D4.2 Revised SpaceWire-RT Outline Specification

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1 Introduction

This document records changes made to the SpaceFibre standard following the design of the VHDL IP core and the ASIC feasibility analysis.

1.1 SpaceWire-RT Objectives Addressed

This report addresses the following objectives of the SpaceWire-RT project:

- A draft standard document for SpaceWire-RT, which has been reviewed by the International SpaceWire Working Group.

In particular this report provides an update to the SpaceFibre standard, which includes the novel features provided as a result of the SpaceWire-RT research and which takes into account feedback from the VHDL IP core design and testing.

1.2 Guide to the Report

Section 2 describes the layers that have been added to the SpaceFibre standard as a result of the SpaceWire-RT project.

Section 3 presents an update to the SpaceFibre protocol stack rationalising some of the layers and clarifying the service interfaces.

Section 4 is an update to the SpaceWire-RT outline specification. The resulting SpaceFibre standard specification is provided in a separate document D6.1.

Section 5 present the conclusions of this report and outlines the next stages of the SpaceWire-RT project.

1.3 References

[1] Parkes SM, Ferrer Florit A, Gonzalez A, and McClements C, “SpaceFibre Standard Specification”, Draft F4, SpaceWire-RT Project deliverable D6.1, Space Technology Centre, University of Dundee, 30th April 2013.

2 Layers Added to the SpaceFibre Standard

The SpaceWire-RT project builds on the emerging SpaceFibre standard which is being designed by the University of Dundee with inputs from international spacecraft engineers. The aim is to publish the final standard though the European Cooperation for Space Standardization (ECSS). The SpaceWire-RT project has contributed to the following parts of the SpaceFibre standard:

- QoS Mechanisms in the Virtual Channel layer,
- FDIR Mechanisms in the Retry layer,
- Network level concepts in the Network layer.

A description of the research in these three areas is available in sections 6, 7, and 12 respectively of the “D2.1 SpaceWire-RT Outline Specification” SpaceWire-RT report.

The QoS and FDIR work has been fully integrated in section 5.5 of the SpaceFibre standard draft F. A network layer specification has now been added in section 5.4. The overall protocol stack has been rationalised and the SpaceFibre standard restructured accordingly.

3 Updated SpaceFibre Protocol Stack

The revised SpaceFibre protocol stack is illustrated in

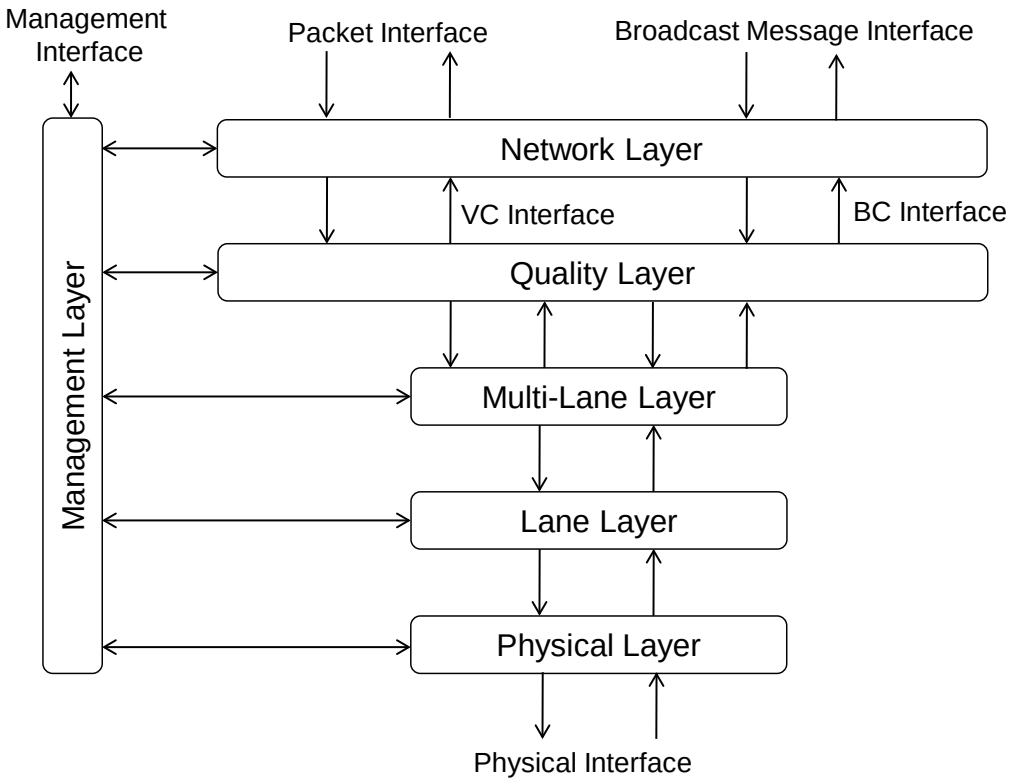

Figure 3-1 Overview of SpaceFibre CODEC

There are six conceptual layers to the SpaceFibre CODEC:

The **Network layer** is responsible for the transfer of application information over a SpaceFibre network. It provides two services: Packet Transfer Service and Broadcast Message Service. The Packet Transfer Service transfers SpaceFibre packets over the SpaceFibre network, using the same packet format and routing concepts as SpaceWire uses. SpaceFibre supports both path and logical addressing. The broadcast message service is responsible for broadcasting short messages (8 bytes) to all nodes on the network. These messages can carry time and synchronisation signals and be used to signal the occurrence of various events on the network.

The **Management layer** is responsible for configuring, controlling and monitoring the status of all the layers in the SpaceFibre protocol stack. For example it can configure the QoS settings of the virtual channels in the QoS and FDIR layer.

The **Quality layer** is responsible for providing quality of service and managing the flow of information over a SpaceFibre link. It frames the information to be sent over the link to support QoS and scrambles the packet data to reduce electromagnetic emissions. The Quality layer also provides a retry capability, detecting any frames or control codes that go missing or arrive containing errors and resending them. With this inbuilt retry mechanism SpaceFibre is very resilient to transient errors.

The **Multi-Lane layer** is responsible for operating several SpaceFibre lanes in parallel to provide higher data throughput. In the event of a lane failing the Multi-Lane layer provide support for graceful degradation, automatically spreading the traffic over the remaining working links.

The **Lane layer** is responsible for lane initialisation and error detection. In the event of an error the lane is automatically re-initialised. The Lane layer encodes data into symbols for transmission using 8B/10B encoding and decodes these symbols in the receiver. 8B/10B codes are DC balanced supporting AC coupling of SpaceFibre interfaces.

The **Physical layer** is responsible for serialising the 8B/10B symbols and for sending them over the physical medium. In the receiver the Physical layer recovers the clock and data from the serial bit stream, determines the symbol boundaries and recovers the 8B/10B symbols. Both electrical cables and fibre-optic cables are supported by SpaceFibre. The electrical signalling can use Low Voltage Differential Signalling (LVDS) for data rates below 1 Gbits/s or Current Mode Logic (CML) for data rates over 1 Gbits/s.

The key characteristics of the different SpaceWire-RT protocols, which are differentiated by their physical layer, are detailed in Table 3-1.

Table 3-1 SpaceWire-RT Protocol Characteristics			
Characteristic	**SpFi-FO**	**SpFi-CML**	**SpFi- LVDS**
Media	Fibre Optic	Copper CML	Copper LVDS
Encoding	8B/10B	8B/10B	8B/10B
Speed Range	0.1 to 20 Gbits/s 50 Gbits/s in future	0.1 to 20 Gbits/s 50 Gbits/s in future	1 to 600 Mbits/s 1 to 100 Mbits/s OS
Distance	100 m	5 m	10 m
Galvanic Isolation	Yes	Yes	Yes
Packet Size	Arbitrary	Arbitrary	Arbitrary
SpaceWire Packet Level	Yes	Yes	Yes
Latency (TBC)	<0.5 µs	<0.5 µs	1 µs
Cable Mass	< 30g/m	< 30g/m	< 30g/m
Power (TBC)	< 200 mW	< 200 mW	< 200 mW
QoS BW Reserved	Yes	Yes	Yes
QoS Priority	Yes	Yes	Yes
QoS Scheduled	Yes	Yes	Yes
QoS Best Effort	Yes	Yes	Yes
Broadcast Message	Yes	Yes	Yes
Determinism	Yes	Yes	Yes
Reliability	Yes	Yes	Yes
Fault Detection	Yes	Yes	Yes
Fault Isolation	Yes	Yes	Yes
Retry	Yes	Yes	Yes
SpaceWire compatible	No	No	No

4 Outline Specification

This section provides an update to the outline specification of the proposed SpaceWire-RT protocols.

4.1 Applicable Documents

AD1 Parkes SM, Ferrer Florit A, Gonzalez A, and McClements C, “SpaceFibre”, Draft F 0.4, Space Technology Centre, University of Dundee, 30th April 2013.

4.2 SpaceWire-RT Protocol Stack

a) The SpaceWire-RT protocol stack shall be as illustrated in Figure 3-1.

4.3 SpaceWire-RT Application Interfaces

a) There shall be three application interfaces to the SpaceWire-RT protocol stack:

   i. SpaceWire Packet Interface
   ii. Broadcast Message Interface
   iii. Management Interface

b) The SpaceWire Packet Interface shall be responsible for sending and receiving SpaceWire packets over a specific virtual channel.
c) The Broadcast Message Interface shall be responsible for sending and receiving broadcast messages over the SpaceWire-RT network.
d) The Management Interface shall be responsible for passing configuration, control and status information between the local system and the SpaceFibre device.

4.4 SpaceWire-RT Packets

a) The SpaceFibre Network Layer shall follow the SpaceFibre network layer specification defined in the SpaceFibre standard [AD1].

4.5 SpaceWire-RT QoS

a) The Quality layer shall be responsible for providing quality of service for SpaceWire-RT.
b) The Quality Layer shall follow the Quality Layer specification provided in the SpaceFibre standard [AD1].

4.6 SpaceWire-RT Multi-Laning

a) The Multi-Laning layer shall follow the Laning Layer specification provided in the SpaceFibre standard [AD1].

4.7 SpaceWire-RT SpaceFibre Lane

a) The Lane Layer shall follow the Laning Layer specification provided in the SpaceFibre standard [AD1].
b) The Physical Layer shall follow the Physical Layer specification provided in the SpaceFibre standard [AD1], including both Fibre Optic and Copper media options.

4.8 SpaceWire-RT SpaceFibre with LVDS

a) The Serialisation Layer shall permit the use of oversampling to perform bit synchronisation in the receiver.

   Note: this will significantly reduce the bit rate but will enable implementation without a phase locked loop or similar clock recovery technology.

   Note: the SpaceFibre specification permits the use of any form of clock-data recovery circuit, including oversampling.

b) The Physical Layer shall provide an additional option to use LVDS instead of CML running over copper cable.
c) The Physical Layer shall provide an additional option to use Fibre Channel physical layer instead of CML running over copper cable.

Note: this type of interface has not yet been included in the SpaceFibre specification.

4.9 SpaceWire-RT Broadcast Messages

a) The Broadcast Message mechanism shall follow the Broadcast Message specification provided in the Network and Quality layers of the SpaceFibre standard [AD1].

4.10 Sending SpaceWire Time-Codes as Broadcast Messages

a) SpaceWire time-codes shall be transmitter over a SpaceWire-RT network encapsulated in a broadcast message.

Note: the way in which time-codes are encapsulated in broadcast messages has yet to be defined. One example is to place the time-code time and flags fields into the reserved field of time type of broadcast message. Another possibility is to use a distinct type of broadcast message to carry time-codes.

4.11 Oversampling Serialisation

a) SpaceWire-RT shall permit recovery of the received data stream using oversampling as well as phase-locked loop clock recovery techniques.
b) The two ends of the link shall operate at the same bit rate with a maximum permitted difference in bit clocks between the two ends of the link of 100 ppm.

Note: The 100 ppm specification comes from the size of the SpaceFibre receive elastic buffers which in turn come from the 100 ppm accuracy of a crystal oscillator.

c) The receiver bit synchronisation circuitry shall track any change in the receive bit interval and sample the received data bit within +/- 25% of the centre of the bit interval.
d) The received data shall be sampled and de-serialised and passed to the encoding layer for decoding.

4.12 SpaceFibre LVDS

a) SpaceWire-RT shall permit the use of an LVDS physical layer with SpaceFibre.

Note: LVDS is not capable of the Gbits/s signalling speed of CML.

4.13 SpaceFibre Fibre Channel Physical

a) SpaceWire-RT shall permit the use of a Fibre Channel type of physical layer.

Note: This is to provide relatively long distance communication (30 m) at data rates of up to 1 Gbits/s.

5 Conclusion

A coherent set of communication protocols have been defined that covers most of the applications for serial data link and network technology on board spacecraft, including payload data-handling and avionic applications. Research on QoS mechanisms suitable for use with SpaceFibre has been carried out in WP2, resulting in the design of a simple, powerful, and comprehensive quality of service mechanism. This QoS mechanism has then been extended to include specific classes of fault detection in support of FDIR. The QoS mechanisms developed in the SpaceWire-RT project have been adopted into the SpaceFibre standard specification and presented to the SpaceWire working group. In WP3 the SpaceFibre protocols including the QoS and FDIR mechanisms were simulated and the results of the simulations used to help remove errors and inconsistencies and to make necessary clarifications to the SpaceFibre standard, which is appended as annex 1 of this document. In WP4 the VHDL IP Core Development has resulted in the successful implementation and testing of the QoS and FDIR capabilities of SpaceFibre. In addition an oversampling implementation using LVDS has been implemented and simulated showing the feasibility of this approach. WP5 used the SpaceFibre IP Core to explore the feasibility of implementing the SpaceFibre interface in an ASIC.

The next stages of the SpaceWire-RT project which are currently running are:

- WP6, in particular feedback on the draft SpaceFibre standard specification and its translation into Russian.

6 Annex 1 SpaceFibre Standard

The final version of the SpaceFibre standard document (draft F) produced as a result of the SpaceWire-RT project is provided in a separate document as deliverable D6.1.