QUALITY OF SERVICE REQUIREMENTS FOR A HIGHER LAYER PROTOCOL OVER SPACEWIRE TO SUPPORT SPACECRAFT OPERATIONS

Session: SpaceWire Networks and Protocols

Short Paper

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ABSTRACT

SpaceWire [1] has been used on many spacecraft as a means of high-rate data transfer between onboard components. It has the capability of moving data from an onboard node to another onboard node and the capability of specifying the route to be traversed in the network. However, it does not have the capability to provide different classes of quality of service (QoS) for different types of data flows. To operate spacecraft onboard components, several types of data need to be transferred between onboard nodes and each of these data types has different QoS requirements. This paper describes the QoS classes that need to be provided by a higher-layer protocol to support spacecraft operations, and proposes simple solutions to implement them.

1 INTRODUCTION

SpaceWire [1] has been used on many spacecraft as a means of high-rate data transfer between onboard components. It has the capability of moving data from an onboard node to another onboard node and the capability of specifying the route to be traversed in the network. However, it does not have the capability to provide different classes of quality of service (QoS) for different types of data flows. To operate spacecraft onboard components, several types of data need to be transferred between onboard nodes and each of these data types has different QoS requirements. If different types of data can be transferred in a single network, we can minimize the implementation efforts and maximize the efficiency of the network. Therefore, it is desirable for most spacecraft applications of SpaceWire if there is a higher-layer protocol that runs over SpaceWire and provides necessary classes of QoS for different types of data.

There are three important measures of QoS for spacecraft applications: latency, reliability, and volume. For example, data used to monitor and control onboard components in real-time need to be transmitted over the network within a limited latency, while data related to science or mission products are not so sensitive to latency. Data used to monitor and control intelligent components need to be transferred reliably, and their losses should be detected immediately. Data generated periodically do not have to be protected against losses so severely. Data used to monitor and control components have small volumes, while data related to science or mission products have large volumes.

This paper describes the QoS classes that need to be provided by a higher-layer protocol to support spacecraft operations in section 2, and proposes simple solutions that implement the QoS classes in section 3.

2 QUALITY OF SERVICE (QOS) REQUIREMENTS

2.1 DATA TYPES USED FOR SPACECRAFT OPERATIONS

To operate spacecraft onboard components, several types of data need to be transferred between onboard nodes. There are three major types of data that are used on most spacecraft: data used for monitoring and controlling onboard components, data used for mission production, and data used for maintaining onboard components.

To monitor and control onboard components, commands are sent from a computer (it may be the central computer of the spacecraft, the attitude and orbit control computer or a payload/mission computer) to components, and telemetry is sent back form the components to the computer. There may be several different types of commands and telemetry depending on the types of the components monitored and controlled. If the component monitored and controlled is an intelligent one having a processor, commands are used to start/stop programs and change settings of the programs. The component returns high-level messages or reports about the status of the execution of the programs. If the component monitored and controlled is a non-intelligent device without a processor, commands are used to control the device directly in real-time. The device returns the status of its various parts (called housekeeping data) periodically. Intelligent components may also generate housekeeping data periodically. The computer also distributes clock data to components to inform them of the value of the master clock of the spacecraft periodically.

Science instruments generate science data that are the products of the mission. For example, cameras generate images. To maintain onboard components, especially those with processors, it is sometimes necessary to upload and download memory data to and from the components. Memory data include computer programs and large tables such as star catalogues.

Table 2-1 summarises the types of data discussed in this subsection.

Table 2-1 Types of Data used for Spacecraft Operations

Data Types		
Data used for monitoring and controlling components	Commands	For intelligent control
		For real-time control
	Clock	
	Housekeeping data	
	Reports	
Data used for mission production	Science data	
Data used for maintaining components	Memory data	

2.2 QoS Requirements for Data Types

Each of the data types described in 2.1 has latency, reliability and volume requirements. Clock data and data used for monitoring and controlling non-intelligent devices (commands for real-time control and housekeeping data) have a high latency requirement (that is, they have to be delivered to the destinations within a short time), a low reliability requirement (that is, small losses of data can be tolerated), and a low volume requirement. Data used for monitoring and controlling intelligent components (commands for intelligent control and reports) have a high latency requirement, a high reliability requirement (that is, losses of data cannot be tolerated), and a low volume requirement. Science and memory data have a low latency requirement, a high reliability requirement, and a high volume requirement.

Table 2-2 summarises the QoS requirements for each data type.

Table 2-2 QoS Requirements for Each Data Type

Data Types		Latency Reqs.	Reliability Reqs.	Volume Reqs.
Commands	intelligent control	High (Asynchronous)	High	Low
	real-time control	High (Periodic)	Low	Low
Clock		High (Periodic)	Low	Low
Housekeeping data		High (Periodic)	Low	Low
Reports		High (Asynchronous)	High	Low
Science data		Low (Asynchronous)	High	High
Memory data		Low (Asynchronous)	High	High

3 Proposed Solutions

3.1 Latency Control

Some of the data types require that data have to be delivered to the destination within a limited amount of time. Assigning dedicated time slots to these data types is a simple way of guaranteeing latency requirements for these data types. SpaceWire [1] has a mechanism of distributing 64 time codes and these time codes can be used to define time slots. A dedicated time slot (or a set of dedicated time slots) should be assigned to each data type (or a set of data types having similar latency requirements). Out of 64 time slots, a small number of time slots will be assigned to the data types with high latency requirements and the other time slots to the other data types.

To control the data traffic in each slot, there must be a master node for each time slot. If the network can be divided into multiple sub-networks each of which does not share network resources with the other sub-networks, there can be a master in each of the sub-networks. The master can either (1) send data to or receive data from the other nodes in the slot or (2) determine which node should send data to which node in the slot. For the master to be able to determine which node should send data to which node, the master should poll data transfer requests form the other nodes and signal its decision in the same slot or in another slot assigned to such usage.

For monitor and control purposes, the node that monitors and controls the other nodes will be the master of the slot and it sends commands to and collects telemetry from the other nodes. For transferring science and memory data, the master can either (1) send or receive data or (2) determine the source-destination pair.

Since the data types with high latency requirements have low volume requirements, and vice versa, the same mechanism can be used to control volume requirements.

3.2 Reliability Control

For data types with low reliability requirements, data should be transmitted only once without retransmission because the receiver can wait for the next data without needing to receive the missing data. For data types with high reliability requirements, retransmission of missing data is necessary either through the same path or through a redundant path. For both types of data, it may be desirable to have a mechanism to let the sender know whether or not the receiver has received the data sent by the sender.

Reception acknowledgement and retransmission control should be implemented by a protocol at a layer higher than the layer that controls the slots. If the Remote Memory Access Protocol (RAMP) [2] is used, only the retransmission control should be implemented on top of RMAP because RMAP has the capability for reception acknowledgement. In this case, RMAP should be used on top of the slot control layer.

4 Conclusion

This paper has shown the QoS classes that need to be provided by a higher-layer protocol to support spacecraft operations, and proposed simple solutions to implement them.

5 References

1. European Cooperation for Space Standardization (ECSS), “Space engineering - SpaceWire - Links, nodes, routers and networks,” ECSS- E- ST- 50- 12C, January 2003.

2. European Cooperation for Space Standardization (ECSS), “Space engineering - SpaceWire - Remote memory access protocol,” ECSS- E- ST- 50- 52C, February 2010.