SpaceFibre: The Standard and the Multi-Lane Layer

Steve Parkes[(1)], Chris McClements[(1)], David McLaren[(1)],

Albert Ferrer Florit[(2)] and Alberto Gonzalez Villafranca[(2)]

[(1)]University of Dundee, Space Technology Centre, Dundee, DD1 4HN, Scotland, UK.

Email: *sparkes@computing.dundee.ac.uk; c.mcclements@computing.dundee.ac.uk*

[(2)]STAR-Dundee Ltd, STAR House, 166 Nethergate, Dundee, DD1 4EE, Scotland, UK.

Email: *albert.ferrer@star-dundee.com; albert.gonzalez@star-dundee.com*

ABSTRACT

SpaceFibre is a new standard for spacecraft on-board data-handling networks, initially designed to deliver multi-Gbit/s data rates for synthetic aperture radar and high-resolution, multi-spectral imaging instruments, The addition of quality of service (QoS) and fault detection, isolation and recovery (FDIR) capabilities to SpaceFibre has resulted in a unified network technology. SpaceFibre provides high bandwidth, low latency, fault isolation and recovery suitable for space applications, and novel QoS that combines priority, bandwidth reservation and scheduling and which provides babbling node protection. SpaceFibre is backwards compatible with the widely used SpaceWire standard at the network level allowing simple interconnection of existing SpaceWire equipment to a SpaceFibre link or network.

Developed by STAR-Dundee and the University of Dundee for the European Space Agency (ESA) SpaceFibre is able to operate over fibre-optic and electrical cable. A single lane of SpaceFibre comprises four signals (TX+/- and RX+/-) and supports data rates of 2 Gbits/s (2.5 Gbits/s data signalling rate) with data rates up to 5 Gbits/s already planned.

Several lanes can operate together to provide a multi-lane link. Multi-laning increases the data-rate to well over 20 Gbits/s.

This paper details the current state of SpaceFibre which is now in the process of formal standardisation by the European Cooperation for Space Standardization (ECSS). The multi-lane layer of SpaceFibre is then described.

1 INTRODUCTION

SpaceFibre [1] [2] [3] [4] is a multi-gigabit/s serial network technology being designed specifically for spaceflight applications. 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 capability.

SpaceFibre provides a quality of service mechanism able to support priority, bandwidth reservation and scheduling. It incorporates fault detection, isolation and recovery (FDIR) capability in the interface hardware. It is designed to be implemented efficiently, requiring only three times the number of logic gates of a SpaceWire [5] interface while providing many capabilities missing from SpaceWire.

2 SPACEFIBRE PROTOCOL STACK

The protocol stack for SpaceFibre is illustrated in Fig. 1.

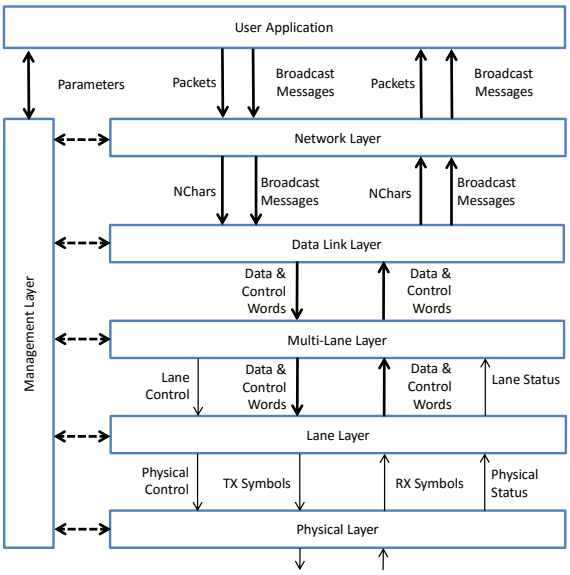

Fig. 1 SpaceFibre Protocol Stack

The Network layer protocol provides two services for transferring application information over a SpaceFibre network: the packet transfer service and the broadcast message service. The Packet Transfer Service transfers SpaceFibre packets over the SpaceFibre network, using the same packet format and routing concepts as SpaceWire. The broadcast message service broadcasts short messages carrying time and synchronisation information to all nodes on the network. The network layer is responsible for the specification of nodes, routing switches, routing mechanisms, message broadcast and the definition of packets.

The Data Link layer provides quality of service, flow control and error handing for a SpaceFibre link. It sends packet information in frames of up to 256 bytes. The Data Link layer is responsible for the overall operation of the link, the quality of service and link error recovery.

The Multi-Lane layer operates several SpaceFibre lanes in parallel to provide higher data throughput. In the event of a lane failing the Multi-Lane layer provides support for graceful degradation, automatically spreading the traffic over the remaining working links. It does this rapidly without any external intervention. The Multi-Lane layer is responsible for lane coordination and lane failure recovery.

The Lane layer initialises each lane and re-initialises the lane when an error is detected. Data is encoded into symbols for transmission using 8B/10B encoding and these symbols are decoded in the receiver. 8B/10B codes are DC balanced, supporting AC coupling of SpaceFibre interfaces. The Lane layer is responsible for the individual lanes providing lane initialisation and encoding of data and control words.

The Physical layer serialises the 8B/10B symbols and sends them over the physical medium. Both electrical cables and fibre-optic cables are supported by SpaceFibre. The physical layer is responsible for the serialisation and de-serialisation (SerDes), electrical driver and receiver, connectors and cables. Flight connectors and cables for both electrical and fibre-optic media are being developed.

The Management layer supports the configuration, control and monitoring of all the layers in the SpaceFibre protocol stack with a management information base.

3 ECSS SPACEFIBRE STANDARD

SpaceFibre is currently undergoing the formal standardisation process of the European Cooperation for Space Standardization (ECSS) [1]. At present the data link layer and lane layer specification are complete, the electrical physical layer specification is close to being finalised and the fibre-optic version is being worked on. The multi-lane layer will be completed in March 2016. The network layer uses the same addressing and routing concepts as SpaceWire, enabling simple bridging between the two standards.

The SpaceFibre standard was written by the University of Dundee and STAR-Dundee for ESA with contributions from many international spacecraft engineers including people from ESA, JAXA, NASA, Airbus DS, Thales Alenia Space, SubMicron, ELVEES, NEC Toshiba Space, Misubishi Heavy Industries, St Petersburg University of Aerospace Instrumentation, University of Pisa.

The SpaceFibre standard has been simulated, implemented and reviewed at all stages of its research, design and development. The physical, lane and QoS layers of SpaceFibre are fully defined and have been extensively tested with simulations by at least three independent organisations, and by implementation in FPGAs. The multi-lane layer has been designed and simulated, and is currently being tested in FPGAs implementations.

4 SPACEFIBRE MULTI-LANE

The full paper will describe the multi-lane layer of SpaceFibre in detail.

5 CONCLUSIONS

SpaceFibre is now in the process of being adopted as a formal ECSS standard. Providing multi-gigabit/s communications it incorporates a comprehensive quality of service capability providing integrated

bandwidth reservation, priority and scheduling. Efficient, effective and rapid fault detection, isolation and recovery mechanisms are included in the SpaceFibre interface, enabling rapid detection and recovery from link level errors.

SpaceFibre multi-laning allows the very high data rates to be achieved which are necessary for future SAR and multi-spectral imaging instruments.

6 ACKNOWLEDGMENTS

The research leading to these results has received funding from the European Space Agency under ESA contract numbers 4000102641 and 17938/03/NL/LvH, from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement numbers 263148 and 284389 and from the UK Space Agency via the Centre for Earth Observation Instrumentation and Space Technology (CEOI-ST). We would also like to thank Martin Suess the ESA project manager for the SpaceFibre related activities for his help, advice and guidance.

7 REFERENCES

[1] S. Parkes, A. Ferrer and A. Gonzalez, "SpaceFibre Standard", Draft H1 September 2015, available from http://space-env.esa.int/indico/confLogin.py?confId=32

[2] S. Parkes, C. McClements and M. Suess, "SpaceFibre", International SpaceWire Conference, St Petersburg, Russia, 2010, ISBN 978-0-9557196-2-2, pp 41-45.

[3] S. Parkes et al, "SpaceFibre: Multi-Gigabit/s Interconnect for Spacecraft On-board Data Handling", IEEE Aerospace Conference, Big Sky, Montana, 2015.

[4] S. Parkes et al, "SpaceWire and SpaceFibre on the Microsemi RTG4 FPGA", IEEE Aerospace Conference, Big Sky, Montana, 2016.

[5] ECSS Standard ECSS-E-ST-50-12C, "SpaceWire, Links, Nodes, Routers and Networks", Issue 1, European Cooperation for Space Data Standardization, July 2008.