Research on Wireless Networks for Intra-spacecraft

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Abstract. With the rapid development of onboard avionic technology, there are increasing requirements for internetworking, modularization and non-cable of spacecrafts. The onboard wireless networks technology provides one of the most important foundation to enable communication among intelligent nodes inside a spacecraft. This paper studies the application of wireless sensor networks for spacecraft. Wireless networks technology has significant advantages in reducing the weight of spacecraft, saving time in spacecraft integration. Based on wireless sensor networks, a scheme for spacecraft avionic system is put forward. The avionic system overall networks are a combination of wired and wireless networks. The block diagram and key interface design of the spacecraft overall networks are given. The design proposal of the wireless node and the data flow of the spacecraft are also analyzed. The results show that the application of wireless networks scheme is reasonable and feasible. The onboard wireless networks technology can meet the new requirements of the spacecraft in internetworking, modularization and non-cable.

Keywords: Wireless networks · Spacecraft · Research and application

1 Introduction

With the development of space technology, wireless communications technology in the spacecraft plays an increasingly important and even irreplaceable role to meet the networking, modular and cableless requirements and other new demands [1]. Wireless communications technology gets more and more attention. The CCSDS (The Consultative Committee for Space Data Systems) has accelerated the research on wireless communications technology in recent years on the basis of years of wireless communications study and tracking. At present, several wireless communications standards have been developed for the application field of aerospace [2–4]. For spacecraft environmental monitoring and control, CCSDS recommends the use of the wireless sensor networks standard IEEE 802.15.4 [5]. IEEE 802.15.4 standard is intended to be used in low-speed wireless personal area networks (PAN). The key objectives are to achieve low power consumption and low cost. The CCSDS has defined the MAC (Medium Access Control) layer and PHY (Physical layer) layer protocol, but the network layer and higher layer are not defined. Based on the CCSDS standard, this

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paper studies the application of wireless sensor networks in spacecraft environment monitoring and control.

2 Advantages of Wireless Communications Technology

In the field of spacecraft environmental monitoring and control, a large number of spacecraft test data and health data need to be collected. These data are generally required to be collected through a dedicated cable for capture and transmission. The demands for this type of transmission cables on spacecraft are generally very high, and the connections between the cables are often very complex. Thus the spacecraft assembly is usually very cumbersome, time-consuming, inefficient and error-prone. These inconveniences prompt spacecraft engineers to concern about the use of wireless communications technology to replace the traditional cables. The use of wireless communications technology can not only achieve cableless data transmission and reduce the weight of the satellites, but also facilitate the modular design of spacecraft equipment, realize information network transmission, and improve the flexibility of spacecraft design, test and assembly. Due to structural reasons places where traditional wired way can not cover are easily covered by wireless way. At the same time, the convenience of the wireless connection is conducive to the realization of spacecraft structure functional innovation.

3 Applications of Wireless Networks on Spacecraft

3.1 Application Situations

The CCSDS standard points out that the wireless communications technology based on IEEE 802.15.4 is used to build wireless personal area network (PAN). The network coverage is generally about 10 m, within the spacecraft size. The data transfer rate is about 250 kbps, almost equal to the data amount of spacecraft telemetry and telecontrol. It is very suitable for the spacecraft environmental monitoring and control identified by the CCSDS recommendation. This paper focuses on the application of wireless sensor networks standard in spacecraft telemetry and remote control.

3.2 Design of Spacecraft Networks

In the wireless personal area network based on IEEE 802.15.4, the network topology is a star topology. The gateway node can communicate with the spacecraft backbone network. The wireless node can communicate with the gateway node. A block diagram of the spacecraft networks based on PAN networks are shown in Fig. 1.

In Fig. 1, each compartment of the spacecraft establishes a separate PAN network. Each PAN network can cover a communication distance of 10 m, supporting the number of wireless nodes in 10–100. Each PAN network has a separate gateway connected to the cable backbone network, and can communicate with the backbone network. The spacecraft backbone network can be a conventional 1553B bus, a CAN bus or

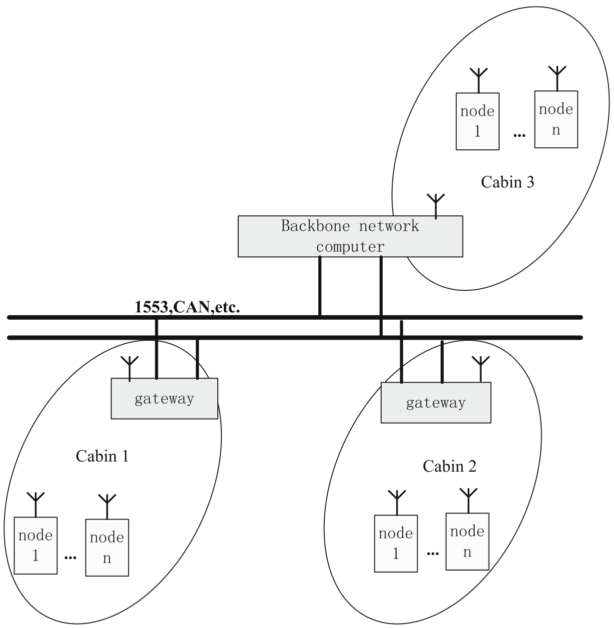

Fig. 1. Block diagram of spacecraft networks based on PAN networks.

other bus. In each cabin, the wireless nodes can only communicate with the gateway nodes, and can not communicate directly with each other. If they need to communicate with each other, they should first communicate with the gateway node, their messages should be exchanged though the gateway node. Wireless nodes have the basic telemetry acquisition, instruction output and other similar functions. The wireless transmitter transmission power is in the range of −15 dBm–10 dBm. Considering the electromagnetic compatibility, radio radiation, interference and other issues, the specific distribution of the RF nodes on the spacecraft should be paid special attention to.

3.3 Wireless Node Design

The design of wireless node needs to consider the reliability of the node itself. One of the byproducts of using wireless technologies in space systems is the extra flexibility introduced when implementing wireless fault-tolerance and redundancy schemes. The redundant design of the wireless interface compared to the traditional cable connection is much easier to achieve well effect. The design is simple, as shown in Fig. 2.

The left of Fig. 2 shows the traditional cable connection implementing the cross redundant backup design. Each device's main and backup is connected to another device's main and backup through two sets of cables. Cable connections are relatively complex outside the devices. The right side in the figure shows the wireless way of cross redundant backup design. The main and backup of each device are connected to two wireless communication modules respectively inside the equipment. No connections are required outside the equipments to realize the cross redundant backup design.

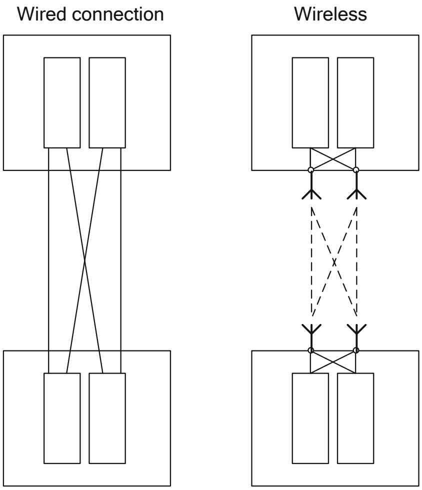

Fig. 2. Redundancy wireless interface design

Wireless communications technology effectively reduces the weight of spacecraft, and makes it easy to achieve networking, modular, cableless design of spacecraft.

Although the wireless communications technology has the above advantages, in practical applications there are many problems to be solved, such as EMC, EMI, RF radiation and other issues [6–8]. The solutions of these problems have a great relationship with the specific structure of the spacecraft. Different structures often require for different solutions. In addition, the advantages of wireless communications lie in the design of wireless nodes. The principle of wireless node design is to simplify the spacecraft cable connection, shorten the spacecraft assembly time, reduce the spacecraft cable weight, and achieve spacecraft modular assembly.

At present, in the field of industrial control, a wide range of complete wireless communications protocols such as ZigBee, based on IEEE 802.15.4 PHY layer and MAC layer protocol, implement higher-level network layer protocol. These protocols not only realize the CCSDS defined single-hop competition access and single-hop scheduling access, but also realize multi-hop relay communications. The user can configure the required communication functions. Texas Instruments also offers a dedicated monolithic solution CC2530. The chip integrates the ZigBee complete protocol stacks and RF transceiver functions. The MAC layer and PHY layer protocol are compatible with IEEE 802.15.4 specification. It can work in the 2.4 GHz frequency band, and is compatible with CCSDS standards. This chip also integrates a 8051 microprocessor and an ADC, SPI/UART ports, GPIO ports and other peripherals. Its power consumption is very low. It consumes only 0.4 μA current in the idle state. In the working state, It consumes about 24–29 mA current. The supply voltage is 3.3 V, assuming 10% duty cycle operating conditions, the average power consumption is only

8.3 mW, meets the CCSDS proposal of less than 10 mW. The wireless node (or gateway node) design based on this chip is shown in Fig. 3.

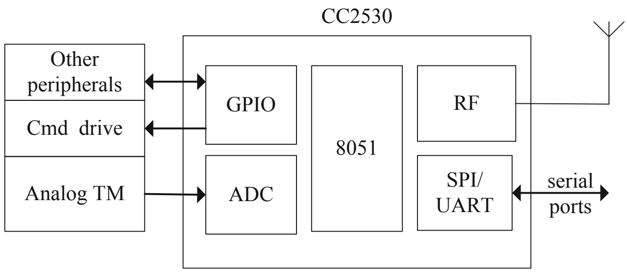

Fig. 3. Wireless node design

Based on the design of wireless node above, traditional devices of the spacecraft only need to add a few small components (such as command-drive chips, multi-channel analog multiplexers, etc. according to the specific requirements of the single device) so as to discard the heavy cables for telemetry and telecontrol. In this way, it is very easy to extend more than 10-channels of command-drive and telemetry acquisition channels for each device. The channel number is enough for each device. Gateway nodes need to use the serial ports to communicate with the spacecraft backbone network through the gateway computer. This scheme easily meets the spacecraft common equipment requirements for remote control and telemetry. And the cost is very low. For each device, the weight of the new added wireless node is much lighter than the weight of external cables. The advantages of wireless communications technology are fully reflected. Low-speed wireless communications technology not only reduces the weight of spacecraft, but also reduces the time cost in spacecraft assembly. Spacecraft testing is also simplified. Improving efficiency is the purpose and real reason to apply wireless communications technology on spacecraft.

3.4 TC and TM Data Flows

For the TC data flow, if the spacecraft receives direct commands from the ground, the TC data flow is the same as the original wired connection. This article will not describe. For indirect commands or data injection, the backbone network computer will first send the received data to the corresponding gateway computer, the gateway computer will then transfer the information to the gateway node through the serial ports interface, and finally the gateway node will send the data wirelessly to the target wireless node. If the wireless node receives the TC information, it will execute the commands directly.

For the TM data flow, each wireless node sends their telemetry data to the gateway node of the PAN network. The gateway node collects the data and then transfers the data to the gateway computer through the serial ports. The gateway computer then processes the data and then sends the data to the backbone network. The backbone network computer groups the data into packages and sends them down to the ground.

4 Conclusion

Based on the analysis of the CCSDS standard of wireless networks, this paper summarizes the advantages of wireless communications technology applying on spacecraft, and puts forward an application example of wireless networks for spacecraft environment monitoring and control. The paper gives the block diagram of the spacecraft networks and the key interface reliability design. It also gives the design suggestions of the wireless nodes, analyzes the feasibility of the design scheme, and points out the problems that need to be solved urgently. Wireless networks technology can meet the spacecraft demands in networking, modularization and non-cable, and is a very promising technology for future spacecraft.

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