A Telecommand Scheme for Spacecraft Based on High-Speed and Low-Speed Hybrid TT&C System

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Abstract. In order to meet the increasing demand for high-speed data uplink of spacecraft, more and more spacecraft have added high-speed TT&C (telemetry, track and command) channels besides retaining the traditional low-speed TT&C channels. This paper proposes a telecommand scheme under the existing spacecraft electronic equipment architecture and uplink data protocol framework, which combines the data processing of high-speed and low-speed TT&C channels, optimizes the data flow design, and gives an efficient and reasonable uplink Space data link protocol, the data fusion of high-speed and low-speed TT&C links is realized, which improves the reliability of the spacecraft and the flexibility of uplink data transmission.

Keywords: Uplink · Telecommand · Space data link · Protocol · TT&C system

1 Introduction

With the continuous growth of the size of spacecraft software and the increasing demand for software on-orbit dynamic loading and reconfiguration, it is more and more urgent to improve the high-speed uplink information transmission capability of spacecraft. The high-speed and low-speed hybrid TT&C (telemetry, track and command) system is a new TT&C system developed in recent years to meet the above needs. On the basis of conventional TT&C system, the new system expands the capability of uplink high-speed data transmission, supplements the design of the uplink channel to accommodate high-speed data transmission and gives consideration to the modulation mode and data structure of the telecommand information.

The existing spacecraft has formed mature data flow design, protocol selection, interface design and stand-alone electrical device design under the conventional low-speed TT&C system. The low-speed uplink channel and high-speed uplink channel of most existing spacecraft are completely independent, and the data protocol chosen is also different. This brings a lot of inconvenience to the uplink data processing on the ground and on-board. In this paper, an uplink telecommand scheme is proposed based on the existing spacecraft electronic architecture and uplink data protocol framework. By combining the data of high-speed and low-speed channel, the existing design of data flow is optimized, the data protocol is carefully selected, and the cost of

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modification of the existing software and electronic equipment is comprehensively considered, this new telecommand scheme can support the high-speed and low-speed hybrid TT&C system, so as to adapt to the current and future 5–10 years of intra-satellite communication and inter-satellite communication requirements.

2 Requirement of Spacecraft Telecommand

There are two main types of uplink telecommand data sent to the spacecraft via TT&C system: Direct Command and Upload Data. In recent years, Direct Command has been gradually reserved with only Direct ON/OFF (DOO) Command. In addition to the traditional Routed ON/OFF (ROO) Command, Memory Load (ML) Command, OBDH (On-board Data Handling Subsystem) House-keeping instructions, bus instructions, on-orbit maintenance data and inter-satellite data have been added. With the increasing demand for on-orbit maintenance and reconfiguration of large-scale/super-large-scale software for spacecraft, updates of on-orbit intelligent processing related algorithms/applications, increasing demand for autonomous constellation operation and large data interaction, the amount of upload data increases in series, and the amount of single upload data increases from KB level to tens of MB level. The high-speed and low-speed hybrid TT&C system can make up for the shortcoming of low speed in traditional system and better meet the needs of spacecraft for high-speed ascending. The following Fig. 1 shows the classification of spacecraft uplink data.

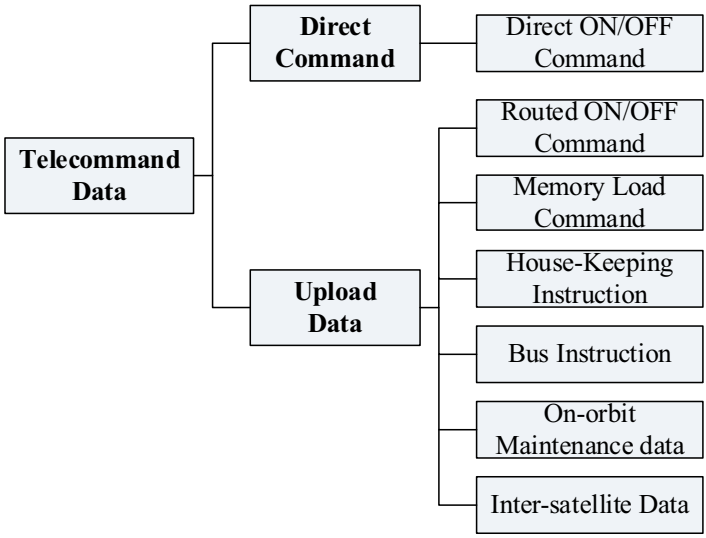

Fig. 1. Classification of spacecraft uplink data

3 Space Data Link Protocols

The space data link protocol used by domestic spacecraft mainly follows the relevant provisions of the Military Standard PCM telecommand protocol and the CCSDS (The Consultative Committee for Space Data Systems) protocol system [1–5] (corresponding Military Standard will be published soon). In recent years, newly developed spacecraft have gradually moved to use CCSDS protocol system.

CCSDS protocols currently widely used in domestic TT&C systems and spacecrafts include TC Synchronization and Channel Coding [4], TC Space Data Link Protocol [1], AOS Space Data Link Protocol [2] and Space Package Protocol [3]. Unified Space Data Link Protocol [5] is the latest space data link protocol introduced by CCSDS. As an improvement of AOS Space Data Protocol, it improves the support of spacecraft constellation and inter-satellite data transmission services in the original space link protocol. It can be used as one of the next generation space data link protocol. The following Fig. 2 shows Relationship of CCSDS Layers with OSI Layers.

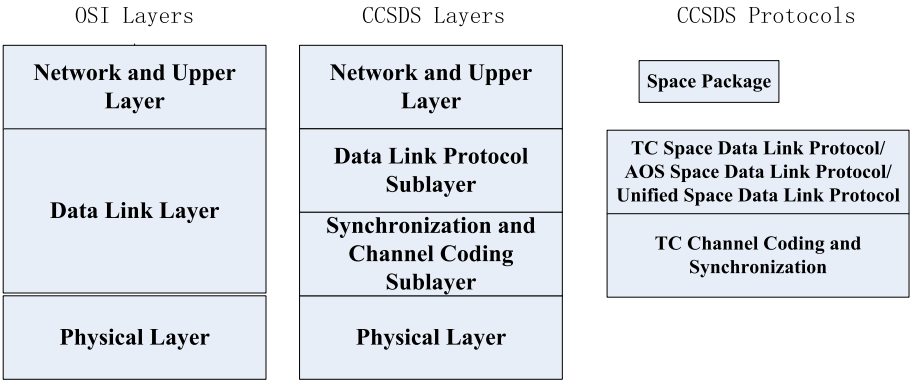

Fig. 2. Relationship with OSI layers

Currently, the Virtual Channel Package (VCP) service in the CCSDS TC Space Data Link protocol is usually used in the channel data link layer under the conventional TT&C system. It supports the transmission of one or more telecommand source packages that compliant to the CCSDS Space Package protocol in a variable-length TC transfer frame with a maximum length of 1024 bytes. The following Fig. 3 shows TC Transfer Frame Structure Component of conventional TT&C Channel.

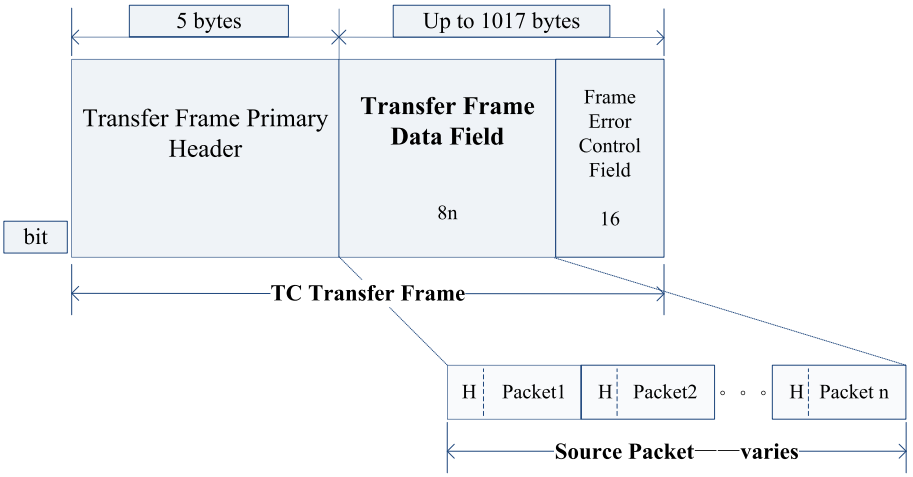

Fig. 3. TC transfer frame structure component of conventional TT&C channel

4 Design of Telecommand Scheme

4.1 Main Ideas

The main aspects to be considered in the telecommand scheme of the hybrid TT&C system are as follows:

1) The on-board data flow design should be adapted to both the high-speed and low-speed TT&C link. Considering the requirements of data encryption and decryption, data storage, on-board data distribution and inter-satellite data forwarding, barrel effect should be avoided to reduce the system application efficiency.
2) Considering the high-speed TT&C link can completely replace the conventional low-speed TT&C link to increase the redundance of TT&C link.
3) The design should consider the mature scheme of the existing system and reduce the design overhead.

4.2 Design of Data Flow

In the conventional low-speed TT&C link, the Synchronization and Encoding module of OBDH subsystem receives the telecommand PCM signal through the on-board transponders, and after channel decoding and decryption, the uplink TC transfer frame is sent to the Instruction module and the Processor module. The Instruction modules receive and decode direct ON/OFF command and output. The processor module recognizes and receives upload data. The Processor module handles upload data or forwards it to other 1553B bus remote terminals, or sends it to other mid-speed bus terminals, such as LVDS (Low-Voltage Differential Signaling) and the SpaceWire (SPW) bus terminals, via the Data multiplexer and Record module.

In the high-speed TT&C link, the Synchronization and Encoding module of the OBDH subsystem receives high-speed TC transfer frames and sends them to the Data multiplexer and Record Module to process. The Data multiplexer and Record module stores on-orbit maintenance data, inter-satellite data, and playbacks and forwards them to mid-speed bus terminals. It also playbacks the stored data to the processor or forwarding them to 1553B bus remote terminals. The Processor module receives and executes house-keeping instruction, and forwards bus instruction from high-speed link.

Through the conventional TT&C channels, the OBDH subsystem can receive, process and store direct command and all upload data. Through the high-speed TT&C channel, the OBDH subsystem can handle all upload data except direct command. Therefore, all direct ON/OFF instructions of the OBDH subsystem have routed ON/OFF instructions backup, the OBDH subsystem can also handle all telecommand functions in high-speed TT&C link. With this design, upload data can be connected to all 1553B bus and medium-speed bus terminals on the whole satellite through high-speed or low-speed TT&C channels by the OBDH computer, which improves the reliability of the system and the flexibility of data transmission. The following Fig. 4 shows the design of data flow on hybrid TT&C link.

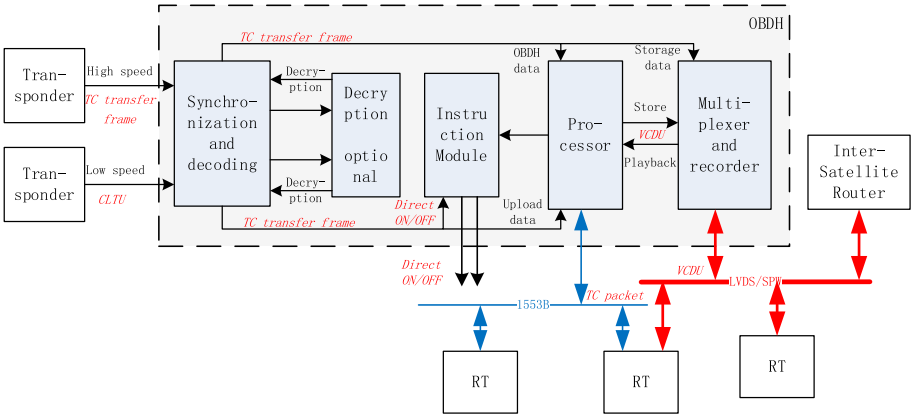

Fig. 4. Design of data flow

4.3 Design of Protocol

Considering the integration of ground data processing and on-board data processing with conventional TT&C uplink data, the TC transfer frame format of high-speed TT&C channel can be selected as CCSDS TC Space data link protocol compliant with conventional TT&C channel. Considering the length of data field required by the proprietary frame format of the high-speed uplink channel and the additional data bit overhead reserved for channel encryption and decryption, the effective data field of the TC transfer frame is set to variable length and maximum 892 bytes. The following Fig. 5 shows the TC Transfer Frame Structure Component of High-speed TT&C Channel.

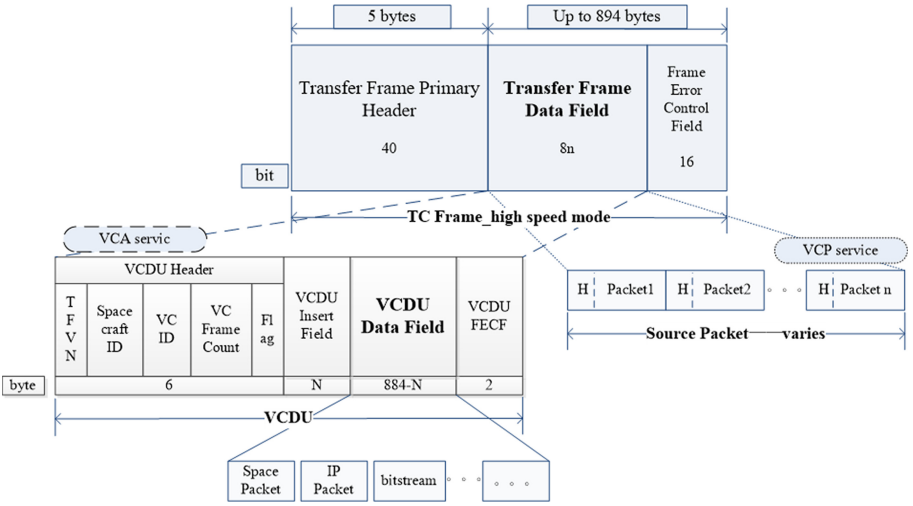

Fig. 5. TC transfer frame structure component of high-speed TT&C channel

When data is sent to the OBDH processor, the VCP service is used to transfer the TC space packet, and the effective data field of the TC transfer frame becomes no longer than 892 bytes.

When data is sent to Data multiplexer and Record Module of the OBDH, a Virtual Channel Access (VCA) service is used, and the data field of TC transfer frame is a fixed length of 892 bytes, including a Virtual Channel Data Unit (VCDU) that compliant with the AOS Space data link protocol. The services provided by this VCDU internally under the AOS Space Data Link Protocol include TC space packages, IP packages, bitstream data, user-defined data, and so on. These VCDUs can be stored and played back/forward to 1553B bus and medium speed bus such as SpaceWire and LVDS.

4.4 Further Recommendation

Further protocol recommendations and other design recommendations include:

1) The spacecraft identification of the TC Transfer Frame and the VCDU should be the same, which represents the spacecraft receiving the upload data.
2) The virtual channel identification of the TC transfer frame is used to indicate the direction of the data: Direct Command, Upload Data sent to the OBDH computer software, and upload data sent to the Multiplexer and record module. The virtual channel identification is used to indicate different data users. The value of this identification should be uniformly specified with the VCDUs of the Data Transmission channel.
3) For storing data that requires a sequence of data receipts, a Zero-start sequential count is required at the VCDU counter. The Data multiplexer and Record Module of OBDH computer will store or forward the data frame only after it receives a frame that meets the expected count.

4) High-speed and low-speed channels can use the same data frame structure to share channel decryption devices.
5) The Synchronization and decoding module of High-speed and low-speed channel are recommended isolation to improve redundancy capability and system reliability.
6) Instructions over high-speed channels executed immediately by OBDH computer software or other on-board 1553B bus remote terminals, and the data rate of the instructions should take into account the ability of the user to receive instructions.

5 Summary

In view of the rapid development of high-speed and low-speed hybrid TT & C system in recent years, this paper proposes a telecommand scheme under the existing spacecraft electronic system architecture and space data protocol framework, which combines the data processing of high-speed and low-speed TT&C channels, optimizes the data flow design, and gives an efficient and reasonable uplink data link protocol, the data fusion of high and low speed TT&C links is realized, which improves the reliability of the system and the flexibility of uplink data transmission.

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