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A Study on Framework Design of Wireless Inner-Satellite Networks

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Abstract Recently, new researches substituting the wireless connection for wired-interface buses in an inner-satellite network have been addressed to reduce weight of a satellite system. In the previous research, it is shown that transmission rate can be achieved to 480Mbps with the delay spread of 60ns by using UWB (Ultra Wide Band) system. Therefore, this paper surveys the wireless systems that can be applied in the inner-satellite network. Candidate systems are the IEEE 802.11ac for the local area network, 802.15.4 for the sensor network, and UWB system for the personal area network. We also consider possible candidate wired-cables to be wireless connection. Finally we propose the framework of the wireless inner-satellite network.

Key words Inner-satellite network, IEEE 802.11ac, IEEE 802.15.4, UWB

1. Introduction

In the satellite manufacture, it is important to reduce the weight of the satellite because the lunching cost increases with increasing the satellite weight. Therefore, new researches substituting the wireless connection for wired-interface buses in the inner-satellite network have been addressed to reduce cable weight [1]. In previous works, experimental results show that commercial UWB device can be used to achieve 480Mbps with the delay spread of 60ns within a satellite system. Also, replacing wired-interface buses can be helpful for the satellite design because the wireless inner-satellite network also has more flexibility in the layout of satellite subsystems and more reliable connections at joints [1]. Therefore, we propose the framework for wireless inner-satellite networks to support the connection between satellite subsystems.

The remainder of this paper is organized as follows: Section 2 describes candidate systems that can be applied in wireless inner-satellite networks. Section 3 presents the selection of replacing wired-interface buses. Section 4 describes the details of the proposed framework. Finally, the conclusion will be followed.

2. Candidate Systems

A. IEEE 802.11ac

IEEE 802.11ac is a standard providing high throughput wireless local area networks. It uses the multiple-input and multiple-output (MIMO) technology and high-density modulation such as 256 quadrature amplitude modulation (QAM) to achieve the high-throughput [2]. Broadcom Corporation that is a manufacturer of semiconductor solutions for the communication chip introduces first products of IEEE 802.11ac in 2012. Other products of IEEE 802.11ac will be released.

B. IEEE 802.15.4

IEEE 802.15.4 is a standard for low-rate wireless personal area networks. It is specialized in the low cost device and lower power consumption for sensor networks [3]. Therefore, IEEE 802.15.4 system is applied in various areas such as the automation, control,

Table 1. Specification for candidate systems

Specification	IEEE 802.11ac	IEEE 802.15.4	UWB
Frequency band	5GHz	868/915Mhz /2.4GHz	3.1~10.6GHZ
Bandwidth	20/40/80/ 160MHz	1MHz	528MHz
Max. Data rate	> 1Gbps	< 250kbps	< 480Mbps
Max. Transmission range	100m	10~20m	5~10m
Modulation scheme	QAM	BPSK, O-QPSK	QPSK, DCM
Medium access scheme	CSMA-CA	CSMA-CA	TDMA with beacon
Power consumption[5]	200~ 300mW	80~ 90mW	200~ 300mW

monitoring, and situational awareness.

C. UWB system

UWB means a bandwidth of more than 500 MHz or a fractional bandwidth of more than 20% of the carrier frequency. Therefore, the system using UWB can be suffered less than other system from multipath fading since it has the resolvability of multipath components due to its short pulse. It can also achieve the high throughput. There is specification, ECMA for the PAN using UWB [4].

The more detailed specification for candidate systems is shown as Table 1.

3. Selection of Replacing Wired-Interface Buses

In this section, we consider candidate wired-interface buses to be replaced to the wireless connection. To select these, we analyze a small satellite, REIMEI made by JAXA, Japan [6]. The system block of the inner-satellite network is as shown in Fig. 1. Almost tasks for the satellite control are conducted by an integrated control unit (ICU). All subsystems are directly connected to the ICU. In the power subsystem, there are the solar array panels, batteries, and power control units to supply the power for other systems. In the sensing & actuator subsystem, there are sensors (a star tracker, sun and geomagnetic aspect sensors, and fiber optical gyroscopes) and actuators (reaction wheel and magnetic torquers) to control the attitude. In the communication subsystem, there are the S-band receiver, transmitter and a GPS receiver for the communication and tracking. REIMEI can transmit data to a ground station when it passes the sky of the ground station about 10 minute. In the mission subsystem, there are 3 cameras to observe the aurora. These generate the image data of 500Mbit for 7 minutes in an observation.

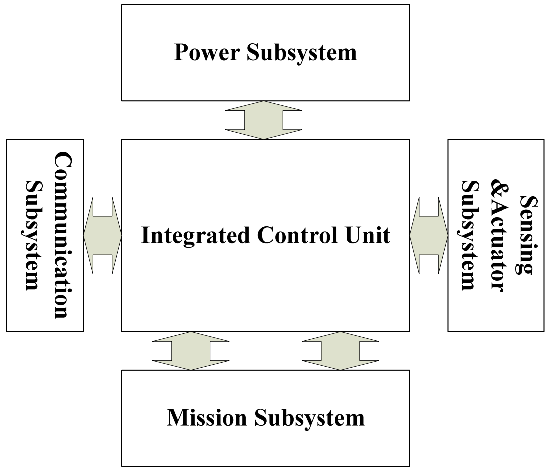

Figure 1. Example of inner-satellite networks

Table 2. Suitability for replacing wired-interface buses

System	RSO	DQ	Suit-ability
Power Subsystem	O	Small	Not suited
Sensor& Actuator Subsystem	O	Small	Partially suited
Comm. Subsystem	∆	Large	suited
Mission Subsystem	X	Large	suited

To select wired-interface buses to be replaced, we consider 2 criteria such as a relation with the satellite operation (RSO) and a data quantity (DQ) as shown in table 2. If the wireless connection is disconnected, it cause the malfunction of the satellite in the attitude, orbit control and power supply. Therefore, the RSO should be considered. We should also consider the DQ because the generated DQ is varied according to the subsystem system. For example, it is inappropriate to select the high data rate system in sensor subsystem in terms of the power consumption and device cost because the generated DQ is low. Consequently, the wired

Table 3. QoS requirements of traffic in inner-satellite networks

System	Trans. rate	Trans. delay
Sensor Subsystem	> 1KB/s	Related to the control interval (ex. 1/32sec. in REIMEI)
Actuator Subsystem	>1KB/s	
Comm. Subsystem	Related to the trans. rate of downlink (ex. >400Mbps ,if bandwidth = 100MHz, modulation =16QAM)	-
Mission Subsystem	Related to the mission data (ex. 240Mbps, if SAR mission subsystem)	

interface bus of the mission and downlink communication subsystem can be substituted with the wireless connection by IEEE 802.11ac and UWB because these systems are not related to the satellite operation and these generate the large data. Also, if the sensor network module using IEEE 802.15.4 is used and the reliable data transmission is supported, the wired interface bus of the sensor and actuator can be substituted with the wireless connection.

Table 3 shows the quality of service (QoS) requirements of the traffic in inner satellite networks. While the low data rate is needed to the sensor and actuator subsystem, the high data should be supported in the communication and the mission subsystem. Since the recent mission subsystem generates the high rate data such as high resolution images, wireless connections between the mission subsystem and ICU and between the communication subsystem and ICU should have the high date rate. In the delay requirement of the traffic for the sensor and actuator subsystem, we consider the control interval of the satellite. Since the ICU periodically transmits the control message to the actuator subsystem, the sensing data and control data should be transmitted within the control interval. In the traffic of the mission and communication subsystem, we don't consider the delay bound. Since the traffic transmitted from the mission subsystem to the communication subsystem is only needed to arrive at the communication subsystem before the communication subsystem communicates with the ground station. The low earth orbit satellite has about 10 chances to

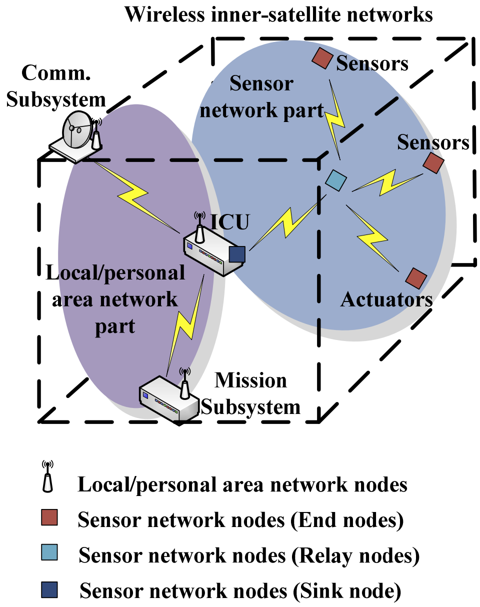

Figure 2. Proposed framework of wireless inner-satellite networks

communicate with the ground station per a day. And the interval time which the satellite communicates with the ground station has hour-scale. While the transmission time from the mission subsystem to the communication subsystem is minute-scale. Therefore, we can say that there is enough time to transmit the packet without considering the delay bound. The loss ratio of the traffic of all subsystems is 0% since the traffic is data.

4. Proposed Framework

In this section, we describe the proposed framework of the wireless inner-satellite network. Fig. 2 shows the proposed framework. In the proposed framework, there are two network domains that are the sensor network and local/personal area network. In the sensor and actuator subsystem, the communication module should be always kept as the active state since the sensor and actuator subsystem continuously communicate with the ICU. The low data rate only is needed because their traffic only consists of the sensing data and control data. Therefore, the sensor network such as IEEE 802.15.4 is suitable to substitute the inner wired network because it is designed to support the low data rate and low power consumption. On the other hand, in the mission and communication subsystem, the high data rate is demanded. Thus, IEEE 802.11ac or UWB system are appropriate for links between

ICU and these subsystems. Since the ICU controls all operations of the satellite and processes the mission data, all data should be gathered at the ICU. Therefore, the ICU node has the both interfaces for the local/personal area network and sensor network interface. It seems unnecessary to implement two kinds of networks in the small satellite. However, these well-designed networks can lead longer lifetime of the satellite by the efficient power consumption. And, in a cost side, the communication chips used in the proposed framework are very popular and produced massively, thus it is cheap enough to implement in the small satellite.

5. Conclusion

In this paper, we proposed the framework of wireless inner satellite networks. To design the framework, we surveyed wireless systems to be applied in the inner-satellite network. And then, we analyzed suitable wired-interface buses to replace by wireless interfaces. Consequently we designed the network framework that consists of the sensor network and local/personal area network.

In the future work, we will research the network protocol in the inner-satellite networks to support the reliability of the data transmission.

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