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Working Group 2

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Packet Data Flow Optimization for VDL Mode 3

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SUMMARY

The Electronic Navigation Research Institute (ENRI) carried out a flight test as well as a laboratory test to explore the best settings of VDL Mode 3 system for expedited recovery in packet data flow after handoff or packet lost occurred. This paper outlines the evaluation results for the packet data flow optimization for VDL Mode 3 system.

1 Introduction

ENRI has carried out a number of tests for evaluation of VDL Mode 3 voice and data performance and impact of radio interference by the use of their VDL Mode 3 test systems.

In a laboratory test in December 2003 and a flight test in March 2004, packet data flow of the VDL Mode 3 test system was evaluated with handoff executed. Those tests results indicated that packet data flow suspended for up to 116 seconds before and after handoff. It was considered that this was caused by packet data lost as well as halt of data transmission during handoff.

Once handoff is executed by a pilot, packet data in a transmission queue for downlink are to be deleted. Also packet data in a transmission queue of a ground station are also deleted once Leave Net message is received from an aircraft station. However, both

DLS layers believe that those deleted packet data were already transmitted to the peer station. As a result, packet data flow remains dormant for some time after net transfer is completed because either station waits for a coming Receive Ready (RR) packet or an expected Data (DT) packet while the other station does not transmit any packet.

Figure 1 represents an example of packet data flow before and after handoff. In this case, at the moment of handoff (net transfer), RR packet to the ground station 1 is deleted before its transmission. Then packet data flow halts until Timer 25 (T25[1]) expires at the Ground Center Station.

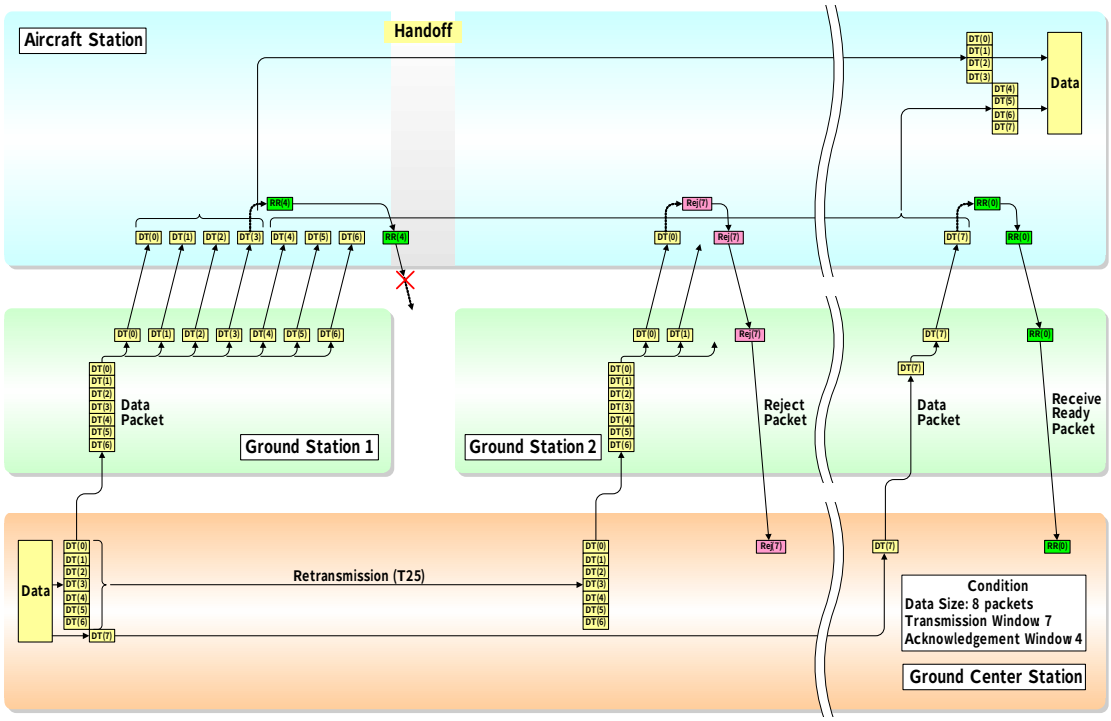

Figure 1 Example of Packet Data Flow with Handoff

2 Modification to the VDL Mode 3 Test System

ENRI's VDL Mode 3 test systems have been modified to explore the best settings of parameters for expedited recovery in packet data flow before and after handoff. The modification included the followings.

1) Configurable action immediately succeeding handoff
   - No action
   - Send a RR packet to notify the next expected packet number with each other
   - Send a Reject (Rej) packet to require retransmission of the expected DT packet

[1] T25 Window Rotation Timer: This timer starts when the DTE transmits a data packet, or the DTE's window is rotated, but there are still outstanding data packets. It terminates when there are no outstanding data packets in the window. If this does not happen within the allowed time, the DTE retransmits all data packets in the window, and restarts this timer. This value is set to 60 sec in the laboratory and flight tests.

with each other

2) Configurable action when Rej packet is received
   - Resend a DT packet designated by the Rej packet
   - Resend a designated DT packet after clearing queued messages (refer to figure 2)
3) Configurable action when Timer 24 (T24[2]) expires
   - Resend a RR packet to notify the next expected packet number
   - Resend a Rej packet to require retransmission of the expected DT packet
4) Configurable action when T25 expires
   - Resend a DT packet waiting for acknowledgement (RR packet)
   - Reset DCE/DTE and send a Reset Request packet
5) Configurable number of queued messages (1 to 16)
6) Clear queued messages by manual control

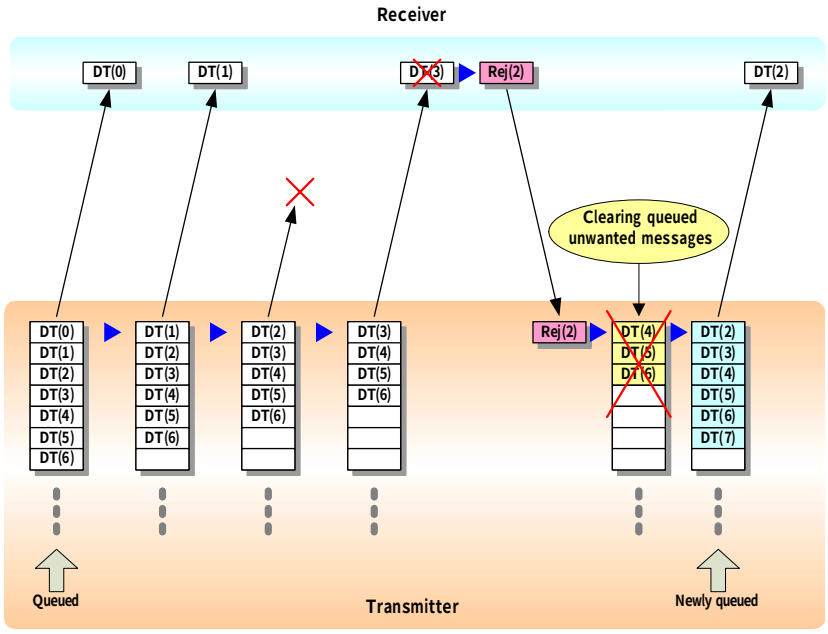

Figure 2 Concept of Clearing Queued Messages

3 Laboratory Test

3.1 Testing Environment

After the test system modification was completed, first, a laboratory test was conducted in November 2004 at ENRI facility to evaluate VDL Mode 3 packet data flow before and after handoff and lost packet in various combinations of settings. Two ground stations and an aircraft station were connected via attenuated circuit in the ENRI laboratory environment. The Ground Center station and two ground stations

[2] T24 Window Transmission Timer: Maximum time interval that a DTE will allow to pass before sending a packet containing its current P(R) sequence number (that is, sending an acknowledgment to the DCE). If no outgoing data is ready at that time, the DTE will generate an RR packet to convey this sequence number to the DCE. This value was set to 30 sec in the laboratory and flight tests.

were connected over TCP/IP. The test setups are shown in figure 3. The test was conducted in the following settings and in various combinations of parameters described in table 1 for handoff test and table2 for packet lost test.

1) Transmission data size: 8 packets (size of one packet is 930 bytes)
2) Transmission window size: 7
3) Acknowledgement window size: 4

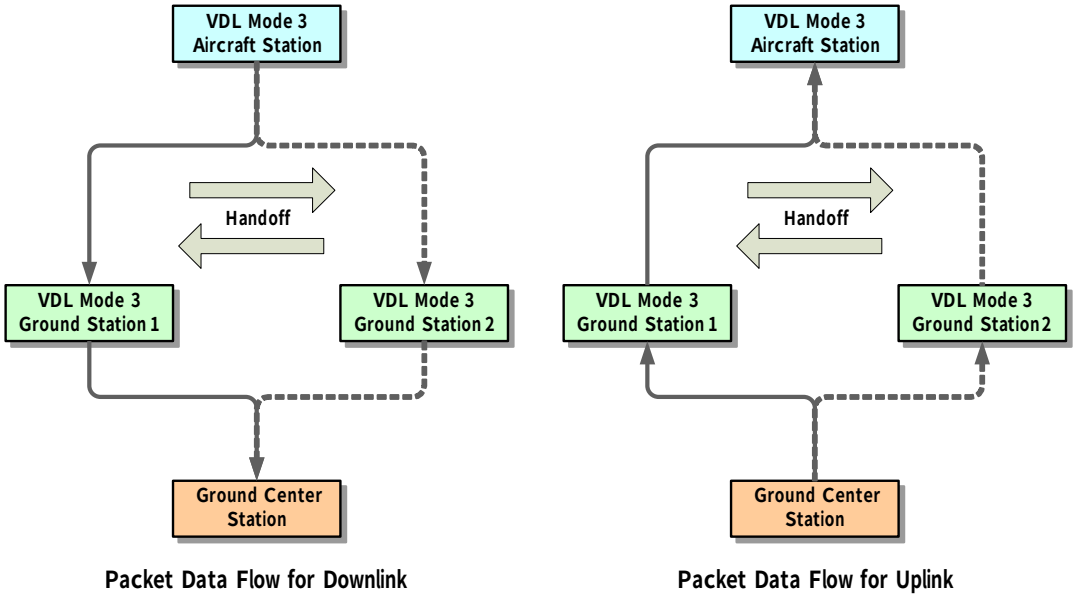

Figure 3 Lab Test Setup

Table 1 Parameter Settings for Handoff Test

Test No.	Up/Down	After H/O[*1]	T24[*2]	T25[*3]	After Rej[*4]
1	Uplink	No action	Send RR	Resend DT	No action
2	Uplink	Send RR	Send RR	Resend DT	No action
3	Uplink	Send Rej	Send RR	Resend DT	No action
4	Downlink	No action	Send RR	Resend DT	No action
5	Downlink	Send RR	Send RR	Resend DT	No action
6	Downlink	Send Rej	Send RR	Resend DT	No action

Table 2 Parameter Settings for Lost Packet Test

Test No.	Up/Down	After H/O[*1]	T24[*2]	T25[*3]	After Rej[*4]
7	Uplink	N/A	Send RR	Resend DT	No action
8	Uplink	N/A	Send RR	Resend DT	Clear Queue
9	Downlink	N/A	Send RR	Resend DT	No action
10	Downlink	N/A	Send RR	Resend DT	Clear Queue

Note) After H/O[*1]: Action immediately succeeding handoff
T24[*2]: Action when T24 expires
T25[*3]: Action when T25 expires
After Rej[*4]: Action when Rej packet is received

3.2 Handoff Test

3.2.1 Test Procedure

The purpose of the handoff test was to evaluate which method was effective for packet data flow recovery after handoff. Figure 4 presents an example of packet data flow in this test. Handoff was executed while two eight-packet-data were uplinked or downlinked consecutively, and then data transfer was halted for 30 seconds. These steps were repeated 20 times. After each test was completed, time "T" and "t" were obtained by analysis of data acquired during the test. Time "T" represents elapsed time from beginning to end of each test. The test ended when two eight-packet-data were successfully received after the 20th handoff was executed. Time "t" represents time required for recovery in packet data flow before and after handoff. It is duration between the time when the last desired DT packet is received before handoff and the time when the first expected DT packet is received after handoff.

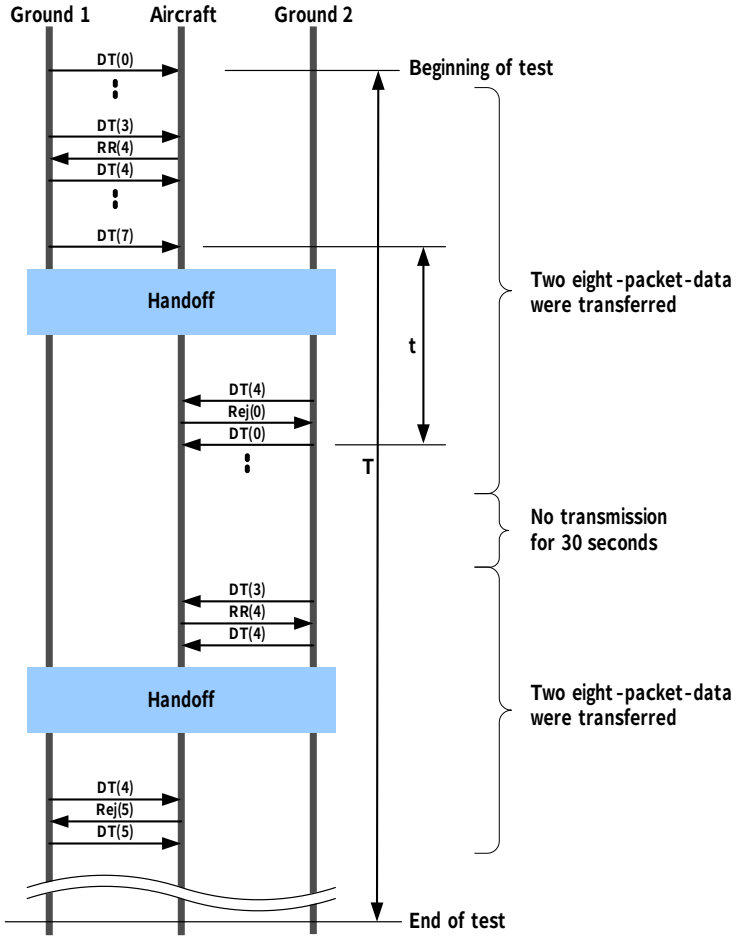

Figure 4 Example of Packet Data Flow in Lab Test

3.2.2 Test Result

Figure 5 represents average recovery time "t" and effective throughput of each test.

The effective throughputs are calculation results using the formula described in figure 6 and are thought to show improvement factor under multi-user environment.

This test results show that sending Rej packet soon after handoff (test No.3 and 6) allows for much shorter recovery time.

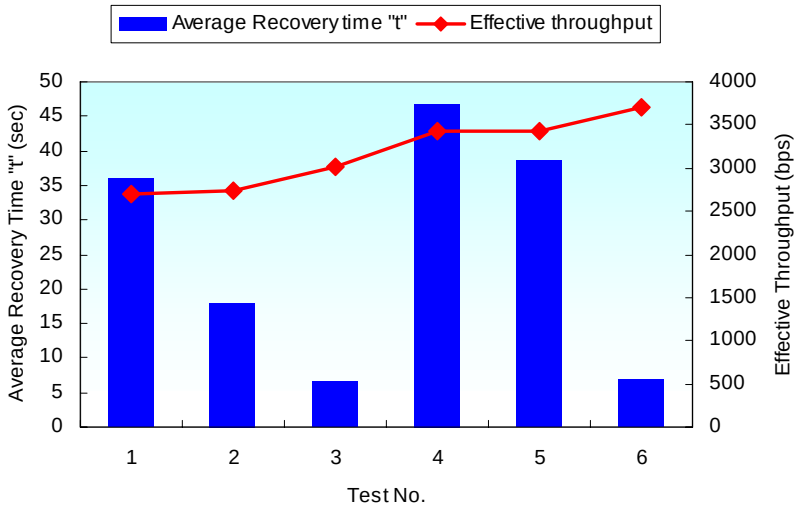

Figure 5 Lab Test Result for Handoff Test

Throughput [bps] = (930 – 7 - 3) x 8 x 8 x (number of data) / T

- number of packets
- bits / byte
- packet header size
- VDL header size
- user data size for one packet (byte)

Effective throughput [bps] = Throughput / Occupied channel rate

Figure 6 Calculation Formula

3.3 Lost Packet Test

3.3.1 Test Procedure

The purpose of the lost packet test was to evaluate effectivity of clearing queued message for packet flow recovery after a Rej packet was received following a transmission packet did not reach a receiver. This test was conducted with a transmission packet per 30 packets removed deliberately while eight-packet-data was repeatedly transmitted 75 times. After each test was completed, time “T” and “t” were obtained by analysis of data acquired during the test. Time “T” represents elapsed time from beginning to end of each test. The test ended when 75th eight-packet-data was successfully received. Time “t” represents time required for recovery in packet data

flow before and after a transmission packet was lost. It is duration between the time when the last desired DT packet is received before the lost packet and the time when the first expected DT packet is received after the lost packet.

3.3.2 Test Result

Figure 7 represents average recovery time “t” and effective throughput of each test. The effective throughputs are calculation results using the formula described in figure 6.

This test results show that clearing message in a transmission queue has the effect of promoting recovery in packet data flow when a Rej packet is received (test No.8 and 10).

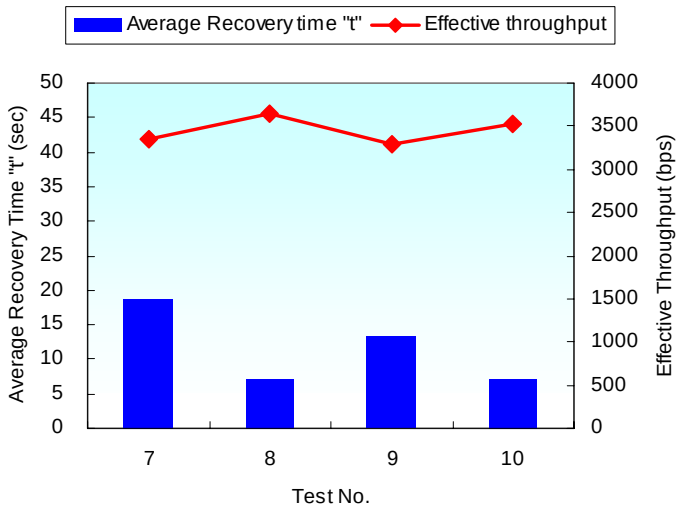

Figure 7 Lab Test Result for Lost Packet Test

4 Flight Test

4.1 Testing Profile

Following the lab test, ENRI carried out a flight test using its Beechcraft B99 with VDL Mode 3 equipment installed (Figure 8). The purpose of this flight test was to verify the effect of new methods for packet data flow control during handoff in actual air-ground communication environment. Figure 9 shows the flight trajectory and the ground equipment layout. The flight test consisted of seven flights with various parameter settings described in table 3.

Figure 8 ENRI Aircraft and VDL3 Aircraft Station

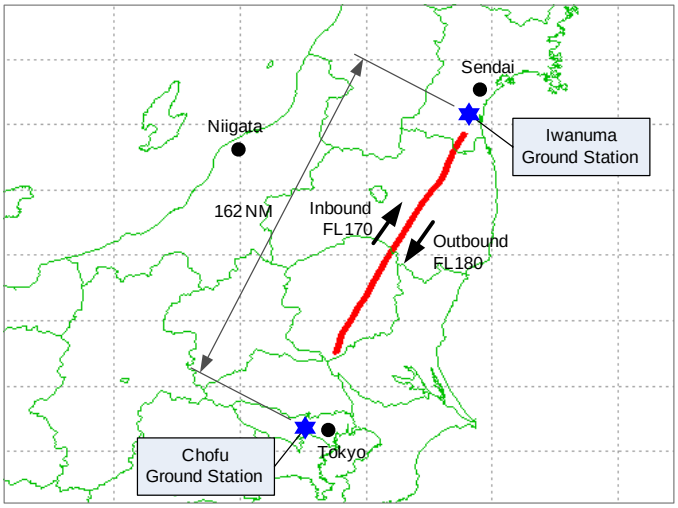

Figure 9 Flight Trajectory and Equipment Layout

Table 3 Parameter Settings for Flight Test

Test No.	Date	Flight Direction	Flight Altitude	Testing Environment				
				Up/Down	After H/O	T24	T25	After Rej
1	16 Nov 04	Outbound	FL180	Down	No action	Send RR	Resend	No action
2		Inbound	Fl170	Down	Send Rej	Send RR	Resend	Clear Q
3		Inbound	Fl170	Down	Send Rej	Send Rej	Resend	Clear Q
4	17 Nov 04	Outbound	Fl180	Up	Send Rej	Send RR	Resend	Clear Q
5		Inbound	Fl170	Up	No action	Send RR	Resend	No action
6		Outbound	Fl180	Up	Send Rej	Send Rej	Resend	Clear Q
7		Inbound	Fl170	Up	Send Rej	Send RR	Resend	No action

Note) Other settings were the same as those of the lab test.
- Transmission data size: 8 packets (Size of one packet is 930 bytes)
- Transmission window size: 7
- Acknowledgement window size: 4

4.2 Test Procedure

Handoffs were performed every two minutes with eight-packet-data successively transmitted on each flight leg. After the flight test was completed, time “tr” and “t” were obtained by analysis of data acquired during the flight. Time “tr” represents time

required for recovery in packet data flow before and after Rej packet transmission. It is duration between the time when the last desired DT packet is received before a Rej packet transmission and the time when the first expected DT packet is received after a Rej packet transmission. Time “t” is defined as the same as the lab test.

Figure 10 presents an example of packet data flow in this flight test.

Note) Time “tr” includes time “t” because a Rej packet was transmitted after handoff in most cases.

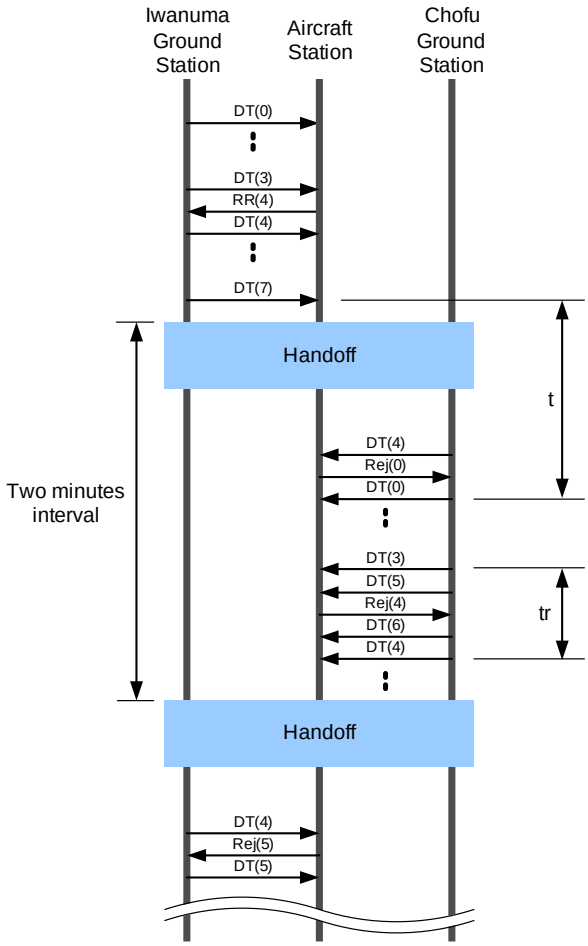

Figure 10 Example of Packet Data Flow in Flight Test

4.3 Test Results

Figure 11 represents received level characteristics obtained in the flight test No.1 on November 16 2004. The horizontal axis represents distance from Iwanuma ground station. Upper lines in the graph represent received level at aircraft receiver input, lower downward-sloping line represents received level at Iwanuma receiver input and lower upward-sloping line represents received level at Chofu receiver input. Handoffs were conducted 17 times in the outbound flight. Figure 12 represents average Reject recovery time “tr” and average handoff recovery time “t” for each flight test.

This flight test results show that similar tendency to the results of the lab test. Sending Rej packet soon after handoff allows for much shorter recovery time and clearing data in a transmission queue when a Rej packet is received also has the slight effect of promoting packet data flow recovery.

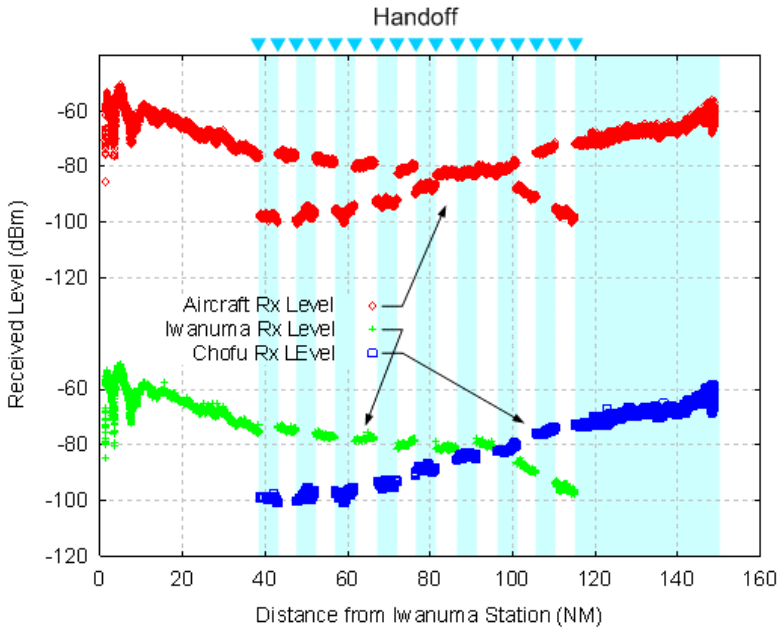

Figure 11 Received Level Characteristics – Test No.1

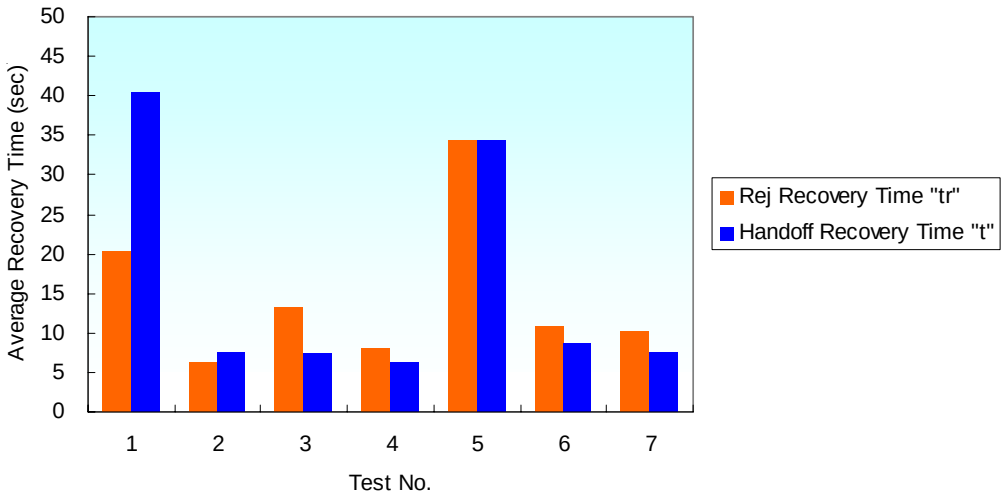

Figure 12 Flight Test Result

5 Conclusion

ENRI has modified the VDL Mode 3 test systems to explore the best settings of VDL Mode 3 system for expedited recovery in packet data flow after handoff and packet lost occurred. The lab test and the flight test were carried out for the evaluation of

various combinations of parameter settings. Analysis of data acquired in these tests indicates the followings. (refer to figure 13)

1) To send a Rej packet has a stimulating effect on packet data flow after handoff.
2) To clear messages in a transmission queue also has a stimulating effect on packet data flow when packet lost occurred.

However, these testing environments were that just single aircraft station transmitted or received packet data to/from peer ground station. Therefore further test will be required under multi-user environment to evaluate this new packet flow control methods.

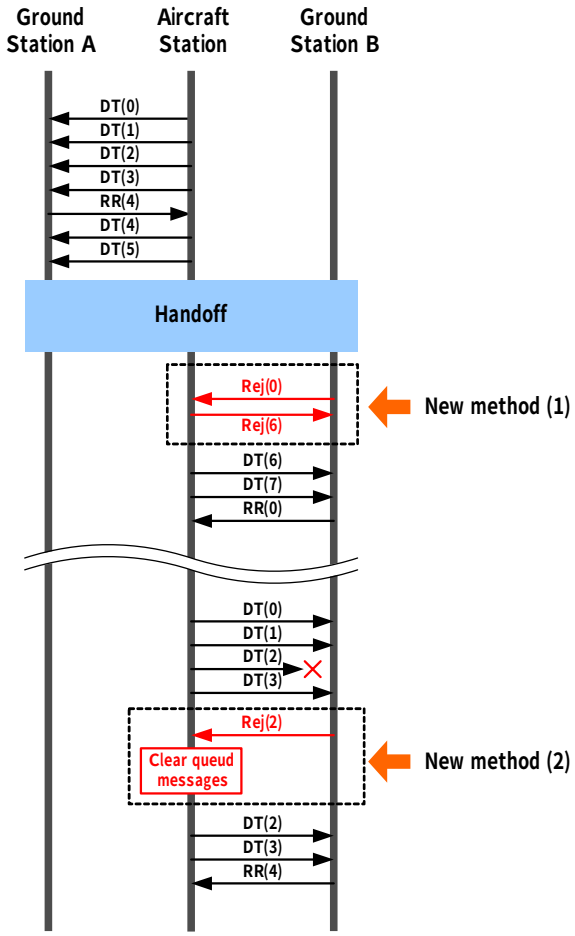

Figure 13 Proposed Packet Flow Control