

VHF Data Link Mode 2 Ground System Supporting The ATS Services Based On The ACARS Over AVLC (AOA)

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Abstract: KARI is developing the VDL M2 system with a simple ATS application system for test and future use. Now, the design and implementation of the system is finishing and the unit tests for the each sub systems are finished. KARI is preparing the ground test and flight test. This paper mainly describes the status of the development of the ground VDL M2 system.

1. Introduction

VHF Data Link Mode 2 (VDL M2) system provides the digital communication link between ground station and aircraft and can be used instead of the current VHF data link such as VDL MA and VDL M1. The ground VDL M2 system consists of data link service providers(DSP) and many ground stations. A ground station consists of a communication management unit(CMU) and a VHF data radio(VDR). The VDL M2 system shall satisfy the requirements specified in the SARPS¹ and Technical Manual² made public by ICAO. VDL M2 protocol is based on the open system interconnection(OSI) reference model.

VDL M2 deals with from physical layer to subnetwork layer, VDR covers up to MAC sublayer and CMU covers the upper layers. The link layer is the key layer for VDL M2 operation and it supports transmission of data frames, link management and handoffs.

KARI is developing the VDL M2 system to support future data link services in Korea. The development is mainly focused on the ground system because the aircraft system can depend on the aircraft manufactures. For the system, three ground stations, a simple DSP, and three airborne systems are used.

Currently, KARI finished the software implementation and now is on the test phase. The unit tests of the GS and DSP are done. In this paper, the software design for GS, DSP and AOA module with interface supporting CPDLC and ADS-B will be mainly described.

2. Ground System Structure

Figure 1 shows the ground system structure with one DSP and three ground stations. The interface between the DSP and the ground station, and between the DSP and the application terminal is TCP/IP. Each ground station has one DLS and several DLEs. DLS supports connection-oriented and connectionless communication. Connection oriented communication is supported by DLE and connectionless communication is supported by LLC_1 which is included in DLS. The software structure and primitives between the VME in the DSP and the DLS in a ground station is shown in Figure 2.

Each DLE has its own timers and INFO queue and XID queue. All retransmission decision making is processed in DLE using T1 and T3 timers. Each LME has a DLE in a normal condition, and 2 DLEs during hand-off.

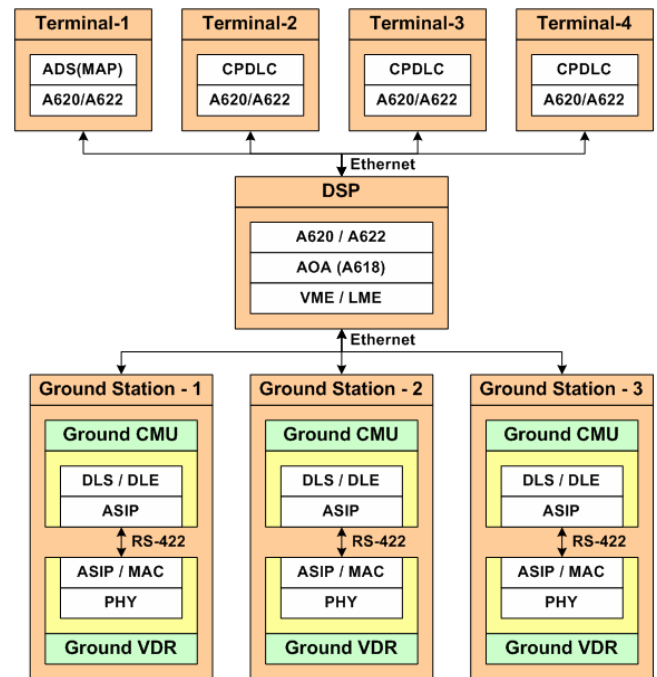
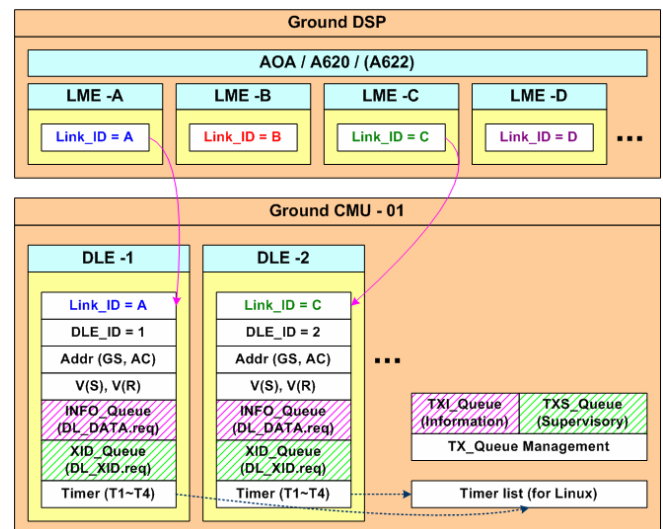
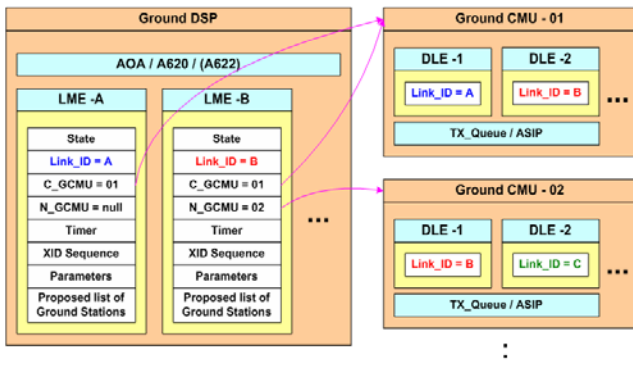


Figure 1. Ground System Structure



(a) Ground CMU

Figure 2. Software Architecture



(b) Ground DSP
Figure 3. Software Architecture

2.1 TX_Queue Management

Each DLE has its own INFO queue and XID queue. It has transmitting and receiving counter, V(R) and V(S). They are used to make AVLC frame in control field and to check the received frame is in sequence. In DLS, there is one TXI_Queue for INFO and UI frames and one TXS_Queue for XID frames and the other supervisory frames. The TXI_Queue and TXS_Queue has pointers to INFO queue, XID queue or DLS information. It is because the state, V(R), V(S), address can be changed during the AVLC frames in the TXI_Queue or TXS_Queue. TX_Queue management function is a process that supports the queue management and the interface to MAC in VDR. The interface to the VDR is RS-422 and is based on the ASIP in ARINC 750.

2.2 Hand-off

Hand-off process shall be started whenever the following conditions are satisfied. (1) frame retransmission counter reaches the maximum retransmission value, (2) LME didn't receive any frame during maximum idle time, (3) channel congestion. Besides the conditions, aircraft or ground shall initiate or request the hand-off when the signal quality of the current link is poor. In the system, the hand-off means only the link hand-off in the same ground system. There are 5 link hand-offs, two are the initiated hand-off(ground or aircraft), two are requested hand-off(ground or aircraft), and the last one is broadcast hand-off. The broadcast hand-off and aircraft requested handoff is not currently supported. So, the last three hand-offs are implemented.

2.3 Application Interface

Basically, the VDL M2 system shall be applied with the ATN network. But the ATN network is not currently constructed and the network for the VDL M2 can be changed to other types, such as TCP/IP. Now, ATS services such as AFN, CPDLC and ADS-B are supported by ACARS network, so to support these services, the VDL M2 system shall have interface to ACARS network. KARI selected AOA to service ATS service with the developed VDL M2 system. AOA is an interface module to support the interface between VDL M2 and ACARS network.

3. Design

For the software detailed design, the functional flow diagram is shown in Figure 3. There are 4 entities in the diagram. They are EN_PHY, EN_MAC, EN_DLS, EN_VME. EN_PHY software is mainly for hardware calculation. EN_VME software is event-driven software. EN_MAC and EN_DLS has sequential and event-driven functions so, their processes are divided into 3 categories, respectively. Each function blocks has its own flow charts. Mainly the flow chart is based on the primitives between the entities.

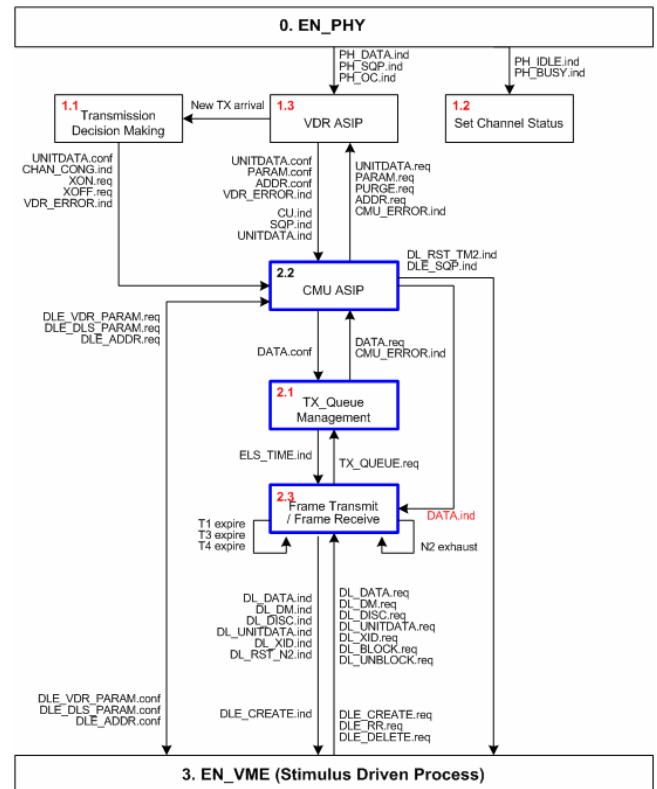


Figure 3. Functional Flow Diagram

3.1 Data Link Service Processor (DSP)

A small data link service processor is used to manage all data links. The DSP includes VME functions to control data links and ground stations. VME makes a LME for each link, and a LME has its own state, link id, DLE list, and timers. LME is implemented by double linked list to be added and removed dynamically. Each LME has four states – ADM, ABM_single, ABM_mult, HO_init_pend. ADM means that there is no link for the LME, ABM means only one link, ABM_mult means two links. HO_init_pend means that the LME requested hand-off and waiting for the response form the aircraft. LMEs are activated by events from GS or timers. A part of state transition table of HO_init_pend state is shown in Figure 4. All timers in VME should be handled in a timer list. The timer is a structure type which has LME id, link id, timer type such as TG1, TG2, time-out value. Each timer is inserted to and deleted from the timer list by

the priority of time-out value. The most urgent timer which has the smallest time-out value has higher priority.

Ground LME Test Script (HO_init_pend)

No	Stimulus	HO_init_pend (GS:c,p)	Description
LG-H1	DL_DM.ind DL_DISC.ind from GS-c	A = DLE_DELETE.req to GS-c DLE_DELETE.req to GS-p S = ADM	GS-p is not currently connected, so if the VME receives DL_DM.ind or DL_DISC.ind from GS-c, it shall process it as if it is in ABM_single.
LG-H2	INFO(GS-x)(P=0)(1)	A = XID_CMD_HO(GS-p)(P=1)	
LG-H3	DL_RST_N2.ind from GS-p or DL_RST_TM2.ind from GS-p or Signal Quality < 4	A = DLE_DELETE.req to GS-p Choose new GS-p2 DLE_CREATE.req to GS-p2 XID_CMD_HO(GS-p2)(P=1)	If N2 is enhanced on GS-p, VME shall select new GS-p2 and try to initiate HO.
LG-H4	Illegal XID frame, XID_CMD_LPM, XID_RSP_LE	A = XID_CMD_LCR(P=0) - illegal to GS-any, DLE_DELETE.req to GS-c and GS-p, S = ADM	For illegal XID frame, VME shall send XID_CMD_LCR(P=0) with illegal cause code. Before transfer to ADM, the LME shall delete its DLE(x).
LG-H5	XID_RSP_LCR(GS-any)(P=1)	A = Display result and cause code S = ABM_single	HO command is refused. Whether the HO will be tried or not is depends on the operator.
LG-H6	XID_CMD_LCR(GS-any)(P=0) - Protocol violation	A = DLE_DELETE.req to GS-c and GS-p S = ADM	
LG-H7	XID_CMD_LE(P=1) - acceptable	A = DLE_DELETE.req to GS-c and GS-p GS-c <= GS-any DLE_CREATE.req to GS-c, XID_RSP_LE(P=1) to GS-c S = ADM_single	AC requests to reestablish a link with GS-any. GS shall reestablish a link for the AC if the parameters are acceptable even if GS-any is a currently connected station, GS-c.
LG-H8	XID_CMD_LE(P=1) - unacceptable	A = XID_RSP_LCR(F=1) - bad parameter to GS-any, DLE_DELETE.req to GS-c and GS-p, S = ADM	AC requests to reestablish a link with GS-any. GS shall disconnect all links for the AC if the parameters are not acceptable.

Figure 4. LME state transition table - HO_INIT_PEND

3.2 Ground Station (DLS)

There is a DLS and several DLEs in a ground station. The ground stations are controlled by the DSP. If a LME requests to create a DLE in the ground station, the ground station create a new DLE with the following data : link id, DLE id, source and destination address, DLE state, send and receive frame number, timers, counters, and queues. There are three queues, INFO queue, SREJ queue, XID queue. INFO queue stores user data to send and SREJ queue stores received out-of-order user data. XID queue stores XID frames to send. The flow chart for the processing of the received INFO frame is shown in Figure 5.

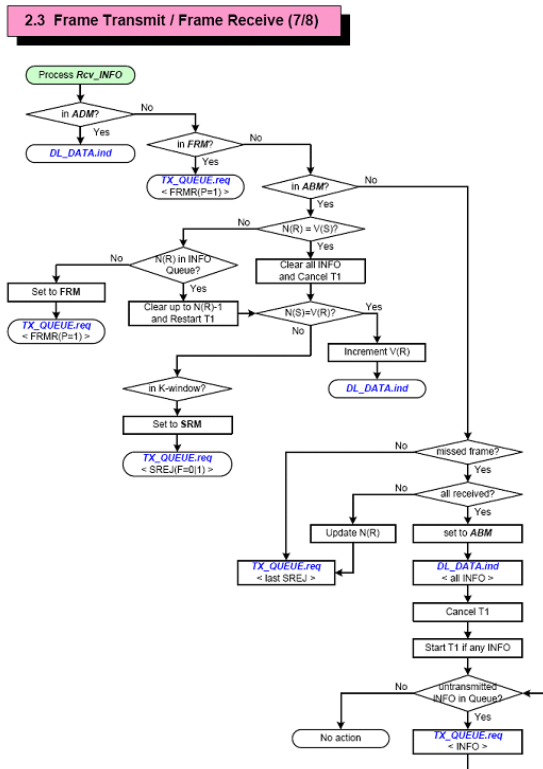


Figure 5. DLE flow chart – Receive INFO

3.3 AOA / ATS Interface

To access ACARS network, KARI VDL M2 system uses AOA. AOA library is an commercial library, so KARI developed an interface module between AOA and application system. KARI wrapper is the interface module. When the DSP receives an AVLC frame, it extracts the AOA packet and sends the packet to AOA processing module. Then the AOA module extracts the ACARS message and sends the wrapper message block to KARI wrapper module. The frame format change is shown in Figure 7. The KARI wrapper communicates with the application system using TCP/IP. The application system is bit-oriented system, so the final data frame uses ARINC 622 data format.

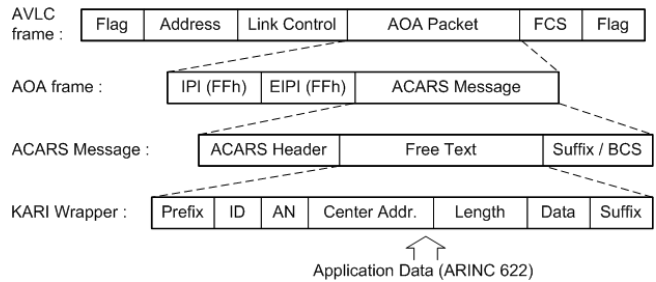


Figure 7. AVLC to KARI wrapper frame format

4. Implementation and Test

4.1 Implementation

The software is implemented by C language at Linux operating system. The software modules are ASIP, DLS, VME, AOA, and CPDLC interface.

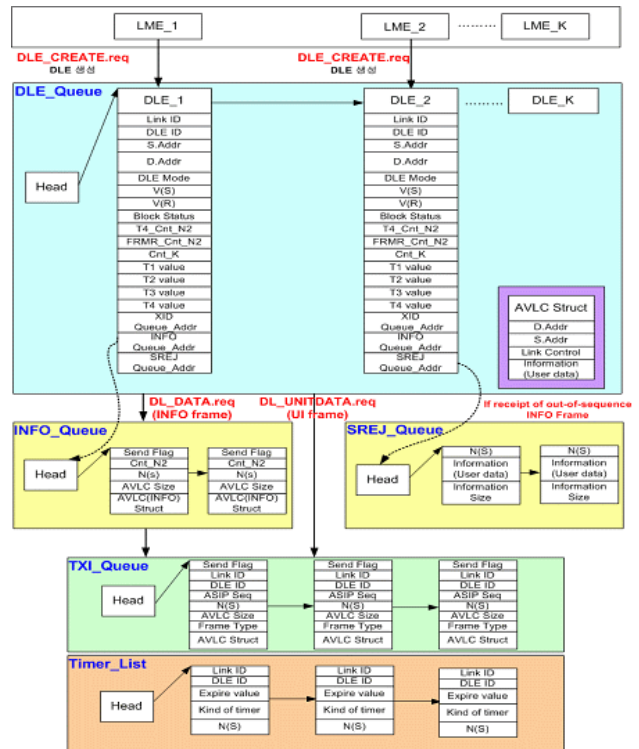


Figure 7. DL_DATA processing in DLS

4.2 Test

The test consists of unit test, interface test, lab test, ground test, and flight test. The unit test is a test for each subsystem, and the interface test is a test between subsystems, and the lab test and ground test is a integration test. The lab test is done with wire connection between VDR. The ground test and flight test will be held at Goheung, the southern part of Korea.

To test the system protocol meets the ICAO standards, a robust test system is used. The test system is MVDL system made by ADS pty in Australia. After the protocol test, KARI will perform the ground/air integration test and full ground test as the ground test. The integration test configuration is shown in Figure 8. For the integration test, a DSP, GS and aircraft system are used. All data are monitored by MVDL system. The test mainly focus on the data transfer between aircraft and ground. The full ground test uses three aircraft systems and a DSP and three GSs. It mainly test the link establishment and link handoff.

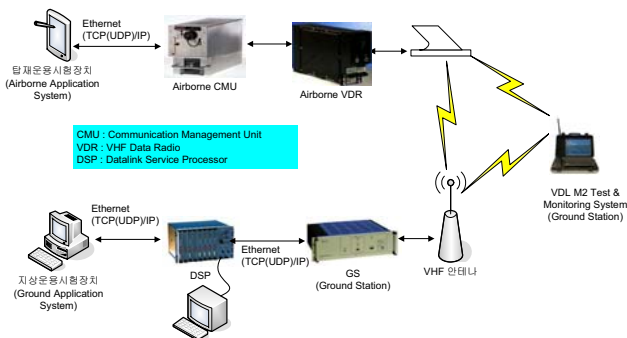


Figure 8. Ground/Air integration test configuration

5. Concluding Remarks

This paper is mainly focused on the ground system of KARI VDL M2 system. The detailed design and the implementation are finished and the unit test is finished. Now, KARI is performing the interface test and preparing the ground test and the flight test. The ground test and the flight test will be held at Go-heung, the southwest area in Korea on early 2009.

Acknowledgement

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