.2 *Replacement ground station list.* This parameter defines a list of ground stations in order of ground LME preference. This parameter shall be encoded as a list of DLS addresses in 32-bit fields as per Table II-5-28. These addresses shall be used by the aircraft LME during handoffs as possible alternate ground stations if the proposed ground station is not acceptable to the LME.

5.4.2.6.3 *Timer T4 parameter.* This parameter defines the value of Timer T4 (in minutes) that the aircraft DLEs shall use. It shall be encoded as an unsigned 16-bit integer as per Table II-5-29.

5.4.2.6.4 *MAC persistence parameter.* This parameter defines the value of the parameter p in the p-persistent CSMA algorithm that an aircraft MAC shall use. This 8-bit integer shall be encoded as hexadecimal 00 (= decimal 1/256) to hexadecimal FF (= decimal 256/256) as per Table II-5-30.

5.4.2.6.5 *Counter M1 parameter.* This parameter defines the value of M1 that an aircraft MAC shall use. It shall be encoded as a 16-bit unsigned integer as per Table II-5-31.

5.4.2.6.6 *Timer TM2 parameter.* This parameter defines the value of Timer TM2 (in seconds) that an aircraft MAC shall use. It shall be encoded as an 8-bit integer per Table II-5-32.

5.4.2.6.7 *Timer TG5 parameter.* This parameter defines the value of Timer TG5 (in seconds) that the initiating and responding LMEs shall use. It shall be encoded as two 8-bit integers per Table II-5-33.

5.4.2.6.8 *T3min parameter.* This parameter defines the value of T3min (in milliseconds) that an aircraft DLE shall use. It shall be encoded as an unsigned 16-bit integer as per Table II-5-34.

5.4.2.6.9 *Ground station address filter parameter.* This parameter defines the DLS address of the ground station from which links are handed-off. This parameter shall be sent in an XID_CMD and a receiving aircraft LME shall process the XID_CMD only if it has a link to the identified ground station. The ground station address filter shall be encoded in a 32-bit field as defined in Table II-5-35.

5.4.2.6.10 *Broadcast connection parameter.* This parameter defines a single aircraft's link attributes for a new link, i.e.:

- aircraft address whose link was successfully established on the new link (minimum information);
- an optional list of one or more subnetwork connections maintained for that aircraft; and
- for each subnetwork connection listed, an indication of whether its subnetwork dependent convergence facility (SNDCF) context was maintained.

As per Tables II-5-36 and II-5-37:

- the aircraft id subfield (a bits) shall be listed once and shall be the aircraft address;
- the optional M/I subfield (m bit) shall be the SNDCF M/I bit in the CALL CONFIRMATION Call User Data field; and
- the optional LCI subfield (l bit) shall be the logical channel identifier of a subnetwork connection on the old link which is to be maintained on the new link.

Any particular aircraft shall not appear in more than one broadcast parameter block.

5.4.2.7 Ground-based initiated information private parameters. A ground LME shall use ground-based initiated information parameters to inform one or more aircraft LMEs about that ground-based system's capabilities. Aircraft LMEs shall not send these parameters.

5.4.2.7.1 Frequency support list (FSL). This parameter defines the list of frequencies, modulation schemes and associated ground stations supported in the coverage area of the originating ground station. The parameter shall consist of a list of 48-bit entries as shown in Table II-5-38. The modulation subfield (m bits) shall be encoded as defined in Table II-5-22. The frequency subfield (f bits) shall be encoded as:

$$\text{Integer } [(\text{frequency in MHz} * 100) - 10000]$$

Note.— As an example, for a frequency of 131.725 MHz, the encoded value is decimal value 3172 or hexadecimal C64.

The ground station address (g bits) shall be the DLS address encoded in a 32-bit field as defined in Table II-5-38. The ground DLS address shall be the DLS address of a ground station which can provide services on the specified frequency and modulation scheme. Ground stations advertised in the FSL shall use the same operating parameters as the transmitting station.

5.4.2.7.2 Airport coverage indication parameter. This parameter defines a list of four-character airport identifiers of airports for which the ground station can support communication with aircraft on the ground. Each four-character identifier shall be encoded as four 8-bit ISO IA5 characters as per Table II-5-39.

5.4.2.7.3 Nearest airport parameter. This parameter defines the four-character airport ID of the airport nearest the ground station. It shall be encoded as four 8-bit ISO IA5 characters as per Table II-5-40. The nearest airport parameter shall not be included in an XID if the Airport Coverage Indication is included.

5.4.2.7.4 ATN router NETs parameter. This parameter defines a list of ATN air-ground routers identified by the "administration identifier" (ADM) and a three octet, User-Defined subfields of their network entity titles (NETs). It shall be encoded as per Table II-5-41. If the ground station does not support ATN operations, then it is to encode the NET parameter as all-zeros in accordance with 5.4.2.4.5.

5.4.2.7.4.1 Recommendation.— The ATN Router NET parameter should contain a single VDL Specific DTE Addressing (VSDA) reachable from the ground station broadcasting the GSIF (see 6.3.2.3).

Note.— ICAO VDL standards permit the advertisement of multiple VSDAs within a single GSIF. There are a range of scenarios supporting end-to-end connectivity for ATS and AOC applications; however, the current favored approach is to use ground-ground networking to support connectivity between adjacent ATS Providers, and consequently that advertisement of only a single VSDA per VGS is necessary to support current requirements. This strategy avoids the necessity for selection logic in avionics. In the event that it is desired to implement a future ground

network architecture that cannot be supported by a single VSDA (e.g., to support separate AOC and ATS A/G Routers), then it will be necessary to ensure that appropriate industry standards are in place to specify criteria by which avionics should select the VSDAs through which connections are required.

5.4.2.7.5 *Ground-based system mask parameter.* This parameter defines the ground-based system mask. It shall be encoded as a 27-bit mask in a 32-bit field as per Table II-5-42.

5.4.2.7.6 *Timer TG3 parameter.* This parameter defines the value of Timer TG3 (in half-seconds) that the ground LME is using. It shall be encoded as a pair of unsigned 16-bit integers as per Table II-5-43.

5.4.2.7.7 *Timer TG4 parameter.* This parameter defines the value of Timer TG4 (in seconds) that the ground LME is using. It shall be encoded as an unsigned 16-bit integer as per Table II-5-44. A value of 0 shall mean that the ground LME is not using this timer.

5.4.2.7.8 *Ground station location parameter.* This parameter defines the position of the ground station. It shall be encoded as shown in Tables II-5-26 and II-5-45.

5.4.3 VME service system parameters for Mode 2

The VME service shall implement the system parameters defined in Table II-5-46 and detailed in 5.4.3.1 through 5.4.3.5.

5.4.3.1 **Timer TG1 (minimum frequency dwell time).** Timer TG1 shall be set to the minimum time (TG1) an aircraft LME dwells on a frequency while attempting to establish a link (in order to receive a valid uplink from at least one ground station). This timer shall be set by an aircraft LME (if it is not already running) when an aircraft tunes to a new frequency during a frequency search. It shall be cancelled when a valid uplink is received. On expiry of the timer the aircraft station shall:

- a) establish a link with one of the ground-based systems from which it has received a valid uplink;
- b) continue searching; or
- c) if an aircraft does not detect any uplink traffic within TG1 seconds, it shall tune to the next frequency in the search table.

Note 1.— The duration of TG1 should be chosen to ensure a valid uplink is received from at least one ground-based system before the timer expires.

Note 2.— There is one Timer TG1 per LME.

Note 3.— In order to allow an aircraft station an opportunity to link to its most preferred ground system, Timer TG1 should not be cancelled unless a valid uplink is received from its most preferred ground station.

5.4.3.2 **Timer TG2 (maximum idle activity time).** Timer TG2 shall be set to the maximum time (TG2) that an LME shall retain information on another station without receiving a transmission from it. The timer shall be started when a valid transmission is first received from a station and shall be restarted on each subsequent receipt of a valid transmission from that station. It shall never be cancelled. If Timer TG2 expires, an LME shall assume that the station is no longer reachable; if a link existed with that station, then site recovery shall be invoked.

Note.— There is one Timer TG2 for each station being monitored.

5.4.3.3 Timer TG3 (maximum time between transmissions). Timer TG3 shall be used at the ground station only. The timer shall be set to the maximum time (TG3) between transmissions on any frequency. Timer TG3 shall be started when the station becomes operational and restarted on the transmission of any frame. This timer shall never be cancelled. On expiration, if the ground station is operational, then it shall transmit a GSIF; the timer shall be restarted. The value to set the TG3 timer to shall consist of a fixed value equal to the minimum value plus a random value uniformly chosen between 0 and 20 seconds.

Note.— There is one Timer TG3 per ground station.

5.4.3.4 Timer TG4 (maximum time between GSIFs). Timer TG4 shall be used at the ground station only. The timer shall be set to the maximum time (TG4) between transmissions of a GSIF on any frequency. Timer TG4 shall be started when the station becomes operational and restarted on the transmission of a GSIF. This timer shall never be cancelled. On expiration, if the ground station is operational, then it shall transmit a GSIF; the timer shall be restarted. The value to set the TG4 timer to shall consist of a fixed value equal to the minimum value plus a random value uniformly chosen between 0 and 20 seconds.

Note.— There is one Timer TG4 per ground station.

5.4.3.5 Timer TG5 (maximum link overlap time). Timer TG5 shall be set to the maximum time that initiating and responding LMEs shall maintain the old link during handoffs. The LME initiating the handoff shall start its Timer TG5 when it receives an XID_RSP_HO. The LME responding to the handoff shall start its Timer TG5 when it transmits its XID_RSP_HO. The initiating LME shall never restart its Timer TG5; the responding LME shall restart its Timer TG5 if it retransmits an XID_RSP_HO. Timer TG5 shall be cancelled if either the old or new link is prematurely disconnected. After TG5 expires, each LME shall silently disconnect its half of the old link.

Note.— There is one Timer TG5 per LME.

5.4.4 Description of LME procedures for Mode 2

The aircraft and ground LMEs shall use the XID frame types listed in Tables II-5-47 a), b) and c), and the procedures described in the text below to provide a reliable connection between the aircraft and ground-based system. Frame collision processing (see 5.3.8) shall be applied before determining if a frame is illegal or unexpected (see 5.4.2.4.7). If an LME receives any valid XID_HO or XID_LPM frame from a system with which it does not have a link, it shall respond with an XID_LCR with the “d” bit set to 1 in the Protocol Violation Cause Code.

5.4.4.1 Frequency management procedures. The aircraft LME shall use the following procedures to acquire a frequency on which reliable VDL services are available.

5.4.4.1.1 Frequency search. The aircraft LME shall initiate the frequency search procedure on system initialization or after link disconnection, if it can no longer detect uplink VDL frames on the current frequency. It shall attempt to identify a frequency on which VDL service is available by tuning the radio to the CSC and to other frequencies on which it knows a priori that VDL service is available. It shall scan until it detects a valid uplink VDL frame with an acceptable source address or until Timer TG1 expires, in which case it shall tune the radio to another frequency and continue to scan.

5.4.4.1.2 Frequency recovery. The aircraft LME shall initiate the frequency recovery procedure if it can no longer establish a link on the current frequency or if the MAC entity indicates that the current frequency is congested. When airborne, it shall tune the radio to an alternate frequency using the data in the air frequency support list previously received on the current link.

5.4.4.2 Link maintenance procedures. The aircraft and ground LMEs shall use the following procedures to maintain connectivity across the VHF link:

- a) ground station identification;
- b) initial link establishment;
- c) link parameter modification;
- d) aircraft-initiated handoff;
- e) ground-based initiated handoff;
- f) ground-based requested aircraft-initiated handoff;
- g) ground-based requested broadcast handoff;
- h) autotune; and
- i) FSL-assisted frequency management.

5.4.4.3 **Ground station identification.** A ground station shall send a GSIF by broadcasting a XID_CMD (P = 0) with parameters as per Tables II-5-47 a), b) and c) if its Timer TG3 expires (meaning that it has not transmitted any frame in TG3 seconds) or if its Timer TG4 expires (meaning that it has not sent a GSIF in TG4 seconds). The GSIF has the “gnd” bit set to one if the frequency support list is only to be used by aircraft which are on the ground at the airport identified by the airport coverage parameter in the GSIF (see 5.4.2.7.1). If a ground station offers Mode 2 service, the operator of that ground station shall ensure that, besides transmitting GSIFs on the service frequency, GSIFs are transmitted on the CSC. The ground system operator will ensure that only current and up-to-date information is contained in the GSIF. Each ground station shall periodically broadcast the VSDA of the air-ground router (if present) reachable through the ground station via the ATN Router NET parameter of the GSIF. Aircraft LMEs receiving a GSIF shall process its content to identify the functionality of the ground station as well as the correct operational parameters to be used when communicating with it. Aircraft LMEs which have a connection with the transmitting ground station shall process only informational parameters and those parameters specified for an XID_CMD_LPM as per Tables II-5-47 a), b) and c). Unrecognized parameters are addressed in 5.3.9.1, and missing mandatory parameters are addressed in 5.3.9.2.

5.4.4.4 **Link establishment.** The aircraft LME shall initiate the link establishment procedure with a ground station only to establish an initial link with the ground-based system. An aircraft transmitting or receiving a DM frame shall initiate link establishment if no links remain.

5.4.4.4.1 **Aircraft initiation.** The aircraft LME shall choose a ground station with which it wishes to establish a link based on the signal quality of all received uplink frames and on information in any received GSIFs. It shall then attempt to establish a link with the chosen ground station by sending an XID_CMD_LE (P=1) frame. This frame shall include the mandatory parameters as per Tables II-5-47 a), b) and c) and also any optional parameters for which the aircraft LME does not wish to use the default value. If the aircraft LME has received a GSIF from the ground station to which it is transmitting the XID_CMD_LE (P=1), then it shall use the parameters as declared; otherwise, it shall use the default parameters.

5.4.4.4.2 **General ground response.** If the ground LME receives the XID_CMD_LE (P=1), it shall confirm link establishment by sending an XID_RSP_LE (F=1) frame containing the parameters as per Tables II-5-47 a), b) and c). The ground LME shall include in the XID_RSP_LE (F=1) any optional parameters for which it is not using the default values. If the XID_RSP_LE (F=1) includes the Autotune parameter then the Replacement Ground Station List parameter shall be included indicating the ground stations on the new frequency that the aircraft LME can establish a new link using the operating parameters specified in the XID_RSP_LE (F=1). If the XID_RSP_LE (F=1) does not include the Autotune parameter, the ground LME shall include the Replacement Ground Station List parameter if it wishes to

indicate the ground stations which can be reached on the current frequency using the same operating parameters as the transmitting station.

5.4.4.4.3 *Exceptional cases.* If an LME receiving the XID_CMD_LE (P=1) cannot establish the link with the sending LME, then it shall transmit an XID_RSP_LCR (F=1) instead of an XID_RSP_LE (F=1). If the parameters in the XID_RSP_LE (F=1) from the ground LME are not acceptable to the aircraft LME, then the aircraft LME shall transmit a DISC to the ground. If the Autotune parameter is included in the XID_RSP_LE (F=1) and the aircraft LME is unable to perform the autotune, then the aircraft LME shall respond with an XID_CMD_LCR (P=0); the link established on the current frequency shall not be affected. While waiting for a response to an XID_CMD_LE (P=1), an aircraft LME receiving any unicasted frame other than a TEST or an XID shall retransmit the XID_CMD_LE (P=1) instead of transmitting a DM.

Note.— See 5.3.8 on the processing of an XID_CMD.

5.4.4.5 **Link parameter modification**

5.4.4.5.1 *Ground-based initiation.* The ground LME shall request a modification of an existing link connection's parameters by sending an XID_CMD_LPM (P=1) to the aircraft LME containing the parameters as per Tables II-5-47 a), b) and c).

5.4.4.5.2 *General aircraft response.* The aircraft LME shall acknowledge with an XID_RSP_LPM (F=1) containing the parameters as per Tables II-5-47 a), b) and c).

5.4.4.5.3 **Recommendation.—** *If Counter N2 is exceeded for the XID_CMD_LPM (P=1), the ground LME should attempt to hand off via another station before disconnecting the link to the aircraft.*

5.4.4.6 **Aircraft-initiated handoff (AIHO).** The aircraft LME shall implement aircraft-initiated handoff (AIHO). The aircraft LME shall always set the “i” bit in the AVLC Specific Options parameter to 1.

5.4.4.6.1 *Aircraft handoff.* Once the aircraft LME has established a link to a ground station, it shall monitor the VHF signal quality on the link and the transmissions of the other ground stations. The aircraft LME shall establish a link to a new ground station if any of the following events occur:

- a) the VHF signal quality on the current link is poor and the signal quality of another ground station is significantly better;
- b) Counter N2 is exceeded on any frame sent to the current ground station;
- c) Timer TG2 expires for the current link; or
- d) Timer TM2 expires;
- e) the flow control window on a subnetwork SVC carried on the link remains closed for greater than 1 minute (see 6.2.4.2);
- f) the aircraft is on a frequency acquired from a GSIF with the “gnd” bit set to one and becomes airborne, when an associated ground station is received from the FSL of a GSIF with the “gnd” bit set to zero; and
- g) the aircraft lands and has received a viable frequency support list within a GSIF with the “gnd” bit set to one.

5.4.4.6.2 *Site selection preference.* From among those ground stations with acceptable link quality, the aircraft LME shall prefer to hand off to a ground station which indicates (in the GSIF) accessibility to the air-ground router(s) to which the aircraft DTE has subnetwork connections.

5.4.4.6.3 **Recommendation.**— *If an aircraft has commenced approach to its destination airport and its current link is with a ground station that does not offer service at that airport, it should hand off to a ground station which indicates in its Airport Coverage Indication parameter that it offers service at that airport.*

5.4.4.6.4 *Interaction of LMEs.* When an aircraft VME hands off from a ground station in one ground-based system (and thus associated with one LME) to a ground station in another ground-based system (and thus associated with a different LME in the aircraft), the new LME shall use the link establishment procedures and the old LME shall send a DISC when directed by the VME.

Note.— *Optimally the old link should not be disconnected until after the new link is capable of carrying application data. However this is outside the scope of this manual.*

5.4.4.6.5 *General ground response.* If the ground LME receives the XID_CMD_HO (P=1), it shall confirm link handoff by sending an XID_RSP_HO (F=1) frame containing the parameters as per Tables II-5-47 a), b) and c). The ground LME shall include in the XID_RSP_HO (F=1) the optional parameters for which it is not using the default values. If the XID_RSP_HO (F=1) includes the Autotune parameter, then the Replacement Ground Station List parameter shall be included to indicate the ground stations with which the aircraft LME can establish a new link on the new frequency, using the operating parameters specified in the XID_RSP_HO (F=1). If the XID_RSP_HO (F=1) does not include the Autotune parameter, the ground LME shall include the Replacement Ground Station List parameter if it wishes to indicate the ground stations which can be reached on the current frequency using the same operating parameters as the transmitting station.

5.4.4.6.6 *Disconnecting old link.* If the new and old ground stations are associated with different systems, the procedures of 5.4.4.6.4 shall be followed. Otherwise, the aircraft LME shall set Timer TG5 when it receives the XID_RSP_HO (F=1) and has validated the received parameters. The ground LME shall set Timer TG5 after it transmits the XID_RSP_HO (F=1). In the event that a further handoff is performed while a TG5 timer is still running, the TG5 timer shall be restarted and the previous link silently disconnected.

5.4.4.6.6.1 *Disconnecting old link (autotune parameter not used).* Both stations shall preferentially use the new link once it has been created. Both stations shall continue to maintain the old link until their respective Timer TG5 expires, after which each will consider the link disconnected without sending or receiving a DISC.

5.4.4.6.6.2 *Disconnecting old link (autotune parameter used).* Both stations shall disconnect any remaining old link after TG5 expiration without sending or receiving a DISC.

Note.— *Following a transfer of an autotune parameter, the aircraft will generally attempt to create a new link on a different frequency, and thus it will no longer be possible to transfer messages on the old link. Under such circumstances, disconnection of the old link following TG5 expiration is intended to provide commonality of procedure over all handoff scenarios, thus easing implementation and integration with other entities such as the ATN.*

5.4.4.6.7 *Exceptional cases.* If the ground LME cannot satisfy the XID_CMD_HO, then it shall transmit an XID_RSP_LCR instead of an XID_RSP_HO; the current link shall not be affected. While waiting for a response to an XID_CMD_HO, an aircraft LME receiving any unicasted frame other than a TEST or an XID from any ground station other than the current station shall retransmit the XID_CMD_HO. If Counter N2 is exceeded on the XID_CMD_HO, the aircraft LME shall attempt to hand off to another ground station; the current link shall not be affected. If the aircraft LME cannot perform the autotune, it shall transmit an XID_CMD_LCR (P=0); the current link shall not be affected. If the parameters in the XID_RSP_HO are not acceptable to the aircraft LME, then the aircraft LME shall transmit a DISC to the ground on the new link.

Note.— See 5.3.8 on the processing of an XID_CMD.

5.4.4.7 **Reserved**

5.4.4.8 **Ground-based initiated handoff.** If a ground LME implements this section, then it shall set the “i” bit in the AVLC Specific Options parameter to 1; otherwise, it shall set the “i” bit to 0.

5.4.4.8.1 **Ground action.** To command an aircraft to establish a new link to a proposed ground station on the same frequency, the ground LME shall send via the proposed ground station an XID_CMD_HO (P=1) to the aircraft with parameters as per Tables II-5-47 a), b) and c). If the ground LME will accept a handoff to other ground stations, the XID_CMD_HO (P=1) shall include the Replacement Ground Station List parameter specifying the link layer address of those other stations. Any operating parameters in the XID_CMD_HO (P=1) (either modification or informational) shall be valid for the transmitting station and for all ground stations listed in the Replacement Ground Station List parameter, except the Airport Coverage Indication parameter and Nearest Airport parameter which are only valid for the transmitting ground station.

5.4.4.8.2 **General aircraft response.** The aircraft LME shall respond by sending an XID_RSP_HO (F=1) with parameters as per Tables II-5-47 a), b) and c) to either the proposed ground station or to the aircraft LME's preferred ground station from the RGSL if the XID_CMD_HO (P=1) included the Replacement Ground Station List parameter.

5.4.4.8.3 **Disconnecting old link.** The aircraft LME shall set Timer TG5 after it transmits the XID_RSP_HO (F=1). The ground LME shall set Timer TG5 when it receives the XID_RSP_HO (F=1). Although new traffic will be sent over the new link, the old link shall not be disconnected immediately to allow any old traffic to be delivered.

5.4.4.8.4 **Exceptional cases.** If the aircraft LME cannot accept the handoff request, it shall respond with an XID_RSP_LCR; the current link shall not be affected. While waiting for a response to an XID_CMD_HO (P=1), a ground LME receiving any unicast frame other than a TEST or an XID from the aircraft shall retransmit the XID_CMD_HO (P=1). If the parameters in the XID_RSP_HO (F=1) are not acceptable to the ground LME, then the ground LME shall transmit a DISC to the aircraft on the new link.

Note.— See 5.3.8 on the processing of an XID_CMD.

5.4.4.8.5 **Recommendation.—** If Counter N2 is exceeded for the XID_CMD_HO, the ground LME should attempt to hand off via another station before disconnecting all links to the aircraft.

5.4.4.9 **Ground-based requested aircraft-initiated handoff (GRAIHO).** A ground LME shall not perform this section with aircraft that do not support handoff initiation.

5.4.4.9.1 **Ground action.** For the ground LME to request an aircraft to initiate a handoff to an alternate frequency, it shall send an XID_CMD_HO (P=0) on the current link with parameters as per Tables II-5-47 a), b) and c), including the mandatory Autotune parameter. The parameters in the XID (both modification and informational) are valid for all ground stations listed in the Replacement Ground Station List. The Replacement Ground Station List parameter applies to the new frequency.

5.4.4.9.2 **General aircraft response.** If the aircraft LME receives the XID_CMD_HO (P=0), it shall commence an aircraft-initiated handoff XID_CMD_HO (P=1) to a ground station, preferably one listed in the Replacement Ground Station List parameter.

Note.— See 5.3.8 on the processing of an XID_CMD.

5.4.4.9.3 **Exceptional cases.** If the aircraft LME cannot initiate the handoff, it shall send an XID_CMD_LCR (P=0); the current link shall not be affected. If the aircraft LME cannot perform the autotune, it shall transmit an XID_CMD_LCR

(P=0); the current link shall not be affected. The aircraft LME shall retransmit on the new frequency the `XID_CMD_HO` (P=1) using the normal retransmission procedures. If the aircraft fails to connect to a ground station after the aircraft retunes, the aircraft LME shall attempt a handoff to another ground station from the Replacement Ground Station List, and if all such stations have been attempted, the aircraft shall switch to the CSC to perform link establishment.

5.4.4.9.4 Recommendation.— *If Counter N2 is exceeded for the `XID_CMD_HO`, the ground LME should attempt to request a handoff via another station before disconnecting all links to the aircraft.*

5.4.4.9.5 Recommendation.— *If an aircraft station fails to establish the requested connection on the new frequency, it may use information available on the new frequency to determine alternate viable ground stations before reverting to the CSC.*

5.4.4.10 Ground-based requested broadcast handoff. If the ground LME broadcasts link handoffs then it shall set the “`bi`” bit in the AVLC options parameter to 1; otherwise, it shall set the “`bi`” bit to 0. If the ground LME supports broadcast subnetwork connection handoff, the ground LME shall also support broadcast link handoffs and shall set the “`bi`” and “`bs`” bits in the AVLC options parameter to 1; otherwise, it shall set the “`bs`” bit to 0.

5.4.4.10.1 Ground action. If the ground LME supports broadcast link handoffs, for each aircraft that indicates it supports broadcast link handoff, the ground LME shall confirm the link handoff by including the Broadcast Connection parameter per Tables II-5-47 a), b) and c). If the ground LME supports broadcast subnetwork connection management, for each aircraft that indicates it supports broadcast subnetwork connection management, the ground LME shall confirm the link handoff and the subnetwork connection maintenance by including the Broadcast Connection parameter per Tables II-5-47 a), b) and c).

5.4.4.10.2 Aircraft response. The LME in each aircraft shall process received broadcast `XID_CMD_HO` (P=0) and determine if the ground LME had performed a broadcast link recovery (and possibly an expedited subnetwork recovery) for it. It shall do this by verifying that the Ground Station Address Filter parameter contains the DLS address of the ground station that it is connected to and that a Broadcast Connection parameter exists containing its aircraft address. Aircraft LMEs supporting broadcast recovery shall consider that a link handoff has occurred with the new link having the same parameters as the old link (as modified by the parameters in the broadcast `XID`). The old link shall be disconnected immediately.

5.4.4.10.2.1 The Broadcast Connection parameter shall include the subnetwork connection information (i.e. the M/I and LCI subfields) for only those subnetwork connections between the aircraft DTE and the peer ground DTEs that the ground LME maintained. Aircraft LMEs supporting broadcast subnetwork connection management shall process the remainder of the Broadcast Connection parameter to determine which subnetwork connections the ground LME maintained. For those subnetwork connections associated with the logical channels on the old link that the ground LME maintained, the aircraft DTE shall consider as if the CALL REQUEST and CALL CONFIRMATION sent on the old link were resent on the new link (except that the M/I bit in the Broadcast Connection parameter shall supersede the value in the previous CALL CONFIRMATION). At this point the aircraft DTE, ground DCE, and ground DTE shall be initialized. If the Broadcast Connection parameter indicates that the ground was not able to maintain a subnetwork connection (i.e. a particular LCI is not mentioned in the Broadcast Connection parameter), the aircraft shall explicitly establish this subnetwork connection as per .

5.4.4.10.3 Exceptional cases. If the aircraft LME does not support broadcast recovery, but the ground LME performed a broadcast link recovery for it, then the aircraft LME shall perform either an aircraft-initiated link handoff, (if the aircraft LME supports same) or request a link handoff. If the aircraft LME finds the new ground station unacceptable, it shall perform an aircraft-initiated handoff (if the aircraft LME supports same) or request a link handoff. If the Ground Station Address Filter parameter does not equal the DLS address of a link that the aircraft LME has or if no aircraft identifier subfield in a Broadcast Connection parameter equals its aircraft address, the aircraft LME shall not process the ground requested broadcast handoff. If the aircraft LME supports broadcast link handoffs but does not support broadcast subnetwork connection management and the Broadcast Connection field is implemented as per Table II-5-37, the

aircraft LME shall explicitly establish its subnetwork connections. If the Broadcast Connection parameter indicates that a subnetwork connection was maintained, but the aircraft LME does not recognize that subnetwork connection, then the aircraft DTE shall transmit a CLEAR REQUEST for each unrecognized subnetwork connection.

5.4.4.11 **Ground-requested autotune.** This section summarizes the autotune details found in 5.4.4.4 (link establishment), 5.4.4.6 (AIHO), and 5.4.4.9 (GRAIHO).

When the ground system requests an autotune, the parameters and the VSDA (if applicable) reachable through the original ground station shall be maintained for each station in the Replacement Ground Station List associated with the autotune.

5.4.4.11.1 *Ground action.* To request an aircraft LME to hand off to a ground station on a different frequency, the ground LME shall include the Autotune and Replacement Ground Station List parameters in an XID it sends during a link establishment (XID_RSP_LE (F=1)) or handoff procedure (GRAIHO XID_CMD_HO (P=0) or AIHO XID_RSP_HO (F=1)).

Note.— Ground service providers should be aware that if the Replacement Ground Station List contains a large number of ground stations, the aircraft may take a significant period of time to attempt each ground station in turn, during which time the aircraft will remain out of communication.

5.4.4.11.2 *General response.* “Silently disconnect” refers to the disconnection of an existing link without sending of a DISC. Typically, this is performed when the peer entity can be assumed to have also disconnected the link by procedural means, such as expiration of a timer.

5.4.4.11.2.1 *Aircraft response.* On receipt of an XID containing an autotune parameter and when permitted by the aircraft preferences for the ground service provider, the aircraft LME shall silently disconnect any existing AVLK link it has with the same ground service provider and then retune the aircraft radio to the new frequency indicated in the Autotune parameter and commence an aircraft-initiated handoff to the chosen ground station selected from the Replacement Ground Station List parameter. When attempting an aircraft-initiated handoff in accordance with an Autotune request, the aircraft LME shall retransmit the XID_CMD_HO (P=1) on the new frequency using the normal retransmission procedures, until either counter N2 is exceeded, or else an XID_RSP_HO (F=1) has been received. If counter N2 is exceeded, the aircraft shall attempt a handoff to another ground station from the Replacement Ground Station List. If all stations in the RGSL have been attempted, then the aircraft shall switch to the CSC to perform link establishment.

5.4.4.11.2.2 *Ground response.* When the ground service provider receives a request to establish a new link on a new frequency by means of an XID_CMD_HO (P=1), it shall transmit an appropriate response.

5.4.4.11.3 *Exceptional cases.* If the aircraft LME cannot perform the autotune, it shall transmit an XID_CMD_LCR (P=0); the current link shall not be affected.

5.4.4.12 **Frequency Support List-assisted frequency management.** If an FSL is provided in an uplink XID (GSIF or other XID) and the aircraft station determines the need to change frequency, the aircraft station shall attempt the available frequencies advertised in the FSL to establish and maintain communications with peer ground systems. When the aircraft is airborne it should use the FSL in accordance with section 5.4.4.12.1 below and when on the ground in accordance with 5.4.4.12.2.

The first frequency/ground station selection shall be made at random from the FSL, so as to give an equal probability of selecting any entry. If the handoff is not successful and there is another frequency/ground station entry in the FSL, then another handoff attempt shall be made until each frequency/ground station entry is tried once using normal retransmission logic. If the resulting new link is disconnected by the ground station while the aircraft's TG5 timer is running, the aircraft station cannot assume that the previous link is still valid. In such a case, the aircraft station shall

consider the handoff to have failed and attempt a handoff to another frequency/ground station as described above. If all of the handoff attempts fail, then the aircraft station shall switch to the CSC and scan for a link establishment.

Ground stations advertised in the FSL shall use the same operating parameters as the transmitting station (similar to Replacement Ground Station List used in the Autotune procedure).

Note.— The CSC is always considered available regardless of its inclusion or exclusion from air or ground FSL.

5.4.4.12.1 Frequency Support List for aircraft in the air. If the “gnd” bit in the AVLC options parameter of a GSIF is set to zero, then the FSL shall be used by aircraft which are airborne. Aircraft in the air shall not use an FSL carried in a GSIF with the “gnd” bit set to one. When airborne, the aircraft station shall use the FSL either:

- a) following transition from the ground to air as described in 5.4.4.12.2; or
- b) perform the frequency recovery, whenever it is unable to establish or maintain a link on the current frequency or when Timer TM2 expires.

An airborne aircraft station shall not change to a frequency from the FSL under any other circumstances. The GSIFs on a ground frequency shall contain an FSL and the AVLC options parameter with the “gnd” bit set to zero.

5.4.4.12.2 Frequency Support List for aircraft on the ground. If the “gnd” bit in the AVLC specific options parameter of a GSIF is set to one, then the FSL shall be used by aircraft stations which are on the ground at the airport identified by the airport coverage parameter in the GSIF. Aircraft stations which support the “gnd” bit and which are on the ground shall attempt a handoff to a frequency and associated ground station(s) in the Frequency Support List. When the aircraft station is on the ground, it shall only use ground stations that advertise coverage for the airport at which the aircraft is located.

Note 1.— It is recognized that the aircraft may receive an FSL for use in the air without receiving an FSL for use on the ground. In that case, if the aircraft lands, it should remain on its current frequency. It is up to the ground system to determine whether an alternate frequency is desirable and use a GRAIHO to attempt to rectify the frequency used.

In the event that all handoffs on the ground frequency fail, the aircraft station shall then revert to, and remain on, the CSC (no more attempts to use the ground FSL) until the aircraft takes off. The aircraft is still obligated to change frequency if it receives an autotune.

Once an aircraft station on a ground frequency leaves the ground, its LME shall handoff to a frequency and associated ground station received from the FSL of a GSIF with the “gnd” bit set to zero.

Aircraft stations which are unable to determine whether the aircraft is on the ground or in the air shall not attempt to use a ground frequency.

Note 2.— The ground system should examine the A/G bit of any downlink AVLC XID frame attempting to establish a link or perform a handoff to a ground station on a ground frequency. In the event that the A/G bit indicates that the aircraft is not on the ground, the link should not be established, and the ground should respond with an XID_RSP_LCR (LCR Cause code 09h).

5.4.4.13 Expedited subnetwork connection management. If a LME implements this section, then it shall set the “v” bit in both the AVLC Specific Options and in the Connection Management parameters to 1; otherwise it shall set them to 0. This section shall only be applicable for the link establishment, and aircraft-initiated handoff processes.

5.4.4.13.1 *Initiating station of subnetwork connection management.* To perform an expedited subnetwork connection establishment or maintenance, the initiating LME shall include in the XID_CMD the Expedited Subnetwork Connection parameter for each subnetwork connection that needs to be established or maintained. The procedures for an expedited link establishment and maintenance shall be the same as outlined in 5.4.4.4, 5.4.4.6 and 5.4.4.8.

5.4.4.13.2 *General responder action.* If the responding LME receives a XID_CMD with one or more Expedited Subnetwork Connection parameters, it shall confirm subnetwork connection establishment or maintenance by sending an XID_RSP containing the parameters as per Tables II-5-47 a), b) and c). The responding LME shall attempt to establish or maintain the specified subnetwork connections as outlined in 6.6.3. The responding LME shall include in the XID_RSP the CALL CONFIRMATION or CLEAR REQUEST responses (i.e. in the Expedited Subnetwork Connection parameter) and any optional parameters for which it is not using the default values. The ground LME shall not process the Expedited Subnetwork Connection parameters if it includes the Autotune parameter in the XID_RSP.

5.4.4.13.3 *Exceptional cases.* If the responding LME cannot support the expedited subnetwork connection establishment or maintenance but can support the link establishment or handoff, it shall respond with XID_RSP with the Connection Management “v” bit set to 0 and shall not include the Expedited Subnetwork Connection parameters in the XID_RSP. If T3min expires, the responding LME shall include all responses (i.e. CALL CONFIRMATION or CLEAR REQUEST) that it has received up to that point in the XID_RSP. Any late responses from respective DTE(s) shall be sent to the initiating LME in INFO frames.

Note.— All XID_CMD retransmissions will cause the responding LME to respond with the same XID_RSP without further processing. All late subnetwork connection responses from ground DTEs will not be included in the retransmitted XID_RSP.

6. SUBNETWORK LAYER PROTOCOLS AND SERVICES

6.1 Architecture

Note.— General information on the VDL subnetwork layer protocol architecture is standardized in the VDL SARPs, Annex 10, Volume III, Part I, Chapter 6. Detailed specifications for VDL Mode 2 are provided in section 6.1.1 (Access Points), section 6.2 (Services), section 6.3 (Packet format), section 6.4 (Subnetwork layer service system parameters), section 6.5 (Effects of layers 1 and 2 on the subnetwork layer) and section 6.6 (Description of procedures) of this manual.

6.1.1 Access points

The subnetwork service access point (SNSAP) shall be uniquely identified by the subnetwork data terminal equipment (DTE) address. SNSAPs shall define the subnetwork point of attachment (SNPA) used by the service primitives that define the subnetwork service to the subnetwork dependence convergence protocol.

6.2 Services

This section specifies the services offered by the subnetwork sub-layer. The services are described in an abstract manner and do not imply any particular implementations. The services provided by the subnetwork to the subnetwork service user shall include the functions described in 6.2.1 through 6.2.4.

6.2.1 Subnetwork connection management

A variety of ISO 8208 packet types, procedures and facilities shall be used to establish, terminate and manage connections across the subnetwork. Connection status information shall be maintained at both ends of the connection. Connection status information shall also be maximized to ensure that the minimum amount of information is passed with each data transfer phase transmission and that ground system operational control of the subnetwork is maximized.

6.2.2 Packet fragmentation and reassembly

This subnetwork capability shall allow the fragmenting of large data units passed from the subnetwork user for transmission across the air-ground portion of the subnetwork. Reassembly shall be performed at the receiving end of the subnetwork.

6.2.3 Error recovery

REJECT packet types shall be used for subnetwork-level error recovery. These packets shall be sent between subnetwork entities to cause retransmission of DATA packets and to recover from error response time-out states. Under no circumstances shall RESET or RESTART be used to recover from an error that can be handled by REJECT. Aircraft DTEs shall accept REJECT packets and should retransmit the specified packets.

6.2.3.1 **Recommendation.**— *The ground DCE with which an aircraft has a VDL link should not clear subnetwork connections on receipt of REJECT packets but should retransmit the specified packet.*

6.2.4 Connection flow control

DATA packet sequence numbering combined with the use of a sliding window shall be used for passive flow control.

6.2.4.1 **Recommendation.**— *Receive not ready (RNR) packets should not be used for explicit flow control.*

Note.— *The use of explicit RNRs requires a subsequent packet to clear the f2 (DXE RECEIVE NOT READY) state (see ISO 8208). The RNRs and subsequent RR frames will cause more RF utilization than would be caused by merely delaying the acknowledgement.*

6.2.4.2 **Flow control window closure.** A complication is known to exist by which disruption on the VDLM2 uplink may cause the downlink VDLM2 8208 flow control window to close, followed by loss of AVLC at the ground station. The closure of the downlink flow control window then prevents the aircraft from discovering the loss of the AVLC link, leading to a sustained loss of ATN end-to-end communication.

In order to recover from this condition, an aircraft shall detect whenever the SVC flow control window becomes closed. Closure of the flow control window is indicated when

$$P(S) = P(R) + W - 1 \text{ under modulo } 8,$$

where

P(S) is the send sequence number of the last packet sent,
P(R) is the last receive sequence number, and
W is the window size.

In the event that closure of the flow control window persists for greater than 1 minute, the aircraft shall consider the underlying AVLC link to have been lost and commence an aircraft-initiated handoff to another ground station.

6.3 Packet format

Except as qualified below, the packet format shall be as specified in ISO 8208, section 12. During call setup, VDL shall use the extended format in conjunction with the fast select facility.

6.3.1 General format identifier

The qualifier bit (Q-bit) in DATA packets shall be set to 0 in VDL. Modulo 8 sequencing shall be used in the VDL.

Note.— A subnetwork entity may receive a CLEAR CONFIRMATION with the appropriate cause code if the peer subnetwork entity wants to use modulo 128 sequencing.

6.3.2 Calling and called DTE addresses

Calling and called DTE addresses shall be as detailed in 6.3.2.1 through 6.3.2.3.

6.3.2.1 **Encoding.** Octet 4 shall consist of the address lengths, encoded as follows:

- a) 4 least significant bits: called DTE address length; and
- b) 4 most significant bits: calling DTE address length.

Octet 5 and consecutive octets shall consist of the following address fields, in order:

- a) called DTE address field; and
- b) calling DTE address field.

The A-bit in the General Format Identifier shall be set to 0 to indicate the use of this Address Block format.

6.3.2.1.1 **Address length and address field.** The address length shall indicate the field length for the calling and called DTE addresses. This variable length field is known informally as the address field. The address field shall be encoded in a BCD form. When appropriate, the address field shall be rounded up to an integer number of octets.

6.3.2.2 **Aircraft DTE address.** The aircraft DTE address shall be the BCD encoding of the octal representation of the 24-bit ICAO aircraft address.

6.3.2.3 **Ground DTE address.** The VDL subnetwork-specific ground DTE address shall be the binary representation of the NET (the facility is to convey the called address that was received from the ground station GSIF). This default addressing is called VDL Specific DTE Addressing (VSDA) and consists of six octets. The first three octets of VSDA shall be the same as the ATN administration domain identifier (ADM) field as defined in the ATN Manual (Doc 9705). The air-ground router is assigned the second three octets of VSDA. The ground system may use these three octets to uniquely address an air-ground router or may use them as a routing area identifier (same as the ATN ARS field specified in the ATN Manual (Doc 9705). If the VSDA assigned to a router does not uniquely identify a specific air-ground router, then the ground system shall support the X.121 addressing option. The VSDA shall be sent in the Called Address Extension facility. Bit 8 of the first octet after the facility code shall be set to 1 and bit 7 shall be set to 0.

The Called Address shall not be included when using VDL subnetwork-specific ground DTE addresses.

6.3.2.4 Ground network DTE addresses. If the ground LME indicates support of ground network DTE addresses during link establishment, it shall accept and process addresses which follow the format used in the ground network.

Note.— This facility allows addressing of ground DTEs other than those associated with the ATN routers in the list of ATN router NETs. It requires however that the aircraft system management entity (SME) know or be informed via an application exchange of the address of the DTE in the ground network.

6.3.3 Call user data field

The fast select facility shall be used to carry the VDL mobile SNDCF Call User Data, including the intermediate system hello (ISH) PDU.

Note.— This reduces the number of transmissions required to set up the various layers. Refer to the Manual of Technical Provisions for the Aeronautical Telecommunication Network (ATN) (Doc 9705).

6.3.4 Packet types

VDL shall not support the following ISO 8208 packet types: Interrupt, Interrupt Confirmation and Receive Not Ready.

6.4 Subnetwork layer service system parameters

The parameters listed in Table II-6-1 shall be used in the subnetwork protocol. Except as noted in 6.6, the description of function and procedures shall be as documented in ISO 8208. For all parameters, Table II-6-1 indicates the configured or negotiated values that shall be used by the aircraft DTE and the ground DCE. T21, T23 and R23 shall also apply to the ground DTE.

6.4.1 Packet size

The Packet Size shall be negotiated via the flow control parameter negotiation facility or Nonstandard Default Packet Size facility to be the value in Table II-6-1 appropriate to the mode for both directions.

6.4.2 Parameter W (transmit window size)

The parameter W shall be the maximum number of outstanding sequentially numbered data packets that may be transmitted before an acknowledgement is required. In the absence of negotiations via the nonstandard default window size facility or the flow control parameter negotiation facility, this parameter shall be as per Table II-6-1. W shall be negotiated to the same value in both directions.

Note.— This parameter is identical to the standard ISO 8208 parameter W.

6.4.3 Parameter A (acknowledgement window size)

This parameter, A, shall be the minimum number of packets the receiver shall receive before it generates an RR packet. Parameter A shall not be separately negotiated, but be set to the smallest integer greater than or equal to the value of one-half of parameter W.

Note.— The purpose of the acknowledgement window is to reduce the probability that an explicit acknowledgement needs to be sent. The acknowledgement window is set to one-half of the transmit window to reduce the probability that a station will go into flow control.

6.5 Effects of layers 1 and 2 on the subnetwork layer

The subnetwork layer virtual circuit shall be valid only on the underlying link layer connection over which it was established.

6.6 Description of procedures

Except where noted in 6.6.1 through 6.6.5, the provisions of ISO 8208 shall apply between the aircraft DTE and the ground DCE. If a ground DCE receives an unsupported packet layer facility, it shall either process the CALL REQUEST without altering the facilities or shall send a CLEAR CONFIRMATION.

6.6.1 Supported facilities

Table II-6-2 lists options and facilities, documented in ISO 8208, that shall be supported by VDL.

6.6.2 Unsupported facilities

Table II-6-3 lists the facilities, documented in ISO 8208, that shall not be supported by the VDL.

6.6.3 Subnetwork establishment and connection management

The subnetwork establishment and connection management options used shall be chosen as required by the operational conditions.

6.6.3.1 **Subnetwork entity initialization.** The ground DCE shall be initialized on receipt of a valid XID_CMD_LE.

Note.— Only the subnetwork entities corresponding to the link on which the XID_CMD_LE/XID_RSP_LE is received will be initialized. The entities assigned to other links will not be affected.

6.6.3.2 **Subnetwork connection establishment.** Only aircraft DTEs shall request subnetwork connection establishment in the VDL subnetwork.

6.6.3.2.1 **Explicit subnetwork connection establishment.** Immediately after link establishment, the aircraft DTE shall attempt to establish a subnetwork connection to at least one ground DTE. The aircraft DTE shall request a single subnetwork connection per ground DTE by the transmission of a CALL REQUEST packet specifying the ground DTE address. On receipt of the CALL REQUEST, the ground DCE shall attempt to establish a subnetwork connection to the aircraft DTE by responding with a CALL CONFIRMATION packet; otherwise, the ground DCE shall send a CLEAR

REQUEST packet including the clearing cause and diagnostic code of the failure. If Ground Network X.121 DTE addressing is implemented, then the ground DCE shall use the Called Line Address Modification Notification facility to inform the aircraft DTE of the ground DTE's X.121 address. Otherwise, if the default Ground DTE addressing is implemented, the ground DCE shall use the Called Address Extension facility to inform the aircraft of the ground DTE's VSDA address that was delivered in the CALL REQUEST.

6.6.3.2.2 Expedited subnetwork connection establishment. An aircraft LME initiating expedited subnetwork connection establishment shall implement this section. The aircraft LME shall invoke the procedures described in 5.4.4.13 when connecting to a ground LME indicating support for expedited subnetwork connection procedures. The aircraft DTE shall reissue CALL REQUESTs for those logical channels for which responses (i.e. either a CALL CONFIRMATION or a CLEAR REQUEST) were not included in the XID_RSP_LE. If Ground Network X.121 DTE addressing is implemented, then the ground DCE shall use the Called Line Address Modification Notification facility to inform the aircraft DTE of the ground DTE's X.121 address. Otherwise, if the default Ground DTE addressing is implemented, then the ground DCE shall use the Called Address Extension facility to inform the aircraft of the ground's VSDA address that was delivered in the CALL REQUEST.

Note.— The CLEAR CONFIRMATION, if required, will be transferred in an INFO frame.

6.6.3.3 Subnetwork connection maintenance. During link establishment a ground DCE shall indicate its available routers in the ATN Router NETs parameter and the aircraft LME shall then attempt to maintain all subnetwork connections.

Note.— For subnetwork connections to be maintained across ground station changes, the LME gives preference in choosing a new ground station to ground stations indicating accessibility to the DTEs to which subnetwork connections already exist.

Explicit subnetwork connection maintenance. To explicitly request subnetwork connection maintenance to a ground DTE, an aircraft DTE shall send a CALL REQUEST packet to the ground DTE with the fast select facility set containing a VDL mobile SNDCF Call User Data Field indicating a request to maintain SNDCF context. If the ground DTE can accept the call, it shall respond with a CALL CONFIRMATION packet with the fast select facility set containing a VDL mobile SNDCF Call User Data field indicating whether the SNDCF context was maintained. If the Ground DTE or a DCE is unable to accept the call, it shall send a CLEAR REQUEST packet to the aircraft DTE including the clearing cause and diagnostic code of failure. If Ground Network X.121 DTE addressing is implemented, then the ground DTE shall use the Called Line Address Modification Notification facility to inform the aircraft DTE of the ground DTE's X.121 address. Otherwise, if the default Ground DTE addressing is implemented, the ground DCE shall use the Called Address Extension facility to inform the aircraft of the ground DTE's VSDA address that was delivered in the CALL REQUEST.

6.6.3.3.2 Expedited subnetwork connection maintenance. An LME initiating expedited subnetwork connection maintenance shall implement this section. If both the aircraft and ground LMEs support expedited subnetwork procedures, then the procedures described in 5.4.4.13 shall be invoked. The initiating DTE shall reissue CALL REQUESTs for those logical channels for which responses (i.e. a CALL CONFIRMATION or a CLEAR REQUEST) were not included in the XID_RSP_HO. A ground DTE shall include its Calling Address in the appropriate field. If Ground Network X.121 DTE addressing is implemented, then the ground DTE shall use the Called Line Address Modification Notification facility to inform the aircraft DTE of the ground DTE's X.121 address. Otherwise, if the default Ground DTE addressing is implemented, the ground DCE shall use the Called Address Extension facility to inform the aircraft of the ground DTE's VSDA address that was delivered in the CALL REQUEST.

Note.— The CLEAR CONFIRMATION, if required, will be transferred in an INFO frame.

6.6.3.3.3 Broadcast subnetwork connection maintenance. In order to set the "b_s" bit in the XID AVLC Specific Options parameter to 1, an LME shall support this section. The procedures described in 5.4.4.10 shall be invoked for

each aircraft that indicates support for broadcast subnetwork procedures. The ground DTE and DCE and aircraft DTE shall assume those subnetwork connections have been maintained per 5.4.4.10. If an aircraft DTE cannot accept a call, it shall send a CLEAR REQUEST. If the ground DTE indicated that it maintained the SNDCF context but the aircraft DTE cannot maintain the SNDCF context, it shall send a CALL REQUEST indicating that the SNDCF context is not to be maintained.

Note.— The CLEAR CONFIRMATION, if required, will be transferred in an INFO frame. How the ground and aircraft LME know how to create the calls with their associated negotiated facilities is outside the scope of this manual.

6.6.3.4 Call redirection for X.121-based networks. Even if the ground network supports X.121 addressing, the aircraft shall generate the new Call Request with the VSDA address of the specific air-ground router in the address extension field of the Called Address Extension facility. For JOIN and HANDOFF operations, the aircraft station shall always generate a Call Request using a VSDA address in the Called Address Extension facility.

If the addressed air-ground router is not reachable from the ground station, the ground system may redirect the call to a different air-ground router DTE and inform the aircraft about the call redirection using the Called Line Address Modification Notification (CLAMN) facility specified in 6.6.3.3.

Note.— A CLAMN facility can be used to modify the address for reasons other than redirection.

Call redirection may be used in case of faults related to the air-ground router. The ground system may redirect a call to another address within the same routing domain.

6.6.4 Error handling

An aircraft DTE or ground DCE shall send a CLEAR REQUEST, RESET REQUEST, or RESTART REQUEST packet only for recovery from a DTE failure. When an aircraft DTE or ground DCE receives a DATA packet with a bad sequence number, it shall transmit a REJECT, as specified in ISO 8208, section 13.4.

6.6.5 Acknowledgements

An RR packet shall be generated only when a DATA packet with a valid P(s) and P(r) is received, which closes the acknowledgement window. The aircraft DTE or ground DCE shall transmit an RR packet acknowledging the outstanding packets as soon as it is able.

7. THE VDL MOBILE SUBNETWORK DEPENDENT CONVERGENCE FUNCTION (SNDCF)

7.1 Introduction

An introduction and new function description of the SNDCF for VDL Mode 2 is provided in Annex 10, Volume III, Part 1, Chapter 6. More detailed specifications are contained in this section.

7.2 Call user data encoding

The Call User Data field shall be as detailed in the ATN Manual (Doc 9705), except as modified below.

7.2.1 ISH PDU

The ISH PDU shall be included in both the CALL REQUEST and CALL CONFIRMATION packets.

7.2.2 Maintained/initialized status bit

The fifth bit of the compression technique octet (i.e. the sixth octet of the Call User Data field) shall be the maintained/initialized (M/I) status bit which is used to indicate whether the SNDCF context (e.g. the compression state) was maintained from an old SVC to a new SVC.

7.2.3 CALL REQUEST

If the calling SNDCF is requesting that the SNDCF context be maintained from an existing call to the new call being established, it shall set the M/I bit to 1; otherwise, the M/I bit shall be set to 0.

7.2.4 CALL CONFIRMATION

If the called SNDCF has successfully maintained the entire SNDCF context to the new call being established, it shall set the M/I bit to 1; otherwise, the M/I bit shall be set to 0.

8. TABLES FOR THE MANUAL ON VHF DIGITAL LINK (VDL) MODE 2 TECHNICAL SPECIFICATIONS

Table II-5-1. MAC service system parameters

<i>Symbol</i>	<i>Parameter name</i>	<i>Minimum</i>	<i>Maximum</i>	<i>Mode 2 Default</i>	<i>Increment</i>
TM1	Inter-access delay	0.5 ms	125 ms	4.5 ms	0.5 ms
TM2	Channel busy	6 s	120 s	60 s	1 s
p	Persistence	1/256	1	13/256	1/256
M1	Maximum number of access attempts	1	65 535	135	1

Table II-5-2. Link layer frame format for VDL

DESCRIPTION	OCTEC NO	BIT NUMBER							First bit transmitted
		8	7	6	5	4	3	2	
FLAG	-	0	1	1	1	1	1	1	0
Destination	1	22	23	24	25	26	27	A/G*	0
Address	2	15		Destination				21	0
Field	3	8		DLS Address				14	0
	4	1						7	0
Source	5	22		24	25	26	27	C/R	0
Address	6	15		Source				21	0
Field	7	8		DLS Address				14	0
	8	1						7	1
Link Control Field	9				P/F				
INFORMATION	N-2			USER DATA					
FRAME CHECK SEQUENCE	N-1	9		MOST SIGNIFICANT OCTET					16
	N	1		LEAST SIGNIFICANT OCTET					8
FLAG	-	0	1	1	1	1	1	1	0

*See also 5.3.3.3.1.

Note.— ISO 3309 states that a transmitter may include more than one frame in a single physical layer transmission, with a single flag separating each frame.

Table II-5-3. Address type field encoding

Bit encoding			Description type	Comments
27	26	25		
0	0	0	reserved	Future use
0	0	1	Aircraft	24-bit ICAO address
0	1	0	reserved	Future use
0	1	1	reserved	Future use

<i>Bit encoding</i>			<i>Description type</i>	<i>Comments</i>
27	26	25		
1	0	0	Ground station	ICAO-administered address space
1	0	1	Ground station	ICAO-delegated address space
1	1	0	reserved	Future use
1	1	1	All stations broadcast	All stations

Table II-5-4. Broadcast address encoding

<i>Broadcast destination</i>	<i>Type field</i>	<i>Specific address field</i>
All aircraft	001	All ones
All ground stations of a particular provider	100 or 101, as necessary	Most significant bits: Variable length provider code <i>Remaining bits: All ones</i>
All ground stations with ICAO-administered addresses	100	All ones
All ground stations	101	All ones
All stations	111	All ones

Table II-5-5. AVLC commands and responses

<i>Commands</i>	<i>Responses</i>
INFO [Information]	INFO
RR [Receive Ready]	RR
XID [Exchange Identity]	XID
TEST	TEST
SREJ [Selective Reject]	SREJ [Selective Reject]
FRMR [Frame Reject]	
UI [Unnumbered INFO]	UA [Unnumbered Acknowledge]
DISC [Disconnect]	DM [Disconnected mode]

Table II-5-6. Data link service system parameters for Mode 2

<i>Symbol</i>	<i>Parameter name</i>		<i>Minimum</i>	<i>Maximum</i>	<i>Mode 2 default</i>	<i>Increment</i>
$T1_{\min}$	Delay before retransmission	Minimum	0 s	20 s	1 s	1 ms
$T1_{\max}$		Maximum	1 s	20 s	15 s	1 ms
$T1_{\text{mult}}$		Multiplier	1	2.5	1.45	0.01
$T1_{\text{exp}}$		Exponent	1	2.5	1.7	0.01
$T2$	Delay before ACK		25 ms	10 s	500 ms	1 ms
$T3_{\min}$	Link initial-ization time	Minimum	5 s	25 s	6 s	1 ms
$T3_{\max}$		Maximum	1 s	20 s	15 s	1 ms
$T3_{\text{mult}}$		Multiplier	1	2.5	1.45	0.01
$T3_{\text{exp}}$		Exponent	1	2.5	1.7	0.01
$T4$	Maximum delay between transmissions	aircraft	1 min	1 440 min	20 min	1 min
		ground	3 min	1 442 min	22 min	1 min
$N1$	Maximum number of bits in any frame		1 144 bits	16 504 bits	8 312 bits	1 bit
$N2$	Maximum number of transmissions		1	15	6	1
k	Window size		1 frame	4 frames	4 frames	1 frame

Table II-5-7. HDLC public parameter set identifier

Parameter ID	0	0	0	0	0	0	0	1	HDLC public parameter set
Parameter length	0	0	0	0	1	0	0	1	
Parameter value	0	0	1	1	1	0	0	0	character '8'
	0	0	1	1	1	0	0	0	character '8'
	0	0	1	1	1	0	0	0	character '8'
	0	0	1	1	0	1	0	1	character '5'
	0	0	1	1	1	0	1	0	character ':'
	0	0	1	1	0	0	0	1	character '1'

Parameter ID	0	0	0	0	0	0	0	1	HDLC public parameter set
	0	0	1	1	1	0	0	1	character '9'
	0	0	1	1	1	0	0	1	character '9'
	0	0	1	1	0	0	1	1	character '3'

Table II-5-8. Timer T1 parameter

Parameter ID	0	0	0	0	1	0	0	1	Timer T1 downlink
Parameter length	0	0	0	0	1	0	0	0	
Parameter value	l_{16}	l_{15}	l_{14}	l_{13}	l_{12}	l_{11}	l_{10}	l_9	($T1_{min}$)
	l_8	l_7	l_6	l_5	l_4	l_3	l_2	l_1	
	u_{16}	u_{15}	u_{14}	u_{13}	u_{12}	u_{11}	u_{10}	u_9	($T1_{max}$)
	u_8	u_7	u_6	u_5	u_4	u_3	u_2	u_1	
	m_{16}	m_{15}	m_{14}	m_{13}	m_{12}	m_{11}	m_{10}	m_9	($T1_{mult}$)
	m_8	m_7	m_6	m_5	m_4	m_3	m_2	m_1	
	e_{16}	e_{15}	e_{14}	e_{13}	e_{12}	e_{11}	e_{10}	e_9	($T1_{exp}$)
	e_8	e_7	e_6	e_5	e_4	e_3	e_2	e_1	

Table II-5-9. VDL private parameters

Bit 8	Bit 7	Purpose
0	0	General purpose information private parameter
0	1	Ground-initiated modification private parameter
1	0	Aircraft-initiated information private parameter
1	1	Ground-initiated information private parameter

Note.— ISO 8885 defines the group identifier of the private parameter function to be the hexadecimal value F0.

Table II-5-10. Private parameter set identification

Parameter ID	0	0	0	0	0	0	0	0	Parameter set identification
Parameter length	0	0	0	0	0	0	0	1	
Parameter value	0	1	0	1	0	1	1	0	Character V

Table II-5-11. Connection management parameter

Parameter ID	0	0	0	0	0	0	0	1	Connection management
Parameter length	n ₈	n ₇	n ₆	n ₅	n ₄	n ₃	n ₂	n ₁	
Parameter value	0	0	0	0	v	x	r	h	

Note.— The value in the parameter length field is variable to allow for the possibility of additional options.

Table II-5-12. Connection management parameter values

Bit	Name	Encoding
1	h	h = 0 No link currently established. h = 1 Link currently established.
2	r	r = 0 Link connection accepted. r = 1 Link connection refused.
3	x	x = 0 Only VDL-specific ground DTE addresses. x = 1 Ground network DTE addresses accepted.
4	v	v = 0 Expedited subnetwork connection not supported. v = 1 Expedited subnetwork connection supported.
5-8	Reserved	Set to 0

Table II-5-13. Abbreviated XID names

Name	C/R	P/F	h	r	x	v	Notes
GSIF	0	0	-	-	-	-	Ground Station Information Frame
XID_CMD_LE	0	1	0	0	x	x	Link Establishment
XID_CMD_LCR	0	0	0	1	x	x	Link Connection Refused
XID_CMD_LPM	0	1	-	-	-	-	Link Parameter Modification
XID_CMD_HO	0	1	1	0	x	x	If P=1, then Initiating Handoff.
XID_CMD_HO	0	0	1	0	x	x	If broadcast and P=0, then commanding a Broadcast Handoff. If unicast and P=0, then Requesting Handoff.
XID_RSP_LE	1	1	0	0	x	x	

Name	C/R	P/F	h	r	x	v	Notes
XID_RSP_LCR	1	1	0	1	x	x	
XID_RSP_LPM	1	1	-	-	-	-	
XID_RSP_HO	1	1	1	0	x	x	

x = don't care case
 - = connection management parameter not included

Table II-5-14. Signal quality parameter

Parameter ID	0	0	0	0	0	0	1	0	SQP
Parameter length	0	0	0	0	0	0	0	1	
Parameter value	0	0	0	0	q ₄	q ₃	q ₂	q ₁	

The contents of the SQP value field (q bits) are as defined in 4.1.1.

Table II-5-15. XID sequencing parameter

Parameter ID	0	0	0	0	0	0	1	1	XID sequencing
Parameter length	0	0	0	0	0	0	0	1	
Parameter value	r ₄	r ₃	r ₂	r ₁	0	s ₃	s ₂	s ₁	

Table II-5-16. AVLC specific options parameter

Parameter ID	0	0	0	0	0	1	0	0	AVLC specific options
Parameter length	n ₈	n ₇	n ₆	n ₅	n ₄	n ₃	n ₂	n ₁	
Parameter value	0	gnd	a	b _s	b _i	i	v	x	

Note.— The value in the parameter length field is variable to allow for the possibility of additional options.

Table II-5-17. AVLC specific option values

Bit	Name	Encoding
1	x	x = 0 Only VDL-specific DTE addresses x = 1 Ground network DTE addresses accepted
2	v	v = 0 Expedited subnetwork connection not supported

Bit	Name	Encoding	
3	i	v = 1	Expedited subnetwork connection supported
		i = 0	Does not support initiated handoff
		i = 1	Supports initiated handoff
4	b _i	b _i = 0	Broadcast link handoff not supported
		b _i = 1	Broadcast link handoff supported
5	b _s	b _s = 0	Broadcast subnetwork connection not supported
		b _s = 1	Broadcast subnetwork connection supported (b _i shall also be 1)
6	a	a = 0	No ACARS over AVLIC service supported and/or requested (see 5.4.2.4.5)
		a = 1	ACARS over AVLIC service supported ¹ and/or requested (see 5.4.2.4.5)
7	gnd	gnd = 0	FSL contains airborne frequencies (see 5.4.2.4.5)
		gnd = 1	FSL contains ground frequencies
8	Reserved	Set to 0	Reserved for future use

¹ Note.— If a = 1 and VDSA is valid, then both 8208 and non-8208 services are supported. To ensure the compatibility of mixed services, the Initial Protocol Identifier ISO-9577 shall be used in any packet header.

Table II-5-18. Expedited subnetwork connection parameter

Parameter ID	0	0	0	0	0	1	0	1	Expedited SN connection
Parameter length	n ₈	n ₇	n ₆	n ₅	n ₄	n ₃	n ₂	n ₁	
Parameter value	p ₈	p ₇	p ₆	p ₅	p ₄	p ₃	p ₂	p ₁	an ISO 8208 octet

Table II-5-19. LCR cause parameter

Parameter ID	0	0	0	0	0	1	1	0	LCR cause
Parameter length	n ₈	n ₇	n ₆	n ₅	n ₄	n ₃	n ₂	n ₁	
Parameter value	c ₈	c ₇	c ₆	c ₅	c ₄	c ₃	c ₂	c ₁	cause
	d ₁₆	d ₁₅	d ₁₄	d ₁₃	d ₁₂	d ₁₁	d ₁₀	d ₉	delay
	d ₈	d ₇	d ₆	d ₅	d ₄	d ₃	d ₂	d ₁	
	a ₈	a ₇	a ₆	a ₅	a ₄	a ₃	a ₂	a ₁	additional data

Table II-5-20. Cause code table

Cause	Function	Additional data encoding							
00h	Bad local parameter. The additional data block, which may be repeated, contains the GI and PI of a parameter which cannot be satisfied by this ground station. This cause will not be sent for an illegal Connection Management parameter.	g ₈	g ₇	g ₆	g ₅	g ₄	g ₃	g ₂	g ₁
		p ₈	p ₇	p ₆	p ₅	p ₄	p ₃	p ₂	p ₁
01h	Out of link layer resources.	undefined							
02h	Out of packet layer resources.								
03h	Terrestrial network not available.								
04h	Terrestrial network congestion.								
05h	Cannot support autotune.								
06h	Station cannot support initiating handoff.								
07h	Autotune rejected – service required from multiple providers								
08h	Autotune rejected – not preferred provider								
09h	Attempting to connect to Ground frequency while still indicating Airborne								
0A-7Eh	Reserved								
7Fh	Other unspecified local reason.								
80h	Bad global parameter. The additional data block, which may be repeated, contains the GI and PI of a parameter which cannot be satisfied by any ground station in the system. This cause will not be sent for an illegal Connection Management parameter.	identical to cause code 00							
81h	Protocol Violation. The first octet of the additional data block contains: 1. C/R bit (c bit) of the received XID; 2. P/F bit (p bit) of the received XID; 3. Disconnected bit (d bit) shall be set to 1 if the LME has no links with the remote LME (the unexpected bit shall also be set to 1); 4. Illegal bit (i bit) shall be set to 1 if the LME receives an illegal XID (i.e. not listed in Tables II-5-47 a), b) and c), and described in 5.4.4); 5. Unexpected bit (u bit) shall be set to 1 if the LME receives a legal XID which is not legal in the context in which it was received.	0	0	0	u	i	d	p	c
		m ₈	m ₇	m ₆	m ₅	m ₄	m ₃	m ₂	m ₁
	The remaining octet(s) contain(s) the parameter value of the Connection Management parameter (m bits) if included in the illegal XID. After transmitting or receiving an LCR with this cause code, an LME shall delete all of its links.								
82h	Ground system out of resources.								
83-FEh	Reserved								
FFh	Other unspecified system reason.								

Table II-5-21. Modulation support parameter

Parameter ID	1	0	0	0	0	0	0	1	Modulation support
Parameter length	0	0	0	0	0	0	0	1	
Parameter value	0	0	0	0	m ₄	m ₃	m ₂	m ₁	

Table II-5-22. Modulation scheme and bit rate

<i>Bit</i>	<i>Name</i>	<i>Encoding</i>	
	Reserved	Set to 0	
2	D8PSK	0	(Not Mode 2)
		1	Mode 2, 31 500 bits/s
3	D8PSK	0	(Not Mode 3)
		1	Mode 3, 31 500 bits/s
4	Reserved	Set to 0	

Note.— More than one modulation scheme may be supported by an aircraft.

Table II-5-23. Acceptable alternative ground station parameter

Parameter ID	1	0	0	0	0	0	1	0	Alternate ground station
Parameter length	n ₈	n ₇	n ₆	n ₅	n ₄	n ₃	n ₂	n ₁	
Parameter value	g ₂₂	g ₂₃	g ₂₄	g ₂₅	g ₂₆	g ₂₇	0	0	DLS Address
	g ₁₅	g ₁₆	g ₁₇	g ₁₈	g ₁₉	g ₂₀	g ₂₁	0	
	g ₈	g ₉	g ₁₀	g ₁₁	g ₁₂	g ₁₃	g ₁₄	0	
	g ₁	g ₂	g ₃	g ₄	g ₅	g ₆	g ₇	0	

Table II-5-24. Destination airport parameter

Parameter ID	1	0	0	0	0	0	1	1	Destination airport
Parameter length	n ₈	n ₇	n ₆	n ₅	n ₄	n ₃	n ₂	n ₁	
Parameter value	a ₈	a ₇	a ₆	a ₅	a ₄	a ₃	a ₂	a ₁	(first character)
	b ₈	b ₇	b ₆	b ₅	b ₄	b ₃	b ₂	b ₁	
	c ₈	c ₇	c ₆	c ₅	c ₄	c ₃	c ₂	c ₁	
	d ₈	d ₇	d ₆	d ₅	d ₄	d ₃	d ₂	d ₁	(fourth character)

Table II-5-25. Aircraft location parameter

Parameter ID	1	0	0	0	0	1	0	0	Aircraft location
Parameter length	0	0	0	0	0	1	0	0	
Parameter value	v ₁₂	v ₁₁	v ₁₀	v ₉	v ₈	v ₇	v ₆	v ₅	latitude (v)
	v ₄	v ₃	v ₂	v ₁	h ₁₂	h ₁₁	h ₁₀	h ₉	longitude (h)
	h ₈	h ₇	h ₆	h ₅	h ₄	h ₃	h ₂	h ₁	
	a ₈	a ₇	a ₆	a ₅	a ₄	a ₃	a ₂	a ₁	altitude (a)

Table II-5-26. Aircraft location subfield description

<i>Subfield</i>	<i>Range</i>	<i>Encoding</i>	<i>Notes</i>	<i>Abbreviation</i>
Latitude	+90 to -90	Integer [degrees*10]	positive = north, negative = south, coded as two's complement	v bits
Longitude	+180 to -180	Integer [degrees*10]	positive = east, negative = west, coded as two's complement	h bits
Altitude	0 to 255	Integer [FL / 10]	use 0 for <999 feet, 255 for >= 255 000 feet	a bits

Note.— For example, 100 degrees 18 minutes west equals 100.3 degrees west, which is expressed as -1003, which is encoded as C15 hexadecimal.

Table II-5-27. Autotune frequency parameter

Parameter ID	0	1	0	0	0	0	0	0	Autotune frequency
Parameter length	0	0	0	0	0	0	1	0	
Parameter value	m ₄	m ₃	m ₂	m ₁	f ₁₂	f ₁₁	f ₁₀	f ₉	
	f ₈	f ₇	f ₆	f ₅	f ₄	f ₃	f ₂	f ₁	

Table II-5-28. Replacement ground station list

Parameter ID	0	1	0	0	0	0	0	1	Replacement ground station list
Parameter length	n ₈	n ₇	n ₆	n ₅	n ₄	n ₃	n ₂	n ₁	
Parameter value	g ₂₂	g ₂₃	g ₂₄	g ₂₅	g ₂₆	g ₂₇	0	0	
	g ₁₅	g ₁₆	g ₁₇	g ₁₈	g ₁₉	g ₂₀	g ₂₁	0	
	g ₈	g ₉	g ₁₀	g ₁₁	g ₁₂	g ₁₃	g ₁₄	0	
	g ₁	g ₂	g ₃	g ₄	g ₅	g ₆	g ₇	0	

Table II-5-29. Timer T4 parameter

Parameter ID	0	1	0	0	0	0	1	0	Timer T4
Parameter length	0	0	0	0	0	0	1	0	
Parameter value	n ₁₆	n ₁₅	n ₁₄	n ₁₃	n ₁₂	n ₁₁	n ₁₀	n ₉	
	n ₈	n ₇	n ₆	n ₅	n ₄	n ₃	n ₂	n ₁	

Table II-5-30. MAC persistence parameter

Parameter ID	0	1	0	0	0	0	1	1	MAC persistence
Parameter length	0	0	0	0	0	0	0	1	
Parameter value	n ₈	n ₇	n ₆	n ₅	n ₄	n ₃	n ₂	n ₁	

Table II-5-31. Counter M1 parameter

Parameter ID	0	1	0	0	0	1	0	0	Counter M1
Parameter length	0	0	0	0	0	0	1	0	
Parameter value	n ₁₆	n ₁₅	n ₁₄	n ₁₃	n ₁₂	n ₁₁	n ₁₀	n ₉	
	n ₈	n ₇	n ₆	n ₅	n ₄	n ₃	n ₂	n ₁	

Table II-5-32. Timer TM2 parameter

Parameter ID	0	1	0	0	0	1	0	1	Timer TM2
Parameter length	0	0	0	0	0	0	0	1	
Parameter value	n ₈	n ₇	n ₆	n ₅	n ₄	n ₃	n ₂	n ₁	

Table II-5-33. Timer TG5 parameter

Parameter ID	0	1	0	0	0	1	1	0	Timer TG5
Parameter length	0	0	0	0	0	0	1	0	
Parameter value	i ₈	i ₇	i ₆	i ₅	i ₄	i ₃	i ₂	i ₁	(initiating)
	r ₈	r ₇	r ₆	r ₅	r ₄	r ₃	r ₂	r ₁	(responding)

Table II-5-34. T3_{min} parameter

Parameter ID	0	1	0	0	0	1	1	1	T3 _{min}
Parameter length	0	0	0	0	0	0	1	0	
Parameter value	n ₁₆	n ₁₅	n ₁₄	n ₁₃	n ₁₂	n ₁₁	n ₁₀	n ₉	
	n ₈	n ₇	n ₆	n ₅	n ₄	n ₃	n ₂	n ₁	

Table II-5-35. Ground station address filter parameter

Parameter ID	0	1	0	0	1	0	0	0	Ground station address filter
Parameter length	0	0	0	0	0	1	0	0	
Parameter value	g ₂₂	g ₂₃	g ₂₄	g ₂₅	g ₂₆	g ₂₇	0	0	DLS address
	g ₁₅	g ₁₆	g ₁₇	g ₁₈	g ₁₉	g ₂₀	g ₂₁	0	
	g ₈	g ₉	g ₁₀	g ₁₁	g ₁₂	g ₁₃	g ₁₄	0	
	g ₁	g ₂	g ₃	g ₄	g ₅	g ₆	g ₇	0	

Table II-5-36. Broadcast connection (link only) parameter

Parameter ID	0	1	0	0	1	0	0	1	Broadcast connection
Parameter length	0	0	0	0	0	0	1	1	
Parameter value	a ₂₄	a ₂₃	a ₂₂	a ₂₁	a ₂₀	a ₁₉	a ₁₈	a ₁₇	Aircraft ID
	a ₁₆	a ₁₅	a ₁₄	a ₁₃	a ₁₂	a ₁₁	a ₁₀	a ₉	
	a ₈	a ₇	a ₆	a ₅	a ₄	a ₃	a ₂	a ₁	

Note.— This table shows the case of a successful link handoff, with no switched virtual circuits (SVCs) maintained.

Table II-5-37. Broadcast connection (link and subnetwork) parameter

Parameter ID	0	1	0	0	1	0	0	1	Broadcast connection
Parameter length	0	0	0	0	0	1	0	1	
Parameter value	a ₂₄	a ₂₃	a ₂₂	a ₂₁	a ₂₀	a ₁₉	a ₁₈	a ₁₇	aircraft ID
	a ₁₆	a ₁₅	a ₁₄	a ₁₃	a ₁₂	a ₁₁	a ₁₀	a ₉	
	a ₈	a ₇	a ₆	a ₅	a ₄	a ₃	a ₂	a ₁	
	0	0	0	m	l ₁₂	l ₁₁	l ₁₀	l ₉	an M/I bit and an LCI
	l ₈	l ₇	l ₆	l ₅	l ₄	l ₃	l ₂	l ₁	

Note.— This table shows the case of a successful link handoff, as well as one SVC having been maintained.

Table II-5-38. Frequency support list

Parameter ID	1	1	0	0	0	0	0	0	Frequency support list
Parameter length	n ₈	n ₇	n ₆	n ₅	n ₄	n ₃	n ₂	n ₁	
Parameter value	m ₄	m ₃	m ₂	m ₁	f ₁₂	f ₁₁	f ₁₀	f ₉	
	f ₈	f ₇	f ₆	f ₅	f ₄	f ₃	f ₂	f ₁	
	g ₂₂	g ₂₃	g ₂₄	g ₂₅	g ₂₆	g ₂₇	0	0	
	g ₁₅	g ₁₆	g ₁₇	g ₁₈	g ₁₉	g ₂₀	g ₂₁	0	
	g ₈	g ₉	g ₁₀	g ₁₁	g ₁₂	g ₁₃	g ₁₄	0	
	g ₁	g ₂	g ₃	g ₄	g ₅	g ₆	g ₇	0	

Table II-5-39. Airport coverage indication parameter

Parameter ID	1	1	0	0	0	0	0	1	Airport coverage indication
Parameter length	n ₈	n ₇	n ₆	n ₅	n ₄	n ₃	n ₂	n ₁	
Parameter value	a ₈	a ₇	a ₆	a ₅	a ₄	a ₃	a ₂	a ₁	(first character)
	b ₈	b ₇	b ₆	b ₅	b ₄	b ₃	b ₂	b ₁	
	c ₈	c ₇	c ₆	c ₅	c ₄	c ₃	c ₂	c ₁	
	d ₈	d ₇	d ₆	d ₅	d ₄	d ₃	d ₂	d ₁	(fourth character)

Table II-5-40. Nearest airport parameter

Parameter ID	1	1	0	0	0	0	1	1	Nearest airport
Parameter length	0	0	0	0	0	1	0	0	
Parameter value	a ₈	a ₇	a ₆	a ₅	a ₄	a ₃	a ₂	a ₁	(first character)
	b ₈	b ₇	b ₆	b ₅	b ₄	b ₃	b ₂	b ₁	
	c ₈	c ₇	c ₆	c ₅	c ₄	c ₃	c ₂	c ₁	
	d ₈	d ₇	d ₆	d ₅	d ₄	d ₃	d ₂	d ₁	(fourth character)

Table II-5-41. ATN router NETs parameter

Parameter ID	1	1	0	0	0	1	0	0	ATN router NETs
Parameter length	n ₈	n ₇	n ₆	n ₅	n ₄	n ₃	n ₂	n ₁	
Parameter value	a ₂₄	a ₂₃	a ₂₂	a ₂₁	a ₂₀	a ₁₉	a ₁₈	a ₁₇	ADM subfield
	a ₁₆	a ₁₅	a ₁₄	a ₁₃	a ₁₂	a ₁₁	a ₁₀	a ₉	
	a ₈	a ₇	a ₆	a ₅	a ₄	a ₃	a ₂	a ₁	
	r ₂₄	r ₂₃	r ₂₂	r ₂₁	r ₂₀	r ₁₉	r ₁₈	r ₁₇	ARS subfield
	r ₁₆	r ₁₅	r ₁₄	r ₁₃	r ₁₂	r ₁₁	r ₁₀	r ₉	
	r ₈	r ₇	r ₆	r ₅	r ₄	r ₃	r ₂	r ₁	

Table II-5-42. Ground-based system mask parameter

Parameter ID	1	1	0	0	0	1	0	1	Ground-based system mask
Parameter length	0	0	0	0	0	1	0	0	
Parameter value	g ₂₂	g ₂₃	g ₂₄	g ₂₅	g ₂₆	g ₂₇	0	0	
	g ₁₅	g ₁₆	g ₁₇	g ₁₈	g ₁₉	g ₂₀	g ₂₁	0	
	g ₈	g ₉	g ₁₀	g ₁₁	g ₁₂	g ₁₃	g ₁₄	0	
	g ₁	g ₂	g ₃	g ₄	g ₅	g ₆	g ₇	0	

Table II-5-43. Timer TG3 parameter

Parameter ID	1	1	0	0	0	1	1	0	Timer TG3
Parameter length	0	0	0	0	0	1	0	0	
Parameter value	1 ₁₆	1 ₁₅	1 ₁₄	1 ₁₃	1 ₁₂	1 ₁₁	1 ₁₀	1 ₉	(lower bound)
	1 ₈	1 ₇	1 ₆	1 ₅	1 ₄	1 ₃	1 ₂	1 ₁	
	u ₁₆	u ₁₅	u ₁₄	u ₁₃	u ₁₂	u ₁₁	u ₁₀	u ₉	(upper bound)
	u ₈	u ₇	u ₆	u ₅	u ₄	u ₃	u ₂	u ₁	

Table II-5-44. Timer TG4 parameter

Parameter ID	1	1	0	0	0	1	1	1	Timer TG4
Parameter length	0	0	0	0	0	0	1	0	
Parameter value	V ₁₆	V ₁₅	V ₁₄	V ₁₃	V ₁₂	V ₁₁	V ₁₀	V ₉	
	V ₈	V ₇	V ₆	V ₅	V ₄	V ₃	V ₂	V ₁	

Table II-5-45. Ground station location parameter

Parameter ID	1	1	0	0	1	0	0	0	Ground station location
Parameter length	0	0	0	0	0	0	1	1	
Parameter value	V ₁₂	V ₁₁	V ₁₀	V ₉	V ₈	V ₇	V ₆	V ₅	latitude (v)
	V ₄	V ₃	V ₂	V ₁	h ₁₂	h ₁₁	h ₁₀	h ₉	longitude (h)
	h ₈	h ₇	h ₆	h ₅	h ₄	h ₃	h ₂	h ₁	

Table II-5-46. VDL management entity system parameters

<i>Symbol</i>	<i>Parameter name</i>	<i>Minimum</i>	<i>Maximum</i>	<i>Mode 2 default</i>	<i>Increment</i>
TG1 (air only)	Minimum frequency dwell time	20 s	600 s	240 s	1 s
TG2	Maximum idle activity time aircraft ground	120 s 10 min	360 s 4320 min	240 s 60 min	1 s 1 min
TG3 (ground only)	Maximum time between transmissions	100 s	120 s	uniform between 100- 120 s	0.5 s
TG4 (ground only)	Maximum time between GSIFs	100 s	N/A	N/A	1 s
TG5	Maximum link overlap time initiating responding	0 s 0 s	255 s 255 s	20 s 60 s	1 s 1 s

Table II-5-47 a). XID parameters

	Source address Destination address		GSIF	Aircraft-initiated link establishment		Link parameter modification	
			Ground station All aircraft	Aircraft Proposed ground station	New ground station Aircraft	Current ground station Aircraft	Aircraft Current ground station
XID parameters	GI	PI	GSIF (P=0)	XID_CMD_LE (P=1)	XID_RSP_LE (F=1)	XID_CMD_LPM (P=1)	XID_RSP_LPM (F=1)
Public parameters							
Parameter set ID	80h	01h	M	M	M	N/A	N/A
Procedure classes	80h	02h	M	M	M	N/A	N/A
HDLC options	80h	03h	M	M	M	N/A	N/A
N1-downlink	80h	05h	O	N/A	O	N/A	N/A
N1-uplink	80h	06h	O	N/A	O	N/A	N/A
k-downlink	80h	07h	O	N/A	O	N/A	N/A
k-uplink	80h	08h	O	N/A	O	N/A	N/A
Timer T1 _ downlink	80h	09h	O	N/A	O	N/A	N/A
Counter N2	80h	0Ah	O	N/A	O	N/A	N/A
Timer T2	80h	0Bh	O	N/A	O	N/A	N/A
Private parameters							
Parameter set ID	F0h	00h	M	M	M	M	M
Connection management	F0h	01h	N/A	M	M	N/A	N/A
SQP	F0h	02h	N/A	O	O	O	O
XID sequencing	F0h	03h	N/A	M	M	M	M
AVLC specific options	F0h	04h	M	M	M	N/A	N/A
Expedited SN connection	F0h	05h	N/A	O	O	N/A	N/A
LCR cause	F0h	06h	N/A	N/A	N/A	N/A	N/A
Modulation support	F0h	81h	N/A	M	N/A	N/A	N/A
Alternate ground stations	F0h	82h	N/A	O	N/A	N/A	N/A
Destination airport	F0h	83h	N/A	M ³	N/A	N/A	N/A
Aircraft location	F0h	84h	N/A	M ³	N/A	N/A	N/A
Autotune frequency	F0h	40h	N/A	N/A	O	N/A	N/A
Repl. ground station	F0h	41h	N/A	N/A	O	N/A	N/A
Timer T4	F0h	42h	O	N/A	O	O	N/A
MAC persistence	F0h	43h	O	N/A	O	O	N/A
Counter M1	F0h	44h	O	N/A	O	O	N/A
Timer TM2	F0h	45h	O	N/A	O	O	N/A
Timer TG5	F0h	46h	O	N/A	O	O	N/A

	Source address Destination address		GSIF	Aircraft-initiated link establishment		Link parameter modification	
			Ground station All aircraft	Aircraft Proposed ground station	New ground station Aircraft	Current ground station Aircraft	Aircraft Current ground station
XID parameters	GI	PI	GSIF (P=0)	XID_CMD_LE (P=1)	XID_RSP_LE (F=1)	XID_CMD_LPM (P=1)	XID_RSP_LPM (F=1)
Timer T3 _{min}	F0h	47h	O	N/A	O	N/A	N/A
Address filter	F0h	48h	N/A	N/A	N/A	N/A	N/A
Broadcast connection	F0h	49h	N/A	N/A	N/A	N/A	N/A
Frequency support	F0h	C0h	O	N/A	O	N/A	N/A
Airport coverage	F0h	C1h	M ¹	N/A	O ²	N/A	N/A
Nearest airport ID	F0h	C3h	M ¹	N/A	O ²	N/A	N/A
ATN router NETs	F0h	C4h	M	N/A	M	N/A	N/A
System mask	F0h	C5h	M	N/A	M	N/A	N/A
TG3	F0h	C6h	O	N/A	O	N/A	N/A
TG4	F0h	C7h	O	N/A	O	N/A	N/A
Ground station location	F0h	C8h	M	N/A	O	N/A	N/A

GI = ISO 8885 Group identifier

PI = ISO 8885 Parameter identifier

M = Mandatory

O = Optional

N/A = Not applicable

h = hexadecimal

Notes.—

1. In a GSIF XID frame it is mandatory to include either the Airport Coverage Indication parameter or the Nearest Airport Identifier parameter but not both (see 5.4.2.7.3).
2. Where the Airport Coverage Indication parameter and the Nearest Airport Identifier parameter are marked as optional, either parameter may be included in the frame or neither but not both.
3. Presence of this field is mandated only when valid data is available. In the absence of valid data, the parameter shall be omitted.

Table II-5-47 b). XID parameters

			Ground-initiated handoff		Aircraft-initiated handoff	
			Proposed ground station	Aircraft	Aircraft	New ground station
	Source address	Destination address	Aircraft	New ground station	Proposed ground station	Aircraft
XID parameters	GI	PI	XID_CMD_HO (P=1)	XID_RSP_HO (F=1)	XID_CMD_HO (P=1)	XID_RSP_HO (F=1)
Public parameters						
Parameter set ID	80h	01h	M	M	M	M
Procedure classes	80h	02h	M	M	M	M
HDLC options	80h	03h	M	M	M	M
N1-downlink	80h	05h	O	N/A	N/A	O
N1-uplink	80h	06h	O	N/A	N/A	O
k-downlink	80h	07h	O	N/A	N/A	O
k-uplink	80h	08h	O	N/A	N/A	O
Timer T1 - downlink	80h	09h	O	N/A	N/A	O
Counter N2	80h	0Ah	O	N/A	N/A	O
Timer T2	80h	0Bh	O	N/A	N/A	O
Private parameters						
Parameter set ID	F0h	00h	M	M	M	M
Connection management	F0h	01h	M	M	M	M
SQP	F0h	02h	O	O	O	O
XID sequencing	F0h	03h	M	M	M	M
AVLC specific options	F0h	04h	O	O	O	O
Expedited SN connection	F0h	05h	X	X	O	O
LCR cause	F0h	06h	N/A	N/A	N/A	N/A
Modulation support	F0h	81h	N/A	N/A	N/A	N/A
Alternate ground stations	F0h	82h	N/A	N/A	O	N/A
Destination airport	F0h	83h	N/A	O	M ³	N/A
Aircraft location	F0h	84h	N/A	O	M ³	N/A
Autotune frequency	F0h	40h	N/A	N/A	N/A	O
Repl. ground station	F0h	41h	O	N/A	N/A	O
Timer T4	F0h	42h	O	N/A	N/A	O
MAC persistence	F0h	43h	O	N/A	N/A	O
Counter M1	F0h	44h	O	N/A	N/A	O
Timer TM2	F0h	45h	O	N/A	N/A	O
Timer TG5	F0h	46h	O	N/A	N/A	O

			Ground-initiated handoff		Aircraft-initiated handoff	
			Proposed ground station	Aircraft	Aircraft	New ground station
	Source address	Destination address	Aircraft	New ground station	Proposed ground station	Aircraft
XID parameters	GI	PI	XID_CMD_HO (P=1)	XID_RSP_HO (F=1)	XID_CMD_HO (P=1)	XID_RSP_HO (F=1)
Timer T3 _{min}	F0h	47h	O	N/A	N/A	O
Address filter	F0h	48h	N/A	N/A	N/A	N/A
Broadcast connection	F0h	49h	N/A	N/A	N/A	N/A
Frequency support	F0h	C0h	O	N/A	N/A	O
Airport coverage	F0h	C1h	O ²	N/A	N/A	O ²
Nearest airport ID	F0h	C3h	O ²	N/A	N/A	O ²
ATN router NETs	F0h	C4h	M	N/A	N/A	O
System mask	F0h	C5h	M	N/A	N/A	M
TG3	F0h	C6h	O	N/A	N/A	O
TG4	F0h	C7h	O	N/A	N/A	O
Ground station location	F0h	C8h	O	N/A	N/A	O

GI = ISO 8885 Group identifier

PI = ISO 8885 Parameter identifier

M = Mandatory

O = Optional

N/A = Not applicable

h = hexadecimal

X = Prohibited

Notes.—

1. In a GSIF XID frame it is mandatory to include either the Airport Coverage Indication parameter or the Nearest Airport Identifier parameter but not both (see 5.4.2.7.3).
2. Where the Airport Coverage Indication parameter and the Nearest Airport Identifier parameter are marked as optional, either parameter may be included in the frame or neither but not both.
3. Presence of this field is mandated only when valid data is available. In the absence of valid data, the parameter shall be omitted.

Table II-5-47 c). XID parameters

	Source address Destination address		Ground requested handoff	Ground requested broadcast	Link connection rejection
			Current ground station	New ground station	Any station
			Aircraft	All aircraft	Any station
XID parameters	GI	PI	XID_CMD_HO (P=0)	XID_CMD_HO (P=0)	XID_RSP_LCR XID_CMD_LCR
Public parameters					
Parameter set ID	80h	01h	M	M	N/A
Procedure classes	80h	02h	M	M	N/A
HDLC options	80h	03h	M	M	N/A
N1-downlink	80h	05h	O	O	N/A
N1-uplink	80h	06h	O	O	N/A
k-downlink	80h	07h	O	O	N/A
k-uplink	80h	08h	O	O	N/A
Timer T1 - downlink	80h	09h	O	O	N/A
Counter N2	80h	0Ah	O	O	N/A
Timer T2	80h	0Bh	O	O	N/A
Private parameters					
Parameter set ID	F0h	00h	M	M	M
Connection management	F0h	01h	M	M	M
SQP	F0h	02h	N/A	N/A	N/A
XID sequencing	F0h	03h	M	M	M
AVLC specific options	F0h	04h	O	O	N/A
Expedited SN connection	F0h	05h	N/A	N/A	N/A
LCR cause	F0h	06h	N/A	N/A	M
Modulation support	F0h	81h	N/A	N/A	N/A
Alternate ground stations	F0h	82h	N/A	N/A	N/A
Destination airport	F0h	83h	N/A	N/A	N/A
Aircraft location	F0h	84h	N/A	N/A	N/A
Autotune frequency	F0h	40h	M	N/A	N/A
Repl. ground station	F0h	41h	M	N/A	N/A
Timer T4	F0h	42h	O	O	N/A
MAC persistence	F0h	43h	O	O	N/A
Counter M1	F0h	44h	O	O	N/A
Timer TM2	F0h	45h	O	O	N/A
Timer TG5	F0h	46h	O	O	N/A

	Source address Destination address		Ground requested handoff	Ground requested broadcast	Link connection rejection
			Current ground station	New ground station	Any station
			Aircraft	All aircraft	Any station
XID parameters	GI	PI	XID_CMD_HO (P=0)	XID_CMD_HO (P=0)	XID_RSP_LCR XID_CMD_LCR
Public parameters					
Timer T3 _{min}	F0h	47h	O	O	N/A
Address filter	F0h	48h	N/A	M	N/A
Broadcast connection	F0h	49h	N/A	M	N/A
Private parameters					
Frequency support	F0h	C0h	O	O	N/A
Airport coverage	F0h	C1h	N/A	O ²	N/A
Nearest airport ID	F0h	C3h	N/A	O ²	N/A
ATN router NETs	F0h	C4h	M	M	N/A
System mask	F0h	C5h	M	M	N/A
TG3	F0h	C6h	O	O	N/A
TG4	F0h	C7h	O	O	N/A
Ground station location	F0h	C8h	O	O	N/A

GI = ISO 8885 Group identifier
PI = ISO 8885 Parameter identifier
M = Mandatory
O = Optional
N/A = Not applicable
h = hexadecimal

Notes.—

1. In a GSIF XID frame it is mandatory to include either the Airport Coverage Indication parameter or the Nearest Airport Identifier parameter but not both (see 5.4.2.7.3).
2. Where the Airport Coverage Indication parameter and the Nearest Airport Identifier parameter are marked as optional, either parameter may be included in the frame or neither but not both.

Table II-6-1. Subnetwork layer service system parameters for VDL Mode 2

<i>Symbol</i>	<i>Name</i>	<i>Minimum</i>	<i>Maximum</i>	<i>Mode 2</i>
T20	RESTART REQUEST response timer	1 s	300 s	180 s
T21	CALL REQUEST response timer	1 s	300 s	200 s
T22	RESET REQUEST response timer	1 s	300 s	180 s
T23	CLEAR REQUEST response timer	1 s	300 s	180 s
T27	REJECT response timer	1 s	300 s	180 s
R20	RESTART REQUEST retransmission count	0	7	1
R22	RESET REQUEST retransmission count	0	7	1
R23	CLEAR REQUEST retransmission count	0	7	1
R27	REJECT retransmission count	0	7	1
P	Packet size	128 octets	2 048 octets	1 024 octets
W	Transmit window size	1 packet	7 packets	7 packets
A	Acknowledgement window size	1 packet	4 packets	4 packets
LTC	Lowest two-way channel	0	4 095	1 024
HTC	Highest two-way channel	0	4 095	3 071

Note.— *P, W, A* values define defaults. Other parameter values are preset and not negotiated. The packet size (*P*) and window sizes (*W, A*) define defaults, and may be negotiated during call setup.

Table II-6-2. Facilities supported by the VDL Mode 2

<i>Facility</i>	<i>ISO 8208 section</i>
Packet retransmission	13.4
Reject response timer (T27 timer)	13.4.1
Nonstandard default packet sizes	13.9
Nonstandard default window sizes	13.10
Flow control parameter negotiation	13.12
Fast select	13.16
Fast select acceptance	13.17
Call redirection	13.25
Called line address modified notification	13.26

<i>Facility</i>	<i>ISO 8208 section</i>
Called address extension	14.2

Table II-6-3. Facilities not supported by VDL Mode 2

<i>Facility</i>	<i>ISO 8208 section</i>
Q-bit	6.6
Non-receipt of window rotation information	11.2
Window status retransmission timer (T24)	11.2.2
Window Rotation Timer (T25)	18
Interrupt Response Timer (T26)	18
Registration Request Response Timer (T28)	18
On line facility registration	13.1
Extended packet seq. numbering	13.2
D-bit modification	13.3
Incoming calls barred	13.5
Outgoing calls barred	13.6
One-way logical channel outgoing	13.7
One-way logical channel incoming	13.8
Default throughput classes assignment	13.11
Throughput class negotiation	13.13
Closed user group related facilities	13.14
Bilateral closed user group related facilities	13.15
Reverse charging	13.18
Reverse charging acceptance	13.19
Local charging prevention	13.2
Network user identification	13.21
Charging information	13.22
RPOA selection	13.23
Hunt group	13.24
Transit delay selection and indication	13.27

<i>Facility</i>	<i>ISO 8208 section</i>
Calling address extension	14.1
Minimum throughput class negotiation	14.3
End-to-end transit delay negotiation	14.4
Expedited data negotiation	14.5

9. REFERENCES

References to Standards from the International Organization for Standardization (ISO) are as specified (including date published) below. These ISO Standards shall apply to the extent specified in the SARPs.

9.1 Normative references

These SARPs reference the following ISO documents:

<i>ISO</i>	<i>Title</i>	<i>Date published</i>
646	Information technology — ISO 7-bit coded character set for information interchange	12/91
3309	HDLC Procedures — Frame Structure, Version 3	12/93 ¹
4335	HDLC Elements of Procedures, Version 3	12/93 ¹
7498	OSI Basic Reference Model, Version 1	11/94
7809	HDLC Procedures — Consolidation of Classes of Procedures, Version 1	12/93 ¹
8208	Information Processing Systems — Data Communications — X.25 Packet Level Protocol for Data Terminal Equipment	3/90 2nd ed.
8885	HDLC Procedures — General Purpose XID Frame Information Field Content and Format, Version [1]	12/93 ¹
8886.3	OSI Data Link Service Definition, Version 3	6/92
10039	Local Area Networks — MAC Service Definition, Version 1	6/91

¹ It should be noted that the HDLC standards referenced are obsolete by ISO and have been replaced by ISO13239. It should be noted that there are still sources for these obsolete standards and that ISO13239 is not fully interoperable with the referenced standards.

9.2 Background references

The following documents are listed as reference material.

<i>Originator</i>	<i>Title</i>	<i>Date published</i>
ITU-R	Recommendation S.446.4	
CCSDS	Telemetry Channel Coding, Recommendation for Space Data System Standards, Consultative Committee for Space Data System, CCSDS 101.0-B-3, Blue Book	5/92

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