SpaceWire Network Management Service Suite Definition And Validation

(ESTEC Contract 4000129566/19/NL/AS)

Executive Summary Report

Prepared for:
European Space Agency

Prepared by:
TELETEL S.A. (ESA Bidder Code: 63051)

teletel

REVISION HISTORY			
Version	***Date***	***Contributors***	***Comment***
Version 1.0	31/01/2023	Vangelis Kollias	Version for FR

TABLE OF CONTENTS

1 INTRODUCTION 4
1.1 PURPOSE AND SCOPE OF THE DOCUMENT 4
1.2 APPLICABLE DOCUMENTS 4
1.3 REFERENCE DOCUMENTS 4
2 BACKGROUND 5
3 INITIAL REQUIREMENTS FOR A DETERMINISTIC SPACEWIRE / SPACEFIBRE PROTOCOL 5
4 PROPOSED PROTOCOL ARCHITECTURE 6
5 PROTOTYPE IMPLEMENTATION 8
6 DEMONSTRATION REPORT 9

1 Introduction

1.1 Purpose and scope of the document

The scope of this document is to provide the Executive Summary Report of the “SpaceWire Network Management Service Suite Definition and Validation” study.

1.2 Applicable documents

The following documents are applicable to the document.

[AD1] Contract between ESA and TELETEL for Deterministic SpaceWire study

[AD2] SAVOIR On-board Communication System Requirement Document. SAVOIR-GS-008

[AD3] [SPACEWIRE NETWORK MANAGEMENT SERVICE SUITE DEFINITION AND VALIDATION - EXPRO+ (SOW) T701-501ED

1.3 Reference documents

The following documents provide background reference.

[RD1] TDP - Technical Data Package (“SpaceWire Network Management Service Suite Definition and Validation” ESA Study)

2 Background

The new concept elaborated by ESA for spacecraft avionics systems is bundled under the common Space Avionics Open Interface Architecture (SAVOIR). SAVOIR working group has issued a requirements document addressing the on-board communication system [AD2] where the term ‘Deterministic / Determinism’ is clearly defined. The objective of the activity is to introduce a novel deterministic protocol layer to the SpaceWire and SpaceFibre on-board networks according to the SAVOIR guidelines. However this results not only in functions ensuring the transmission within a certain time-window (SAVOIR definition), but also in the need for FDIR, network management, quality of service, etc., which are derived from system requirements (e.g. closed-loop control for AOCS). The applied control algorithms need to take into account the uncertain latencies that are a result of a non-deterministic network. For example, the time a sensor value was taken, until its computation inside the loop and the latencies to transmit the control command to the actuators. When drawing the chain of contributors, it is obvious, that the communication system is an essential element.

The MIL-STD-1553 protocol was and it is still used to provide determinism but for low data rate networks. Network topology has also evolved from the single master, as for MIL-1553 to multi master and switched networks. TTEthernet, SpaceWire and SpaceFibre are systems used in modern on-board architectures providing a much higher net data-rate. TTE is baselined for Ariane 6 and in use for the European Service Module for ORION. European contributions to the Lunar Gateway have baselined TTE such as IHAB in the respective systems as well. While combining high-speed communication, up to 1Gbit/s, with determinism, TTE appears to be very suitable. However, the effort for planning and configuring the network as well as for the verification process turned out to be high.

SpaceWire (and in the future SpaceFibre with much higher performance) is widely used in on-board architectures. SpaceFibre, in comparison with SpaceWire, is bringing already the possibility of a significantly higher data-throughput combined with means regarding the quality of service. However, determinism, as defined by [AD2], is not implemented yet in native SpaceWire. In order to extend the capabilities of SpW, some ideas have already been pursued resulting in the definition of N-MaSS for adding FDIR, a certain determinism with SpW-D or SpW-R targeting reliability. These concepts are adding an additional protocol layer (SpW-R, Spw-D) or additional monitoring functions (N-MaSS) to enable the functions.

3 Initial requirements for a deterministic Spacewire / SpaceFibre protocol

According to ESA [AD3], the main means of realizing determinism shall be to add an additional network layer as shown in the figure below.

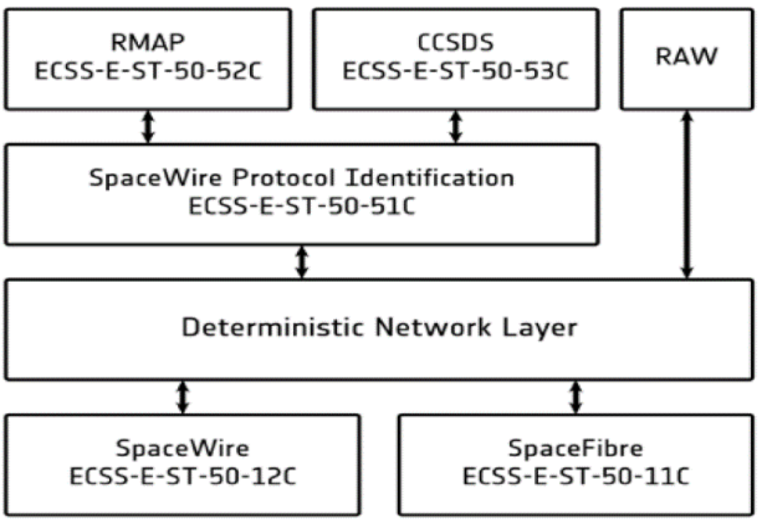

Figure 1: New protocol layer in the existing SpW/SpFi protocol stack

Any feasible design shall be capable of handling new deterministic and other legacy nodes, requiring thus an awareness of the protocol in the switches and the end nodes. The new protocol layer shall be developed in a way that it is mainly managed by the routing switches to keep compatibility with legacy nodes. New deterministic nodes may manage the new protocol layer directly while the new deterministic switches shall act as translator for legacy nodes. Traffic from and to legacy nodes shall be extended or stripped by the switch from the new deterministic layer. That way the switches act as translator between new and legacy protocols if necessary.

Deterministic and time accurate messaging requires all devices in the network to work with the same time basis. Since the native time synchronization mechanism on raw SpaceWire is not robust against failures such as delayed or erroneous time codes, a new concept shall be developed. The new time-code mechanism shall allow more robust and accurate time-code distribution in SpaceWire and SpaceFibre networks.

For deterministic network communication reliability is important. Therefore, the new deterministic layer shall also implement a concept for Fault Detection, Isolation and Recovery (FDIR). This shall include controllability of the new network layer from the user application as well as through the network. Optionally with a basic watchdog mechanism to control the status of the user applications through the network.

4 Proposed protocol architecture

The overall layers used in the different SpaceWire networks can be summarized as presented in the following diagram where the SpW IP block gathers all the SpaceWire standards. At the left the switch IP and on the centre and at the right the SpW IP of an End Node. Regarding the switch, the proposed SpW NMS (in light green) can replace the native Wormhole Routing and is a new behaviour proposed within this study.

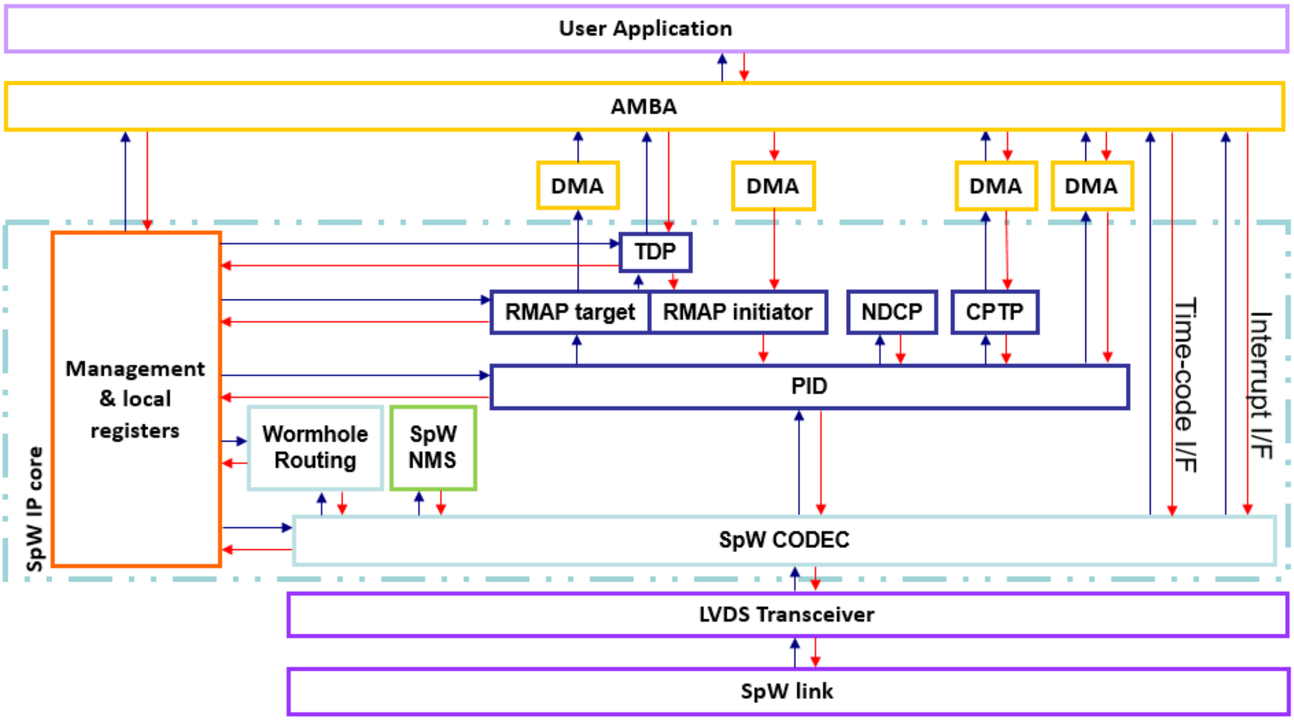

Figure 2: SpaceWire layers with new proposed deterministic layer

The above layers represent the interaction with a SW through the AMBA bus to connect processing subsystem to programmable logic. The bottom layers refers to physical layers of the SpaceWire standard. Then, all the layers inside the dash light blue square belong to SpW. The dark blue blocks are optional standards that can be used alone or together.

Therefore, instead of having a wormhole routing in a topology with SpaceWire, this solution introduces a store and forward routing switch with ingress policing, packet filtering and traffic shaping to support fault tolerance and determinism in the network. The implementation of the new SpW deterministic routing switch is more complex than a simple wormhole switch. In fact, the features and configurations are numerous and has to be well handled. This can be summarized in the following figure where two End Nodes exchange CPTP SpW packets.

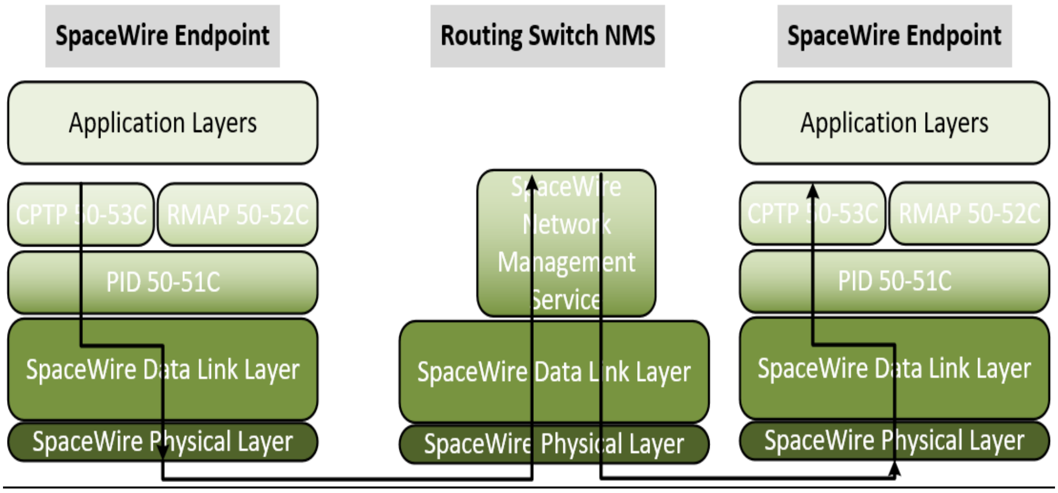

Figure 3: SpaceWire stack in a communication through a routing switch

The SpW CODEC is not modified in order to enable backward compatibility with all the existing units using SpaceWire. In addition, new features are required to enable the following capabilities:

- Stream Identification and priority assignment
- Packet Size protection
- Store and forward
- Priority queues at output ports
- Traffic shapers

A high level diagram of a switch implementation forwarding packets from input ports to output ports is presented in the following figure.

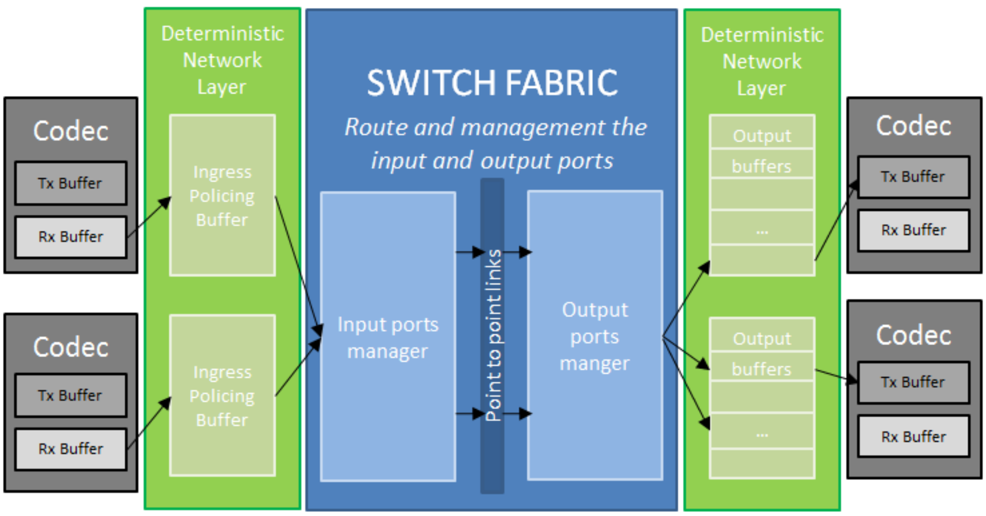

Figure 4: Simple Schematic of a Routing Switch Implementation

5 Prototype Implementation

In the scope of the SpW NMS project TELETEL developed/implemented the proposed deterministic SpW Switch.

The block diagram of the deterministic switch is presented in the following figure. The Switch comprises of 8 SpW ports (at maximum) all connected to the Router's switch fabric. The SpW NMS Router is a store and forward router responsible for routing SpW packets to the appropriate output port. The routing is performed according to the SpW standard (via Physical/Logical address processing), accompanied by a priority stream policy, which indicates the priority level of each packet. In addition, the Ingress and Egress blocks at the input and output of the ports (respectively), implement the logic that enables deterministic behaviour.

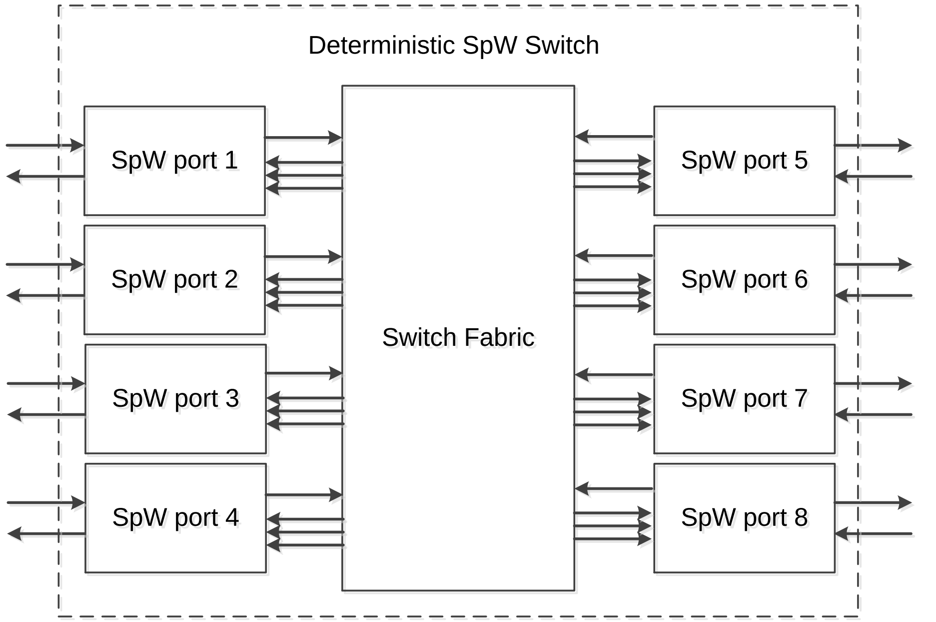

Figure 5: Deterministic SpW Switch block diagram

The next figure presents the architecture of the **SpW port block**. This block implements a SpW CODEC that handles the interface with the SpW link (along with all related logic i.e. the necessary transmission/reception logic), as well as the Ingress and Egress blocks which are responsible for the deterministic behavior of the Switch.

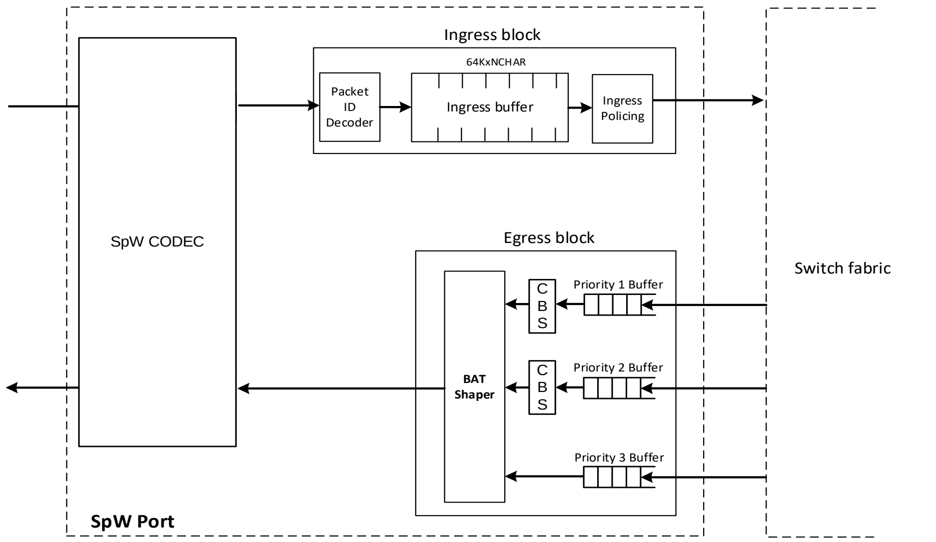

Figure 6: SpW port block diagram

6 Demonstration Report

Two set-ups were used in the tests. A Single Router network and a two Routers in series network.

<u>Set-up A</u>: Single Router

In this set-up, each of the eight SpW Nodes is connected to one Router port (Node 1 to Port 1, Node 2 to Port 2 etc.). This configuration is shown in Figure 7.

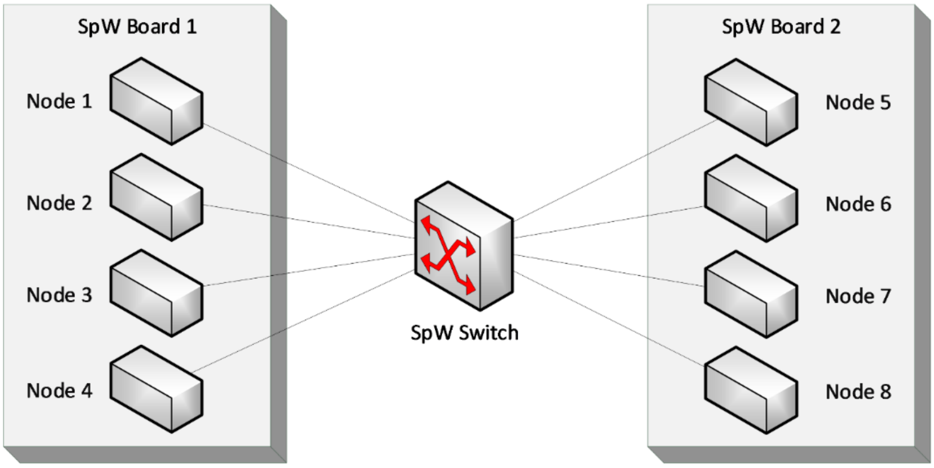

Figure 7: Single Router configuration

<u>Set-up B</u>: Two Routers in series

In this set-up, the first four SpW Nodes are connected to first four Ports of the first Router (Node 1 to Port 1A, Node 2 to Port 2A etc.). The remaining four Ports of the first Router are connected to the first four Ports of the second Router (Port 5A to Port 1B, Port 6A to Port 2B etc.). Finally, the remaining four Ports of the second Router are connected to the last four SpW Nodes (Port 5B to Node 5, Port 6B to Node 6 etc.).

Both Routers are configured with the same values, except for their Routing Tables. When this set-up is used, packets with only logical addresses are used. This is done in order to test the real worst possible operating scenarios for the network (for example, its latency). This configuration is shown in Figure 8.

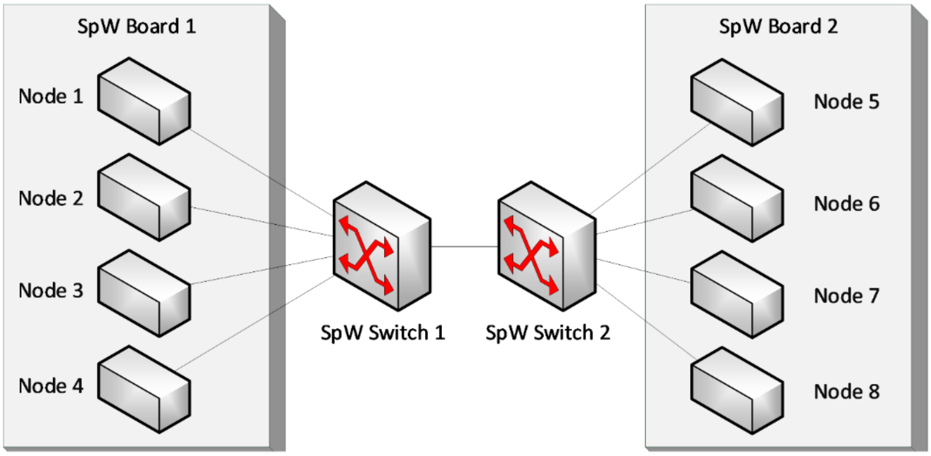

Figure 8: Two Routers in series configuration

A set of tests were executed in order to verify the functionality and measure the characteristics (latency and jitter) of high priority traffic of the SpW NMS Router. The measurements and the behaviour of the SpW NMS Router was according to specification and the verdict for all tests was PASS.