Improved Method for Telemetry Data Processing in LEO Satellite

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***Abstract*—Satellite telemetry data is typically gathered using predefined telemetry data tables. Upon selecting data groups for collection, the same data from the chosen packets is repetitively gathered at predetermined intervals, irrespective of the satellite's operational status. However, in the event of specific errors during satellite operations or transitions to particular states, it becomes imperative to include specific data corresponding to the satellite's state or to modify the collection frequency of certain data sets. Given the constrained contact time and communication speed of low-Earth orbit satellites, complete data transmission may not be feasible under adverse communication conditions or when the satellite is in a safe mode. Therefore, a functionality is essential to selectively transmit only the indispensable data contingent upon the prevailing circumstances. This paper provides an overview of the telemetry data processing methodology utilized for low-Earth orbit satellites developed in Korea and outlines mechanisms for automatic adjustment of telemetry data in alignment with the satellite's operational status. Additionally, it presents various strategies for selectively transmitting essential data based on the prevailing conditions.**

Keywords-telemetry; downlink; playback.

I. INTRODUCTION

The telemetry data is categorized into specific packet groups based on data type, and the designated items for each packet are collected every second according to a predefined telemetry data table, then stored in mass memory. These stored data are transmitted to the ground in the form of playback data, along with real-time data, during ground communication [1]. Table 1 illustrates the protocols governing the generation and transmission of telemetry data.

TABLE I. THE RULES FOR TELEMETRY DATA PROCESSING

Telemetry Format	Consultative Committee for Space Data Systems (CCSDS) [2][3]
Downlink Rate	4.096 Kbps (Low), 1.5625 Mbps (High)
CADU / VCDU Size	256 / 220 Bytes
Packet Group	State Of Health (SOH1~SOH4), Precise Orbit Determination Data (POD), Precise Attitude Determination Data (PAD) Payload Telemetry (PLD),
Mass Memory Size	4 Gbits
Playback Downlink	756 VCDUs per second
Telemetry Tables	Master Telemetry Table (MTT), Packet Sequence/Contents Table (PST, PCT)

Figure 1 shows telemetry format and Figure 2 shows the table driven telemetry acquisition.

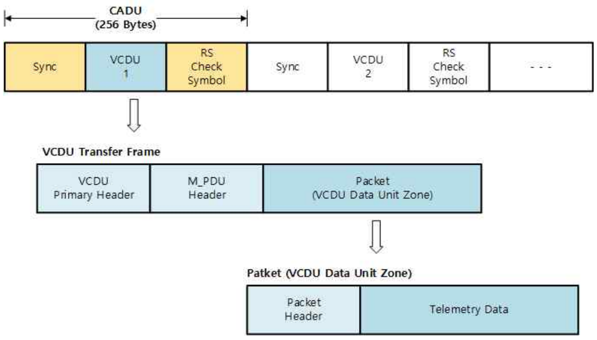

Figure 1. Telemetry Format

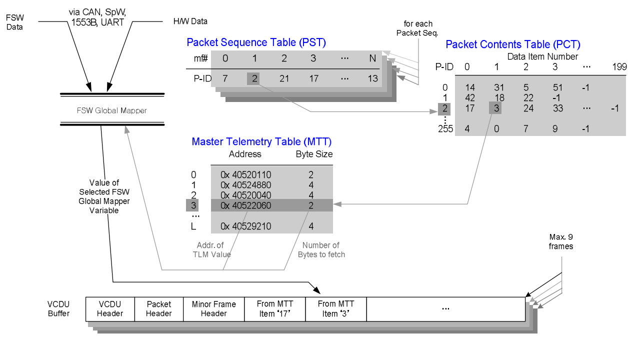

Figure 2. Table Driven Telemetry Acquisition

Given the limited storage capacity of the satellite's mass memory and the constrained transmission speed during communication, the duration of data storage is determined based on the significance of each data item, ensuring it does not surpass the capacity limit. The storage duration ranges from 1 to 32 seconds, varying accordingly. Upon selection of a packet group by the ground, data collection ensues as per a predefined data table. Once the data group is chosen, the selected packet data are repetitively collected at fixed intervals. However, in the event of specific errors or state transitions during satellite operation, certain data may become redundant or require less frequent collection, while others may necessitate inclusion or a shorter collection cycle.

In such scenarios, it is imperative to eliminate redundantly generated data depending on the satellite's status, include essential data, or adjust the cycle of specific data. To address this requirement, a functionality is needed to monitor the satellite's status and automatically modify telemetry data packets to collect the requisite data in accordance with the prevailing state.

Furthermore, low-Earth orbit satellites store all telemetry data generated in a mass memory in the sequential order of generation. Subsequently, the accumulated telemetry data is transmitted collectively to the ground control system during communication with the ground. Figure 3 illustrates the process by which telemetry data is stored and downlinked via the mass memory [1].

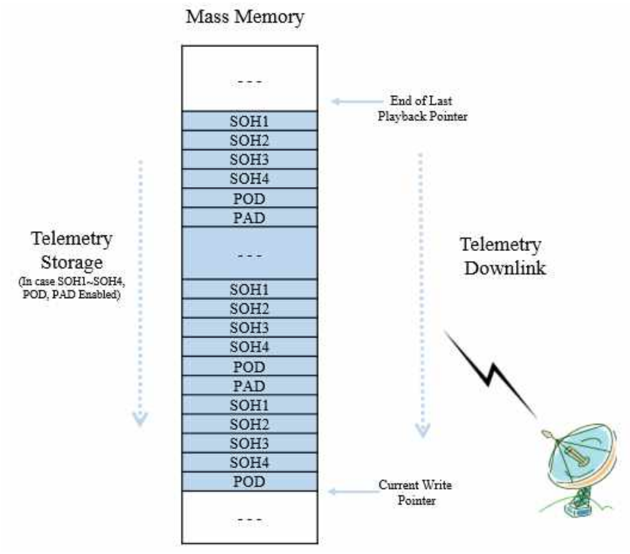

Figure 3. Telemetry Data Storage and Downlink Example

Nevertheless, due to the extremely limited communication time, while all data may be transmitted under normal circumstances, it may not be feasible to transmit all data if the communication environment is compromised or the satellite is in safe mode. In such instances, there is a need for a functionality to selectively transmit only the essential data contingent upon the prevailing circumstances.

In essence, to address challenges stemming from restricted storage capacity, limited contact time, and downlink transmission speed, the storage phase should employ adaptable data formats tailored to the satellite's status. This ensures the storage of as much pertinent data as possible. Similarly, in the transmission phase, the inclusion of a functionality capable of transmitting only essential data becomes imperative.

This paper outlines the pertinent methodologies. Section II delineates the telemetry acquisition approach predicated on the satellite's status. Section III expounds upon the enhanced telemetry storage and downlink methodologies aimed at selectively transmitting solely the indispensable data. Lastly, Section IV encapsulates the conclusions drawn and outlines avenues for future research.

II. Telemetry Acquisition Based on Satellite Status

The fundamental processing concept of the telemetry data acquisition method, contingent upon the satellite's status, is illustrated in Figure 4. Under normal circumstances, data predetermined or ordered by the ground are collected. However, if the satellite's state transitions to a specific condition or encounters predefined errors, a procedure is initiated to exclude redundant data packets while automatically incorporating essential ones. This process can be executed through the utilization of the satellite's Relative Time Command Sequence (RTCS) processing function [4].

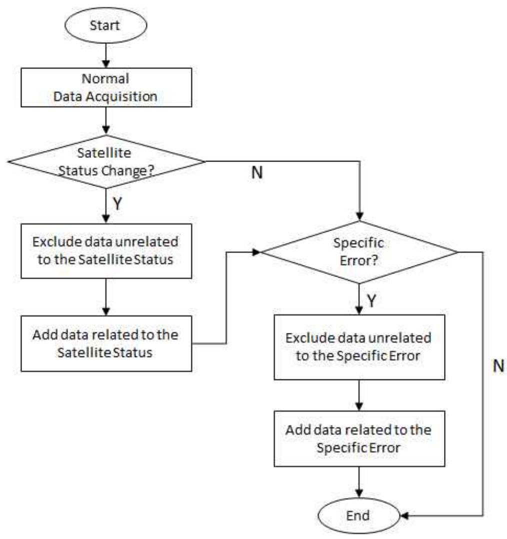

Figure 4. Basic Concept of Telemetry Acquisition

TABLE II. Telemetry Packet Sequence by Satellite Status

TM Group	Packet Sequence (by Satellite Status)			
	Normal	State #1	State #2	State #3
SOH1	PKT1, PKT3 PKT3, PKT4	PKT1, PKT2 -	- PKT3, PKT4	PKT1, PKT2
SOH2	PKT5, PKT6 PKT7	PKT5, PKT6 -	- PKT7	PKT5, PKT6 -
SOH3	PKT8 PKT9	- PKT9	- PKT9	- PKT9
SOH4	- -	PKT10, PKT11 -	- PKT12, PKT13	PKT10, PKT11 PKT12, PKT13
POD	POD	POD	-	POD
PAD	PAD	PAD	PAD	-
PLD	PLD	-	-	PLD

Table 2 presents an illustrative example of how telemetry data packets may vary depending on the specific state of the satellite. Under normal operating conditions, the SOH1 group comprises PKT1, PKT2, PKT3, and PKT4 packets, the SOH2 group contains PKT5, PKT6, and PKT7 packets, the SOH3 group consists of PKT8 and PKT9 packets, and packets from the POD, PAD, and PLD groups are collected. However, when the satellite transitions to a particular state (State #1), PKT3, PKT4, PKT7, PKT8, and PLD packets are excluded, while PKT10 and PKT11 packets from the SOH4 group are added. PKT10 and PKT11 packets encompass critical data required for monitoring and assessment during State #1.

Incorporating a functionality that automatically adjusts data collection according to the satellite's operational state can significantly enhance the accuracy of satellite status analysis. By excluding superfluous data and selectively including pertinent data, this approach enables more focused analysis while maintaining consistent data volume. Consequently, it facilitates more precise insights into the satellite's condition without imposing additional strain on data storage and computational resources. Moreover, it enhances the overall reliability and responsiveness of satellite monitoring and control systems.

III. IMPROVED TELEMETRY STORAGE AND DOWNLINK METHOD

To establish a functionality capable of swiftly transmitting solely the requisite data contingent three potential methods can be contemplated. Method 1, as depicted in Figure 5, adheres to the previous storage protocol. During transmission, each data type is discerned, and solely the pertinent data is transmitted. While this approach maintains the existing system to a significant extent, it entails extensive processing time. This is because, during transmission, data must be read and verified in frame units, and only the relevant data must be selected and transmitted.

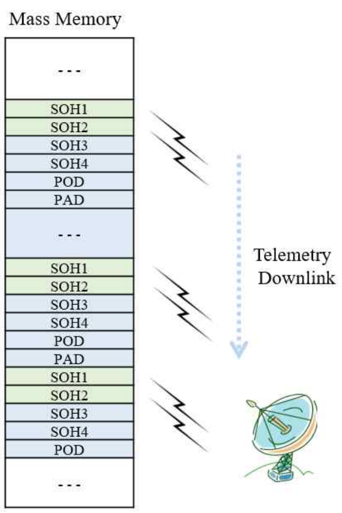

Figure 5. Basic Concept for Telemetry Acquisition (Method 1)

Method 2 involves the utilization of separate memory areas for each data type, as depicted in Figure 6. In this approach, it is presumed that SOH data is stored in Block 1, POD in Block 2, PAD in Block 3, and PLD in Block 4. While this method enables the transmission of only necessary data to the ground in necessary situations, it necessitates the separate management of pointers for each block. Additionally, the size of the memory block must be appropriately allocated in accordance with the data type

Method 3 involves storing data of the same type on each page, as depicted in Figure 7, and managing it with a data table stored in each page. Data is stored in chronological order, but each page contains the same type of data. For example, SOH data is stored in Pages 1 to 3, POD in Page 4, PAD in Page 5, PLD in Page 6, and SOH data is stored again in Page 7. By maintaining a record of the type of data stored in each page within the page table, it becomes possible to classify and transmit only the necessary data based on the prevailing situation. While Method 3 is somewhat more intricate than Option 2, it eliminates the need to consider memory allocation size for each data type.

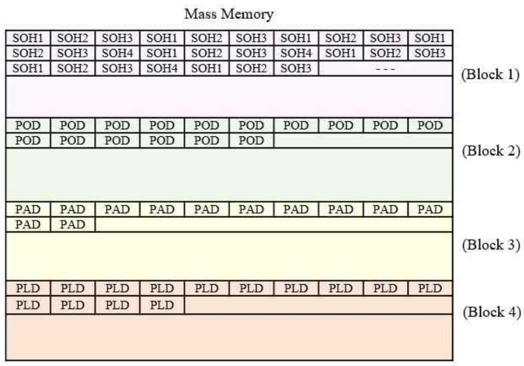

Figure 6. Basic Concept for Telemetry Acquisition (Method 2)

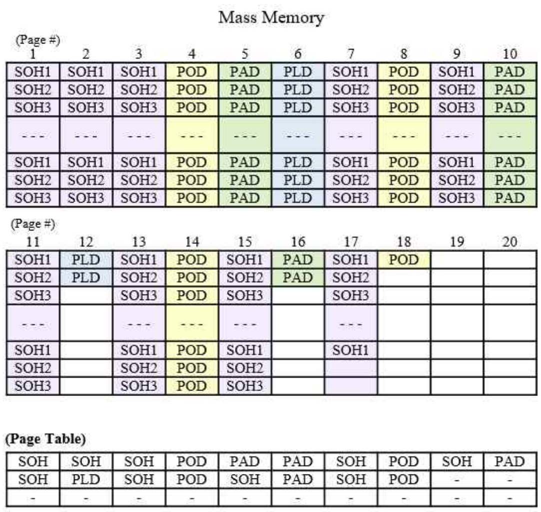

Figure 7. Basic Concept for Telemetry Acquisition (Method 3)

Each method has its own set of advantages and disadvantages. However, in the current system, Method 1 is considered the simplest and most practical option for implementing the necessary functionality. Nevertheless, to ensure the effectiveness and efficiency of the chosen method, it is essential to conduct an analysis of the software timing that governs its functions.

IV. CONCLUSION AND FUTURE WORK

Given the constraints of limited memory size and communication time inherent to low-orbit satellites, it becomes imperative to generate meaningful data aligned with the satellite's status, rather than redundantly transmitting data. Furthermore, the capability to swiftly transmit only essential data in response to the prevailing situation is indispensable. Several methods to address this challenge have been outlined. To implement this functionality effectively, a comprehensive assessment is required, taking into account the existing flight software's downlink driving method and its integration with hardware functions.

In future efforts, detailed analyses of each method will be conducted to identify the most appropriate approach. Additionally, for transmitting stored data, consideration is being given to designating a memory area and implementing a method for transmitting data from the satellite corresponding to a specific time designation.

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