SpaceFibre

SpaceFibre is a very high-speed serial data-link developed by the University of Dundee for ESA which is intended for use in data-handling networks with high data-rate payloads. SpaceFibre is able to operate over fibre-optic and copper cable and support data rates of 3.125 Gbit/s and up to 6.25 Gbit/s in the future. It aims to complement the capabilities of the widely used SpaceWire onboard networking standard: improving the data rate by a factor of 15, reducing the cable mass and providing galvanic isolation. The use of the Multi-Lane allows data-rates in excess of 40 Gbits/s.

SpaceFibre provides a coherent quality of service (QoS) mechanism able to support bandwidth reserved, scheduled and priority based qualities of service. It improves considerably the fault detection, isolation and recovery (FDIR) capability provided by SpaceWire.

The SpaceFibre interface is designed to be implemented efficiently, requiring substantially fewer logic gates than a RapidIO interface. Furthermore, SpaceFibre uses the same packet level protocol as SpaceWire, enabling simple connection between existing SpaceWire equipment and high-speed SpaceFibre links and networks.

SpaceFibre aims to support high data-rate payloads, for example synthetic aperture radar and hyper-spectral optical instruments. It provides robust, long distance communications for launcher applications and supports avionics applications with deterministic delivery constraints through the use of virtual channels. SpaceFibre enables a common onboard infrastructure to be used across many different mission applications resulting in cost reduction and design reusability.

SpaceFibre Protocol Stack

The main layers of the SpaceFibre protocol stack are illustrated in Figure 1.

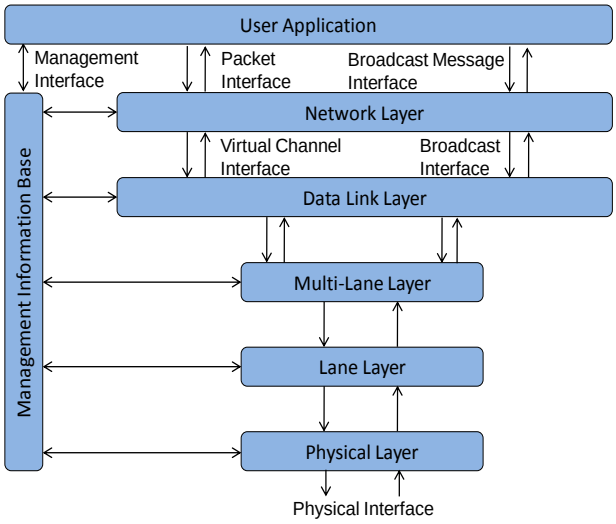

Figure 1 SpaceFibre Protocol Stack

SpaceFibre provides three interfaces to the user application:

- A packet interface which is used to send and receive packets. SpaceFibre packets have the same form as SpaceWire packets making it simple to connect between SpaceWire and SpaceFibre networks.
- A broadcast message interface which is used to broadcast short messages over the SpaceFibre network.
  This can be used for broadcasting system time information, synchronisation signals, equipment events, interrupts, and network management information, all with very low latency.
- A management interface which is used for configuring, controlling and monitoring the status of the SpaceFibre interface.

The **Network layer** is responsible for transferring packets over a SpaceFibre link or network. The information to be sent is packaged in the same format as SpaceWire: <Destination Address> <Cargo> <End of Packet Marker>. It uses the same routing concepts as SpaceWire including both path and logical addressing. The network layer is also responsible for broadcasting short messages across the SpaceFibre network and for receiving and checking those messages.

The **Data Link layer** is responsible for quality of service, flow control and for resending information in the event of a temporary fault on the SpaceFibre link. Virtual channels are used to provide separate packet streams and to support the various qualities of service. Data packets from each virtual channel are segmented into frames which are interleaved over the SpaceFibre link according to available flow control and QoS information. In the event of an error occurring on the SpaceFibre link, SpaceFibre is able to detect the error, and rapidly resend the data of one or more frames.

The **Multi-Lane layer** is responsible for running several SpaceFibre lanes in parallel to provide higher data throughput and redundancy with graceful degradation. In the event of one lane failing the remaining lanes will automatically share the load, resulting in continuous operation with reduced capacity. Unidirectional lanes are supported to reduce cable mass and power consumption.

The **Lane layer** is responsible for lane initialisation, error detection and re-initialisation. Data is encoded prior to transmission using 8B/10B encoding which supports AC coupling of the data signals.

The **Physical layer** is responsible for serialising the SpaceFibre symbols and transmitting the serial data over fibre optic or copper cables using differential current mode logic (CML). The physical layer is also responsible for clock-data recovery from the received serial bit-stream and for de-serialising it into a stream of 8B/10B symbols.

The **Management information base** provides the means for configuring, controlling and monitoring the status of each layer of the SpaceFibre interface and network.

SpaceFibre Application Architectures

SpaceFibre is specifically designed for handling data on-board spacecraft. It can be used to provide point-to-point connections between equipment or, using SpaceFibre routers, to provide a complete interconnection network.

In Figure 2, SpaceFibre is being used to connect various instruments to the on-board mass memory unit using point-to-point links. Instrument 1 is a very high data-rate instrument which requires a two-lane SpaceFibre link to transfer data from the instrument to the mass memory. Instrument 2 is a high data-rate instrument with a single-lane SpaceFibre link connecting it to the mass memory. There are several moderate data-rate instruments, each with a SpaceWire interface. Rather than connect all of these SpaceWire links directly to the mass memory unit, a SpaceWire to SpaceFibre Bridge device is used which is able to multiplex several SpaceWire links over a single SpaceFibre link that goes to the mass memory unit. This single SpaceFibre link saves significant mass on the spacecraft if it has to run over a few metres, compared to running the separate SpaceWire links.

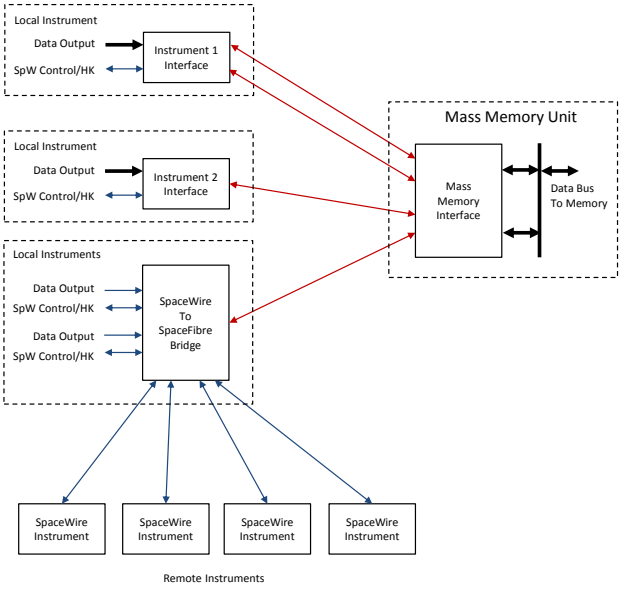

Figure 2 Spacecraft Data Handling with SpaceFibre Links

The SpaceWire to SpaceFibre Bridge provides a separate virtual channel for each SpaceWire link. The quality of service for each of these virtual channels can be specified according to the needs of the individual instruments. For example, each virtual channel can be allocated a bandwidth corresponding to the expected bandwidth from the corresponding instrument.

When SpaceFibre is used to provide point-to-point connections there is no need for a network layer. The packets being sent are SpaceWire packets, but there are no routers.

The data handling architecture of Figure 3 is similar to that of Figure 2, with the addition of a downlink telemetry unit and a control processor. The control processor is used to configure and control all of the on-board data-handling equipment. It therefore needs a connection to every instrument and to the mass memory. This could be provided using a separate command and control network, but this would result in additional mass and power consumption. The addition of a SpaceFibre router connected to all of the on-board equipment allows the control processor to send commands and receive information from all of the on-board data handling units. No additional network is required. A small amount of network bandwidth can be reserved for the control processor, so that it can operate without being affected by other traffic flowing over the network.

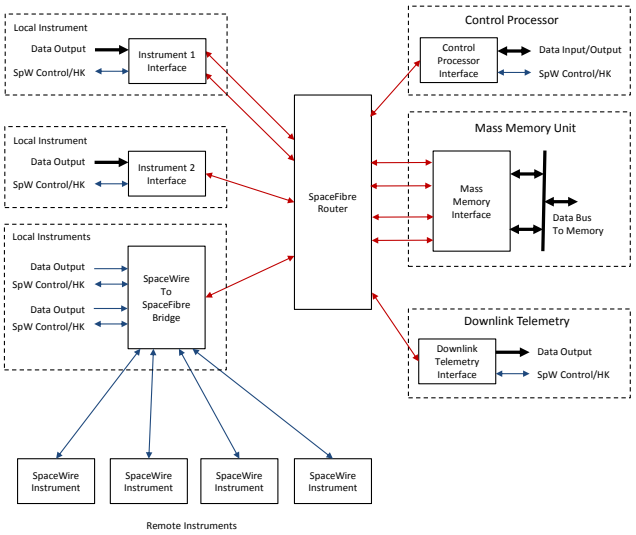

Figure 3 Spacecraft Data Handling with SpaceFibre Network

Specifications

Data rate:

- 3.125 Gbits/s line rate with current space qualified technology (2.5 Gbits/s effective user data rate)
- 6.25 Gbits/s line rate planned
- Multi-Lane can provide much higher data rates for SAR and multi-spectral imaging instruments (up to 40 Gbit/s when using 2.5 Gbit/s line rates)

QoS:

- Supports multiple Virtual Channels with independent flow control.
- Bandwidth reservation
- Priority
- Scheduling

FDIR:

- AC coupling
- Error detection with 8B/10B encoding and CRC
- Single-bit flip error always detected and never produces a loss of data
- Use of both ACKs and NACKs to hasten detection of error
- Error recovery of packet data, broadcast messages and flow control information in the event of a fault being detected
- Link error detection and recovery has minimum latency as it depends on cable propagation delay, not on the use of timeouts
- Data and Broadcast babbling idiot detection and containment
- Detection of unexpected inactivity in a virtual channel
- Multi-Lane graceful degradation, warm and hot redundancy

Physical media:

- Copper: using differential current mode logic CML (< 10 m)
- Fibre optic: up to 100 m

Further information on SpaceFibre

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