Design of Distributed Satellite Data Management System with Wired /Wireless Interconnection

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Abstract. A wired/wireless distributed on-board data management system is proposed in this paper, in which Distributed IO Modules are embedded in all kinds of on-board equipment that need to be measured and controlled, and provides interface services such as measurement and control, Low-speed serial data, 1-wire Temperature measurement, etc. The distributed information management device is used to replace the traditional integrated electronic centralized telemetry acquisition and control architecture to form a distributed satellite information acquisition and control network. The wireless Wi-Fi channel or a standardized control bus is used to replace hundreds or even thousands of analogy signal cable networks, which makes the external interface of satellite electronic equipment with different forms and functions standardized To be possible, it simplifies the process of field integration and assembly, and is an important support technology for the standardization and rapid assembly of electronic interface of satellite equipment.

Keywords: Wireless interconnection · Distributed · Satellite Data Management

1 Introduction

The traditional remote control and telemetry of satellite is centralized collection and control through the data handle subsystem. One or two stand-alone computers of the data handle subsystem or integrated electronic subsystem of the satellite platform provide hundreds or thousands of satellite analog data collection and transmission, so as to realize the monitoring of the operation status of satellite equipment on the ground [1]. At the same time, hundreds or thousands of tele-command pulse channels are provided for the control of many devices on the satellite [2]. At the same time, it also provides other low-speed data interfaces, such as ML, DS, UART interfaces, which are not connected to the whole satellite bus network.

The above-mentioned traditional mode is provided by one or two centralized devices, which results in a large number of cables to connect the discrete signal line and low-speed data line of centralized acquisition and control equipment to the electronic devices

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distributed in all corners of the satellite during the general assembly of the satellite electronic information system equipment [3]. As a result, the overall assembly and integration of the satellite is more complex, which is not conducive to the rapid production and test of the satellite; and the weight of the cable network that provides the connection for thousands of remote control and telemetry is much heavy, statistics show that the weight of the cable network has accounted for about 15% of the weight of the whole satellite.

In order to effectively solve this problem, this paper proposed a Distributed Satellite Data Management System Supporting Wired /Wireless Interconnection for satellite on orbit assembly, which adopts the Distributed IO module (DIO) to meet the measurement control and low-speed data interface requirements of satellite electronic equipment. The Distributed IO module is installed in each electronic equipment of the satellite. The relevant discrete telemetry signal interface and low-speed data telemetry interface are converted and packaged into standard data frame format by the distributed wireless measurement device in each electronic equipment. Multiple distributed wireless measurement and control modules form a distributed information network use wireless/wired interconnection interfaces, to pass the information to the satellite computer and send it to the ground. In turn, the uplink control instructions are received by the on-board computer and then transmitted to the distributed measurement and control system, and then sent to the corresponding distributed wireless measurement control module for instruction decoding or given through the low-speed data interface.

2 Distributed Satellite Data Management System

Distributed IO module is an important part of information system, which is embedded in the measurement and control signal equipment of spacecraft to provide IO signal interface services (Fig. 1).

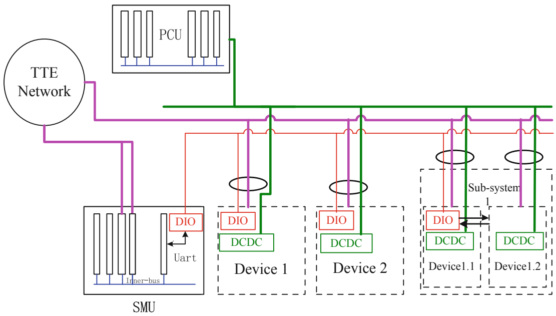

Fig. 1. Distributed Satellite Data Management System

As shown in the figure above, the distributed IO module, as a satellite micro neuron, can be used in a variety of flexible ways. That is to say, it can be embedded in each electronic device as the information acquisition and control node, or it can be installed

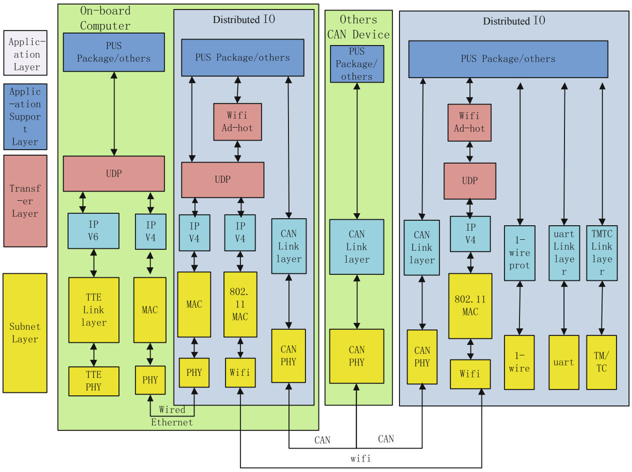

Fig. 2. Communication Protocol stack of Distributed Satellite Data Management System

on the whole satellite structure for acquisition and control of multiple small or passive devices (Fig. 2).

The peripheral topology of the DIO related system is shown in the figure below. The system includes two sets of buses. The first bus uses dio1 as the main uplink channel as the bridge from TTE to Can bus 1. The telemetry data is transferred and combined to dio1 according to APID, then sent to the on-board computer, and then sent to the software radio for downlink through TTE. In contrast to telemetry, the information flow of remote control data is also distributed according to the APID forwarding table saved in each distributed IO (Fig. 3).

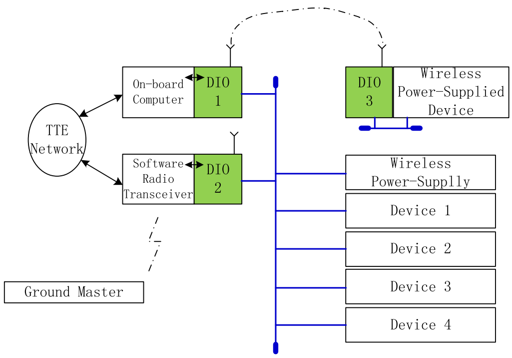

Fig. 3. The peripheral topology of the DIO related system

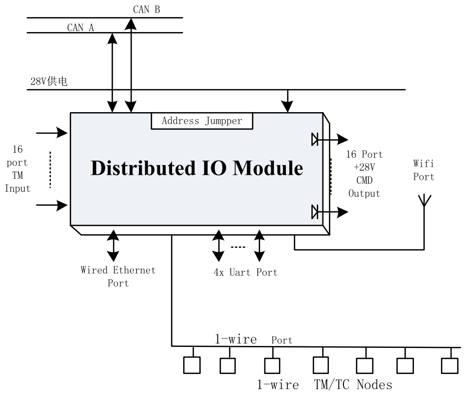

Fig. 4. Interface of distributed IO modules

3 Design of Distributed IO Modules

3.1 Interface Design of Distributed IO Modules

As shown in the figure above, the external interface of the distributed IO module includes a pair of Dual Redundant CAN bus interfaces, 28V control bus interfaces, 16 channels configurable analog quantity acquisition interfaces, 16 channels 28V pulse command output interfaces, 1-wire interfaces and 4 UART interfaces, Wi-Fi and wired Ethernet interfaces (Fig. 4).

3.2 Function Design of Distributed IO Modules

Distributed IO module has the following functions:

(1) Telemetry signal acquisition

- Support telemetry signal acquisition of temperature, 5V analog and switching value;
- Adopt telemetry acquisition interface sub card to adapt the above acquisition requirements according to the requirements;
- Acquisition frequency can be adjusted from 2Hz to 0.1Hz;
- Acquisition accuracy is 12bit.

(2) Pulse command output

- Output 28V positive pulse command;
- Command pulse width can be adjusted from 64ms to 1s (interval of 10ms);
- Command driving capacity 200mA;

(3) Control bus communication

- CAN bus bidirectional communication ability;
- Two way communication conversion from bus to wired Ethernet port;

- Support multi master communication mode.

(4) UART interface communication

- Provide 4-way external UART communication capabilities
- See baud rate for supporting standards;
- Adopt RS422 level;

(5) Data and protocol processing

- Analyze the data sent by CAN bus or wired Ethernet (or UART) bus to generate command signal;
- Acquisition of semaphore data, framing sent to data request end, can be fed back to can bus or wired Ethernet (or UART) bus;
- Receive the data of CAN bus and convert it to wired Ethernet (or UART) for sending;
- Receive wired Ethernet (or UART) data and convert it to can bus output;

(6) Wireless communication function

- Provide 1 channel of wireless transceiver;
- Acquisition signal can be sent to other equipment through wireless channel;
- Command data sent by other equipment can be received through wireless channel;

4 Software Design of Distributed IO Modules

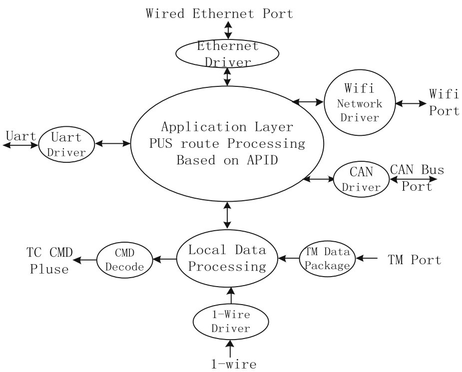

Fig. 5. Software Demands of Distributed IO Modules

The software requirement architecture of distributed IO is shown in the above image, including interface, processing, forwarding and other blocks. The following sections will make detailed requirements for the function points (Fig. 5).

4.1 PUS Route Processing Based on APID

The application layer software in DIO carries out data forwarding and local processing based on the destination APID [4] in pus package;

(1) If it is an APID processed locally, it will be forwarded to the local processing process. In the local processing process, the local business processing will be carried out.

(2) If the APID is not processed locally, it needs to be forwarded to other devices. The forwarded port and addressing parameters required for forwarding are obtained by querying "DIO APID data processing table" (Fig. 6). (Table 1).

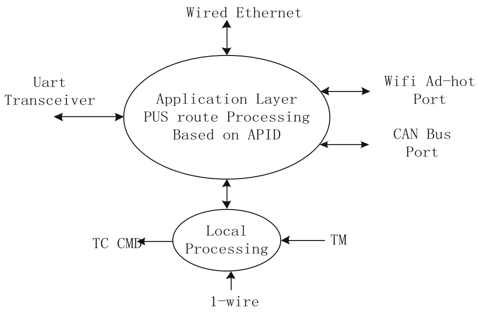

Fig. 6. Application Layer PUS route Processing Based on APID

Table 1. DIO1 APID data processing table

Destination APID	Process	Addressing parameter
0 × 402	wired Ethernet sending	IP = 192.168.2.1(general computer intranet)
0 × 541	Wi-Fi sends	IP = 10.74.1.3(Wi-Fi address of DIO)
…	…	…
0 × 583	can bus sends	can id = = xx_000100 (distributed peak regulator)

4.2 Communication Interface

(1) CAN Bus Interface [5]

It can be seen from the figure that there are two can buses in the system, namely the system can bus and the 1-to-1 local can bus in the wireless charger. The can addresses on both buses are assigned as follows (Table 2, 3):

(2) Wi-Fi Ad Hoc Bus Communication

Realize the Wi-Fi self-organizing communication between the devices on the satellite, support the wireless connection of the devices on the satellite, adopt 802.11 protocol standard, and the rate is not less than 1Mbps.

Table 2. Address Allocation of 1st CAN bus

CAN Devices	CAN **Address**(11bit)	Mask code (PJA1000)
DIO1	xx_000000_xxx	11_000000
DIO2	xx_000001_xxx	11_000000
Wireless Power-Supplly	xx_000010_xxx	11_000000
Device 1	xx_000011_xxx	11_000000
Device 2	xx_000100_xxx	11_000000
Device 3	xx_000101_xxx	11_000000
Device 4	xx_000110_xxx	11_000000

Table 3. Address Allocation of 2nd CAN bus

CAN Devices	CAN **Address**(11bit)	Mask code (PJA1000)
DIO3	xx_100101_xxx	11_000000
Wireless Power-Supplied Device	xx_100110_xxx	11_000000

(3) Wired Ethernet Communication

When the distributed IO module is placed inside the device, the data communication between the upper computer inside the device and the distributed IO is realized, supporting 10m/100Mbps wired Ethernet communication, which supports TCP/IP or UDP communication protocols. The data of application layer adopts pus communication protocol.

(4) UART Serial Communication

Adopt 3.3V power supply RS422 three wire serial port. The bus features are as follows: the camera remote control and telemetry function is realized by adopting bidirectional asynchronous serial communication interface. Communication rate: the baud rate of asynchronous serial communication is 115.2kbps.

Frame format: 1-bit start bit, 8-bit data bit, 1-bit stop bit. In the transmitted bit-stream, the standard serial digital communication protocol is adopted, with the low bit first and the high bit last. In multi-byte data transmission, the high byte is the first and the low byte is the last (Fig. 7).

4.3 Local Business Processing

According to the purpose APID of the pus package, the type of pus package distributed to the local service processing includes instruction decoding or 1-wire instruction.

(1) TC Command Decoding

The instruction data [6] is packaged in pus format and sent by the ground master. The data field content of PUS package is in the following format:

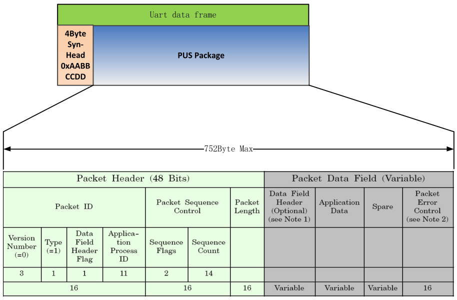

Fig. 7. Uart communication protocols

Word Order	b15 ~ b8	b7 ~ b0
1	DATA_TYPE(=0x00)	Reserve(=0x00)
2	LENGTH(=0x0050); means 80ms	
3	CMD_Index1	CMD_Index2
4	Reserve(=0x00)	Reserve(=0x00)

(2) Telemetry Acquisition Package

The telemetry acquisition data is packaged and sent to the application layer forwarding module by the pus package, and sent to the final ground master according to the destination APID. The data domain content of the pus package is in the following format:

Word Order	b15 ~ b8	b7 ~ b0
1	DATA_TYPE(0x01)	Reserve(0x00)
2	TM_Num(=0x0010)	
3	TM Channel 1, 12bit TM data	
4	TM Channel 2, 12bit TM data	
…	…	
18	TM Channel 16, 12bit TM data	

(3) 1-Wire Drive and Acquisition Packaging

The 1-wire Temperature is sent to the application layer forwarding module in a package of pus packets, which are sent to the final ground master according to the destination APID. The data field content of pus packets is in the following format:

Word Order	b15 ~ b8	b7 ~ b0
1	DATA_TYPE(=0x02)	Reserve(=0x00)
2	Number of TM data, TM_Num	

(*continued*)

(*continued*)

Word Order	b15 ~ b8	b7 ~ b0
3	TM Channel 1, 12bit TM data	
4	TM Channel 2, 12bit TM data	
…	…	
N + 2	TM Channel N, 12bit TM data	

(4) Local Machine and Network State Feedback

DIO, which is set as the main node, needs to report to the ground the current equipment connection on the CAN bus and Wi-Fi bus, and design the corresponding regular query and response mechanism to reflect the connection status of the equipment.

4.4 Other Functions

Support "APID data processing table" injection and update for the purpose of equipment replacement, fault repair and task migration. The software of multiple distributed IO modules is consistent. The differential can address, IP address, initial APID processing query table and other parameters are configured through the software header file.

5 Implementation Results

The system adopts the form of main board plus acquisition sub board, in which the main board is realized by the finished core board plus customized sub board, acquisition sub board completes telemetry signal acquisition and pulse command output, and the operating system is Linux or domestic embedded real-time operating system. The extended interfaces on the backplane include SPI interface for connecting wireless data transmission module and redundant ADC controller, multiple UART interface for RS-422 communication, one 10/100M adaptive Ethernet interface, two can interfaces, on-chip ADC interface and sufficient GPIO pins. In addition to the interface conversion, the baseboard also completes the conversion of external 28V power supply to the 5V power supply of the machine, and provides over-voltage, over-current and over temperature protection functions for the whole machine (Figs. 8, 9).

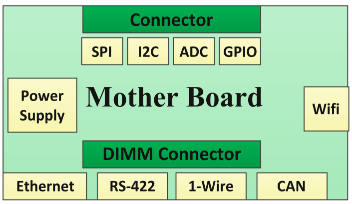

Fig. 8. Mother Board

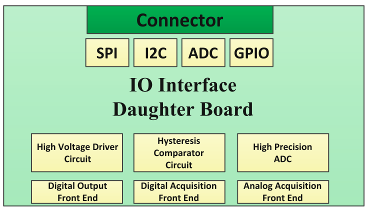

Fig. 9. IO Interface Daughter Board

The front-end of digital acquisition and the front-end of analog acquisition share the same input port. After filtering circuit, they are respectively input to comparator circuit and high-precision ADC circuit for digital and analog acquisition. The back end of the comparator circuit is connected with the input port of the IO expansion chip to collect 16 channels of digital signals in parallel, and the processor reads back the data through the SPI interface; the processor also configures and reads the parameters of the ADC chip through the SPI interface (Fig. 10, 11)

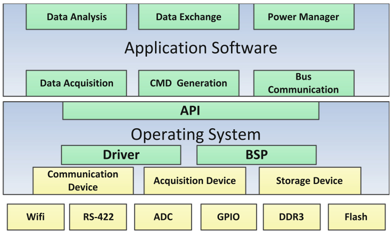

Fig. 10. Software Hierarchy Diagram

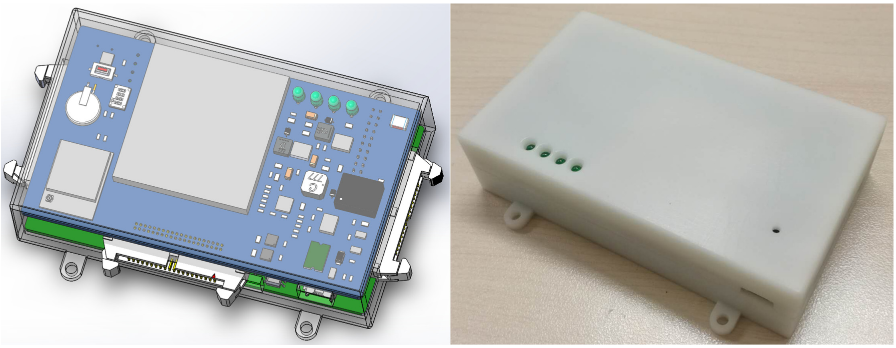

Fig. 11. Appearance of Distributed IO Modules

The output port of the IO expansion chip is the TTL input signal of the pulse instruction output circuit. After the high voltage drive circuit and the current limiting circuit composed of MOSFET, the 28V pulse instruction signal is generated.

The operating system abstracts the data transmission module, RS-422 interface, DDR3 and other interfaces, peripherals and memory into different types of devices and files, realizes the relevant device drivers, and forms the board level support package (BSP); on the operating system, the application software operates the abstract devices through the standard API provided by the operating system, and realizes data reading and interface cooperation The conversion and power management are discussed to realize the functions required by the system.

6 Design Results Analysis

To test the functional requirements of Distributed Satellite Data Management System, we build a test environment as shown in the following figure. The whole test environment includes: Test monitor computer: running test software, connecting with distributed IO main node (dio1/dio2) through Ethernet; three sets of distributed IO modules: dio1 as the main node and test upper computer through Ethernet, dio2, DIO3 as the slave node, dio1 and dio2 through Ethernet, dio1 and DIO3 through wireless Wi-Fi; can simulation card simulation load can equipment, It is connected with dio2 through CAN bus B. The load simulator can simulate load output TM, receive command and can data communication function; at the same time, it is the main control, which can display the data collected and processed on the satellite, and the ground command control load; it can also display the satellite status as the ground main control, including the command control switch, satellite operation and status simulation display (Fig. 12).

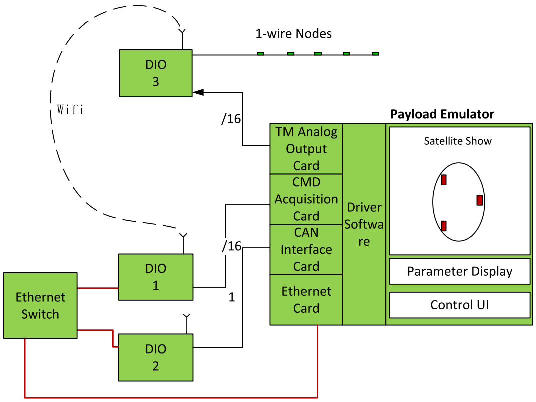

Fig. 12. Test environment of Distributed Satellite Data Management System

It is verified that the distributed satellite data management system based on wired/wireless interconnection can be embedded in all kinds of satellite equipment that need to be measured and controlled by spacecraft, and provide interface services such as measurement and control, Low-speed serial data, 1-wire Temperature Measurement and collection. The function, performance and technical index of the distributed module of the core equipment have been tested and meet the design requirements.

7 Conclusion

In this paper, a wired/wireless distributed on-board data management system is proposed, which is embedded in all kinds of on-board equipment that need to be measured and controlled, and provides interface services such as measurement and control, Low-speed serial data, 1-wire Temperature measurement, etc. The distributed information management device is used to replace the traditional integrated electronic centralized telemetry acquisition and control architecture to form a distributed satellite information acquisition and control network. The wireless Wi-Fi channel or a standardized control bus is used to replace hundreds or even thousands of analogy signal cable networks, which makes the external interface of satellite electronic equipment with different forms and functions standardized It simplifies the process of field integration and assembly, and is an important support technology for the standardization and rapid assembly of electronic interface of satellite equipment.

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