Telemetry Storage and Donwlink Management for a LEO Satellite

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***Abstract*—Because Low Earth Orbit (LEO) satellite has very limited contact time between satellite and ground station, all telemetry data generated on satellite are stored in a mass memory and downlinked to the ground together with real-time data during the contact time. There are two mass memory modules. Normally, one mass memory module is used and the other is ready for backup. If required, both memory modules can be used at the same time. If the selected module is not available, the other module can be automatically used for telemetry storage without ground intervention. Two downlink channels are available at the same time but only one channel should be used for downlink. The downlink channel can be changed automatically by on-board flight software as well as step by step by ground command. This paper presents the telemetry storage and downlink management method implemented in flight software of a LEO satellite developed in Korea. All functions related to telemetry storage and downlink management were fully verified through the real satellite operation as well as the various tests during satellite development phase.**

Keywords-telemetry; downlink; flight software.

I. INTRODUCTION

On-Board Computer (OBC) for a LEO satellite developed in Korea Aerospace Research Institute (KARI) is one unit box which includes primary and redundant side. It consists of Processor Module (PM) for supplying Flight Software (FSW) execution platform, Tele-command and Telemetry Module (TCTM) for performing uplink and downlink, Bus I/O Module (BIOM) for interfacing with bus units, Payload I/O Module (PIOM) for interfacing with payload units, power converter and the others [1][2]. Figure 1 shows the telemetry data downlink interfaces.

TCTM modules are cross-strapped with two processor modules and activated simultaneously as hot redundancy. Mass Memory Management Unit (MMU) receives telemetry frames from PM through space-wire interface [3] and transmits them to Telemetry Unit (TMU) or stores into mass memory and reads the stored frames from mass memory and transmits them to TMU. TMU receives the telemetry frames from MMU and transmits them to transponder. The mass memory for telemetry storage consists of two modules. TCTM has its own mass memory. PM can access each mass memory, but MMU can access only its own mass memory.

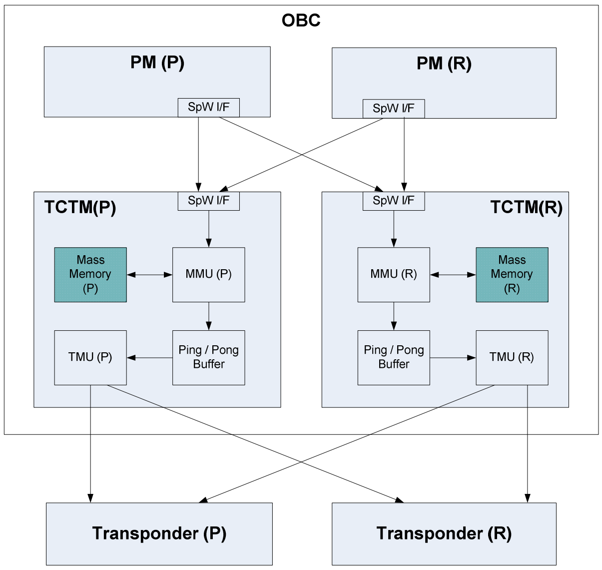

Figure 1. Telemetry Data Downlink Interfaces

Telemetry uses Consultative Committee for Space Data Systems (CCSDS) compliant VCDU frames [4][5]. Telemetry data storage method is described in section 2. Downlink management method is described in section 3.

II. TELEMETRY DATA STORAGE

A. *Mass Memory Data Structure*

Figure 2 shows the mass memory data structure. The mass memory for telemetry data storage is divided into blocks that are called pages. Each memory module has 2048 pages and a page consists of 128 Kbytes. Normally, one mass memory module is used and the other is ready for backup. If required, both memory modules can be used at the same time. If the selected module is not available by memory full condition or interface problem, the other module can be automatically used for telemetry storage without ground intervention. The page structures are shown in Figure 3. 585 Virtual Channel Data Unit (VCDU) frames are stored on each page.

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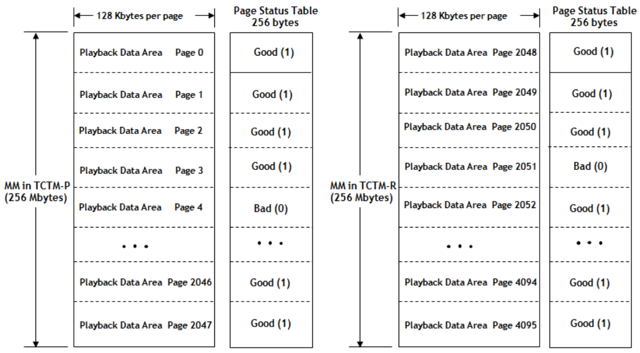

Figure 2. Mass memory structure for telemetry storage

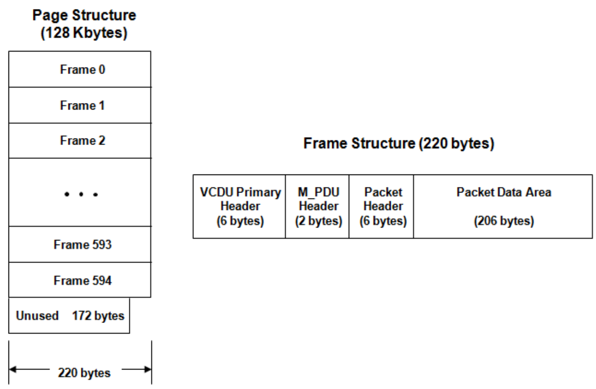

Figure 3. Page structure of mass memory

B. Telemetry Data Type and Storage

All telemetry data are formatted into Consultative Committee for Space Data Systems (CCSDS) compliant VCDU frames [4], and stored into mass memory. Telemetry types are shown in Table I.

TABLE I. TELEMETRY TYPE

Type		Max # of Frame	Period (sec)
Real Time	SOH	4	1
Storage-Only	SOH	5	1
	POD	1	1
	PAD	4	1
	PLD SOH 1	5	1
	PLD SOH 2	4	24
	PLD SOH 3	3	24
	PLD SOH 4	3	64

Each telemetry frame has its own VCDU ID and sequence counter, and stored in satellite memory in chronological order without overwriting older data which has not yet been downlinked. Newly generated telemetry frames are stored on the memory location pointed out by current write pointer. If the mass memory page status is marked as bad, the page is not used anymore for telemetry storage. If the selected module is not available by memory full condition or interface problem, the other module can be automatically used for telemetry storage without ground intervention. In case of real-time telemetry, they are stored into mass memory and downlinked to the ground simultaneously. Two real-time SOH frames in low downlink rate, or two to four real-time frames in high downlink rate are generated, stored into mass memory and downlinked to the ground every second. In case of storage only telemetry, they can be generated and stored into mass memory regardless of the hardware downlink rate.

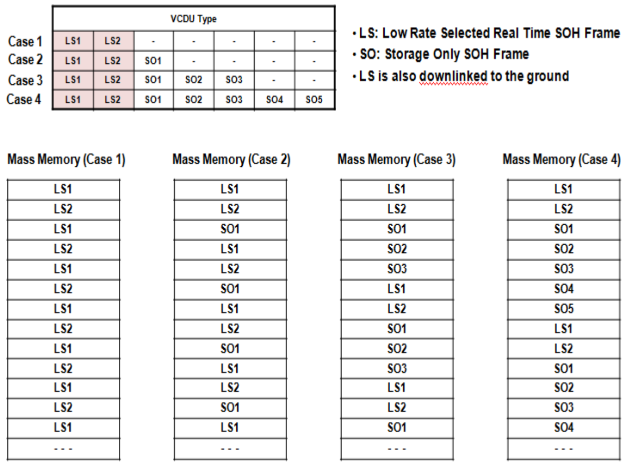

Figure 4. Telemetry storage example (low rate)

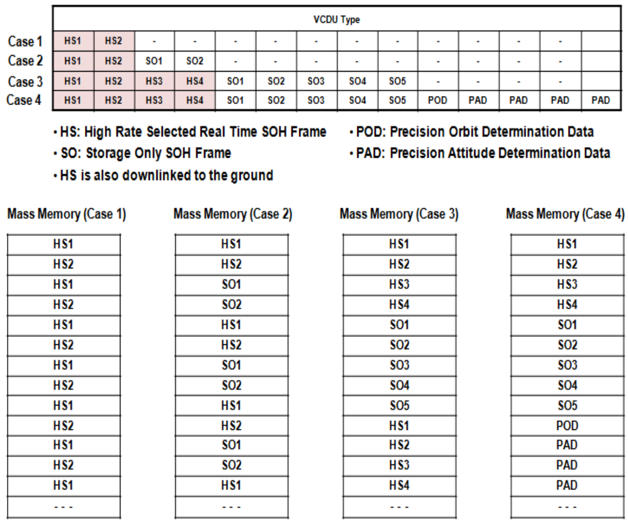

Figure 5. Telemetry storage example (high rate)

Figures 4 and 5 show the examples of several cases of telemetry storage in the mass memory in accordance with the hardware downlink rate.

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III. DOWNLINK MANAGEMENT

A. Downlink Rate

There are two downlink rates, low downlink rate (4096bps) and high downlink rate (1.5626Mbps). Only real-time telemetry frames can be downlinked to the ground in low downlink rate. In high downlink rate, there are two downlink modes, real-time mode and playback mode. Only real-time telemetry frames are downlinked in real-time mode and real-time and stored telemetry frames in the mass memory are downlinked in playback mode. Two real-time frames in low downlink rate and two to four real-time frames in high downlink rate can be downlinked to the ground every second. Total 762 telemetry frames including two to four real-time frames can be downlinked to the ground every second in high downlink rate. Figure 6 shows the downlink examples in high downlink rate.

	Downlink Frame Sequence				
	1	2	3	4	5~762
Case 1	HS1	HS2	PB	PB	PB
Case 2	HS1	HS2	HS3	PB	PB
Case 3	HS1	HS2	HS3	HS4	PB
Case 4	HS1	HS2	HS3	HS4	Fill

- **HS : High Rate Selected Real Time SOH Frame, PB : Playback Frame**
- **762 frame/sec:**
  - Case 1: 2 RT + 760 PB frames (Playback Mode)
  - Case 2: 3 RT + 759 PB frames (Playback Mode)
  - Case 3: 4 RT + 758 PB frames (Playback Mode)
  - Case 4: 4 RT + Fill Patterns (Real Time Mode)
- **PB is replaced by fill pattern if PB mode is not selected**

Figure 6. Downlink example

B. Downlink Operation

Playback operation is started by ground command. Several types of playback command are used. Telemetry frames are downlinked from the last playback pointer, and proceed until the current write pointer is reached upon receipt of the PB Start command. Telemetry frames are downlinked from the specified location, and proceed until the current write pointer is reached upon receipt of the PB Location command. All Telemetry frames are downlinked upon receipt of the PB All command. Telemetry frames are downlinked from a start address to the end address upon receipt of the PB Specified Area command. The downlink mode is automatically switched to the real-time mode when playback is completed.

C. Downlink Channel and Rate control

Because two TCTM modules are operated as hot redundancy, two downlink channels are available at the same time but only one channel should be used for downlink. Each TCTM has own mass memory and is able to access only own mass memory. In case of real-time mode, any downlink channel can be used because it does not need to access mass memory. But, in case of playback mode, the downlink channel of the TCTM including the selected mass memory should be used. If the mass memory is changed to the other module, the downlink channel should be changed in accordance with the mass memory change. In this case, the downlink channel can be changed automatically by on-board flight software as well as step by step by ground command. If two mass memory modules are used at the same time, change between two mass memory modules and two downlink channels are performed automatically by on board flight software for performing playback operation continuously.

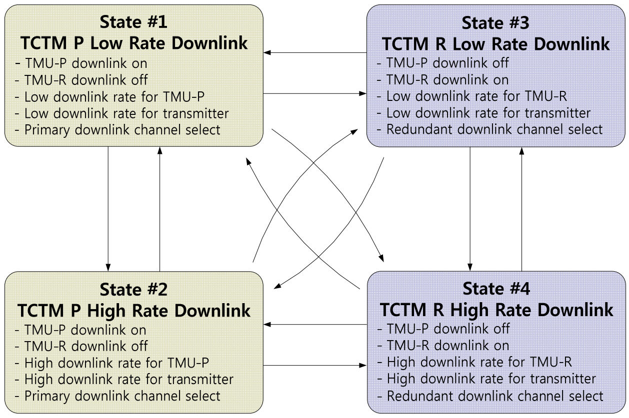

Figure 7. Downlink channel and rate state transition diagram

Figure 7 shows the downlink channel and rate state transition diagram. There are 4 states and 12 state transition cases to change the downlink rate and the downlink channel.

IV. CONCLUSION

Telemetry storage and downlink management method implemented in flight software of a LEO satellite developed in Korea were described in this paper. In case all types of telemetry frame are selected, it takes about one day to fill up one mass memory module. It takes about 27 minutes to play back all area of one mass memory. Just one ground station is enough to receive the telemetry.

Most of all functions required to manage mass memory, to store telemetry and to downlink telemetry data are automatically performed by on-board flight software. Operator has only to select the telemetry types to be downlinked to the ground or stored into mass memory, and to send command to start playback. If the mass memory has interface problem or fault in specific area, it is possible to change to other module and to initialize all or specific area of mass memory by ground command. All functions related to telemetry storage and downlink were fully verified through the real satellite operation as well as the various tests during satellite development phase.

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