THE SYSTEM APPROACH FOR A SPACEWIRE NETWORK

<u>Session</u> : SpaceWire Network and Protocol session

Bruno Masson[1] bruno.masson@thalesaleniaspace.com
Stéphan Dethève[1] stephane.detheve@external.thalesaleniaspace.com
Bernard Alison[1] bernard.alison@thalesaleniaspace.com

[1] *Thales Alenia Space 100 bd du Midi BP 99 06156 Cannes la Bocca Cedex France*

Introduction

The need of high speed board-to-board communication links has led to define a new standard, extending the previous 1355 point-to-point, to SPACEWIRE network standard concept. However each space mission will need a specific network architecture in terms of its objectives. So, it is important to establish an approach of SpaceWire networks at system conception level in order to optimize their performance, their robustness and their weakness. For this reason, a top-down approach is promoted to be sure that top level needs are well implemented. It is why SpaceWire technology is now fully considered in the overall THALES ALENIA SPACE (TAS) avionics roadmap.
This paper introduces the different ways which are implemented to master and to optimize SpaceWire standard features for future space missions:

- A full numerical simulator
- A scalable and adaptable HW/SW mock-up

MOST, a representative simulation tool

MOST (Modeling Of Spacewire Traffic) is built upon the OPNET tool dedicated to network modeling. A specific SpaceWire library is provided and developed by TAS, containing validated models of SpaceWire elements (routers and nodes). The models are fully representative of the standard and of the characteristics of available hardware components (i.e. ESA router).

The nodes models let users implement application specific behaviors as packets consumers and/or providers. These models can be enhanced anytime, when the design of the nodes becomes more precise.
The tool lets user configure network models with the different options proposed by the standard: logical or physical addressing, Group Adaptive Routing (GAR), …
In addition, MOST implements the main features of RMAP protocol layer (selectable options) and lets user provoke anomalies chosen in a pre-defined set of reasonable cases, at chosen dates within simulation sequences.

MOST is based on a realistic representation of the traffic at character level.
This option has been chosen due to the dependence between traffics on both directions of a SpaceWire bidirectional link (see SpaceWire protocol description and FCT characters (Flow Control Token) in SpaceWire communication standard, titled ECSS-E50 12A).

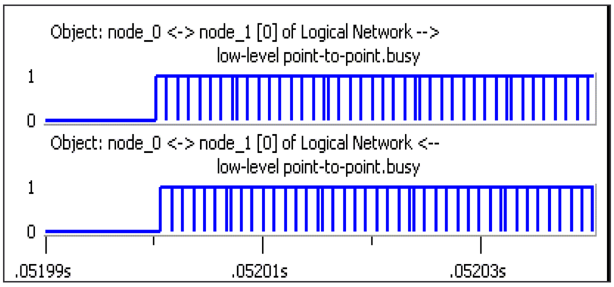

Figure 1 : MOST provides an accurate character level modeling

When the network topology is available, the designer develops the network model under the OPNET environment, by picking the components in the SPACEWIRE library. The graphical editor makes easy connections between representations of routers and nodes.

Once created, each node and router can be parameterized, using the pre-defined set of properties accessed via graphical editor commands (i.e. data rates, routing table, buffer size…).

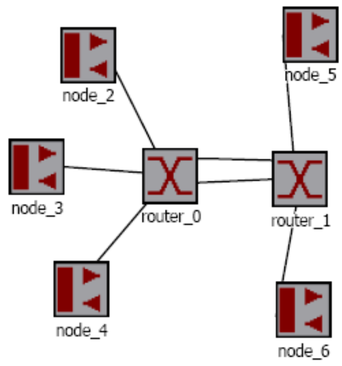

Figure 2 : OPNET Graphical User Interface lets user build quickly any network topology

When the scenarios have been specified (nodes behavior defined, network parameterized and output parameters selected), the network model can be executed for a programmed simulation duration as provided by the OPNET tool. This run results in a recorded history of outputs.

MOST is fully representative of the previous properties and of the components implementing the standard. Prototyping with MOST gives quick return on design weakness or risks of any simple or complex network. For instance, the influence of key parameters (i.e. packet size and frequency) can be accurately measured.

The advantages of this tool are the ability to restitute the traffic of the whole network, when the analyzer logs traffic on one point-to-point link and the customization of different network elements in terms of needs for a specific space mission.

This way, results of simulations can be correlated with results obtained on avionics test bench, containing SpaceWire traffic analyzer in order to qualify MOST simulator. As it was not yet an industrial tool because it needs to be formally validated, how do we validate this tool ?

Breadboarding mock-up of a SpaceWire network

MOST is a simulator based on behaviour of real hardware components. So it is necessary to make a cross-checking between a network simulated by MOST and a breadbording mock-up using real hardware components which will be for us a reference point.

This comparison study has been developed in two steps.

- The first one is the system specification for SpaceWire network architectures and high level protocols (including a dedicated FDIR definition).

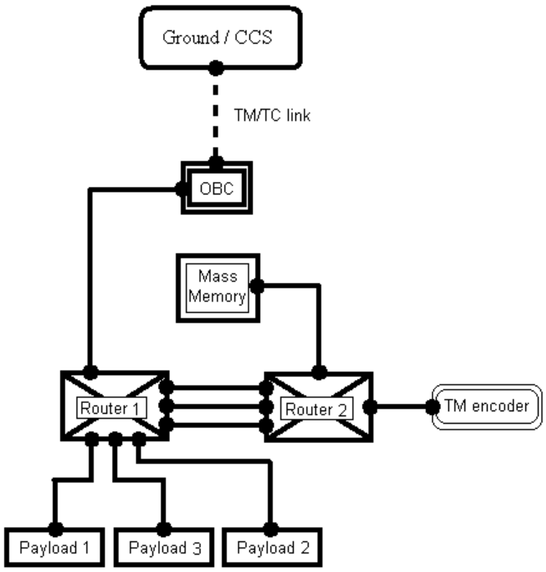

Figure 3 : Representation of network topology

Here, the experiment specification is defined by :

- a specific topology,
- scenarios and network characteristics,
- SpaceWire features,
- ways to monitor the network state,
- ways to detect failures and blocking,
- improvements of SpaceWire utilization.

And, the experiment network is consisted of :

- a Center Check-out System (simulating ground station),
- an On-Board Computer,
- a Mass Memory,
- a Telemetry Encoder,
- three Payloads,
- two Routers.

- The second one is the development of avionics mock-up which includes TM/TC functions, processor module, mass memory module, SpaceWire routers and payload modules providing science data.

Applicative software in middleware layers has been developed in order that it is in charge of the SpaceWire handling. Global validation has been performed in order to verify the concept.

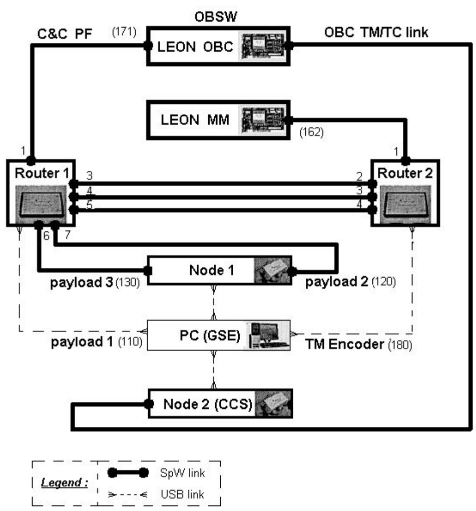

Figure 4 : Representation of mock-up topology

For the breadboarding, the hardware is :

- LEON boards,
- bricks & routers.

The TAS avionics software mock-up is a software emulating a platform which is reused and adapted to SpaceWire standard.

Applications of middleware layers have been developed to simulate :

- On-Board Computer & Mass Memory by LEON boards,
- Payload, Telemetry Encoder & ground station behind bricks or routers by a host PC (Ground Support Equipment)

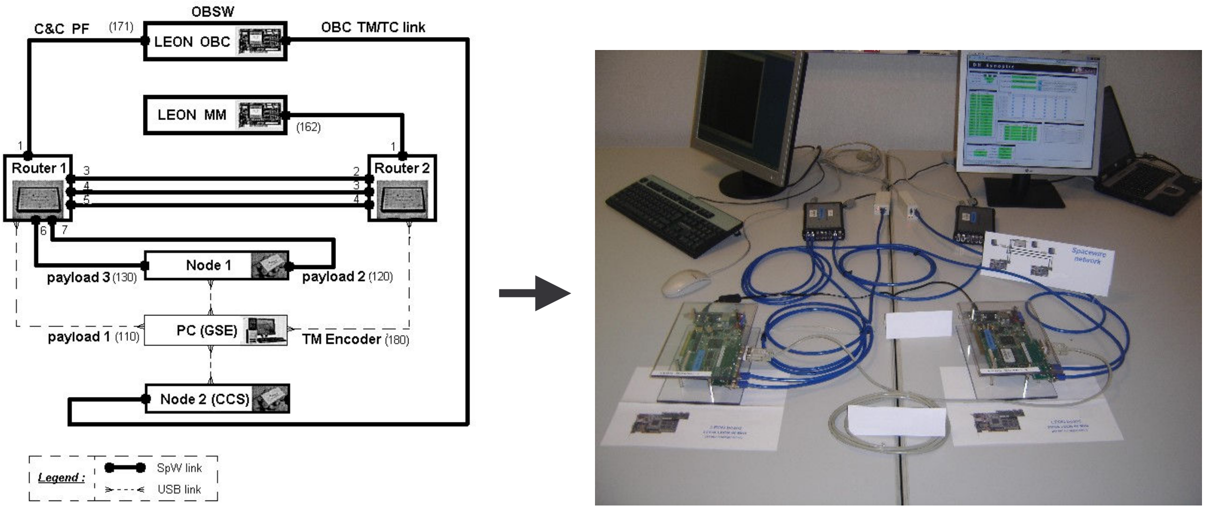

Figure 5 : SpaceWire mock-up overview

Once node behaviours have been simulated (MOST level) and breadboarded (mock-up level), an identical scenario is played for both networks, then their results are compared.

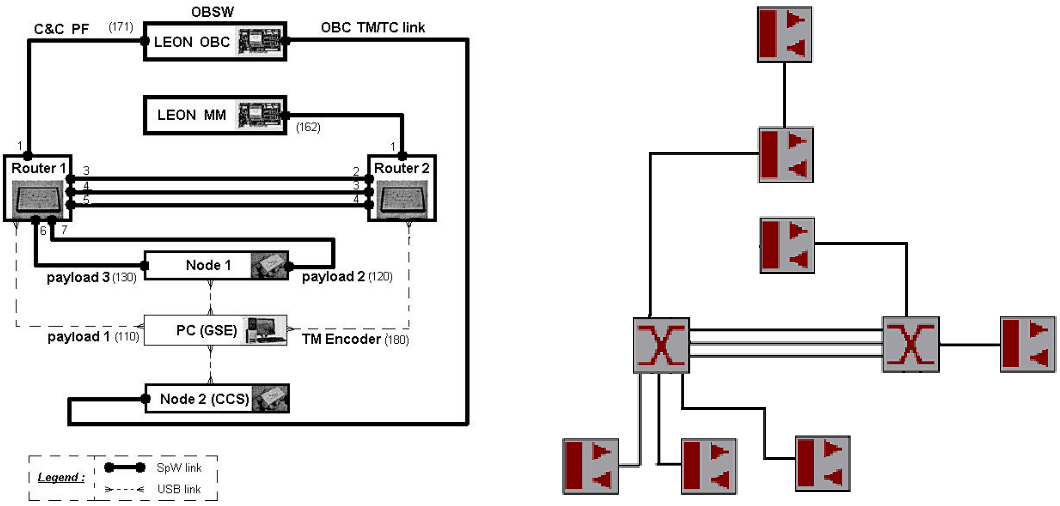

Figure 6 : Representation of the breadboard network on MOST

MOST validation is mainly based on SpaceWire standard features (for instance, packet size, packet generation, FCT generation, …) and the visualization of eventual bottlenecks and failures.

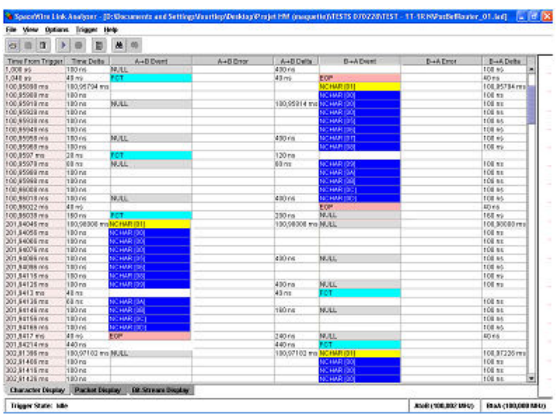

Figure 7 : Breadboarding network traffic on SpaceWire link analyzer

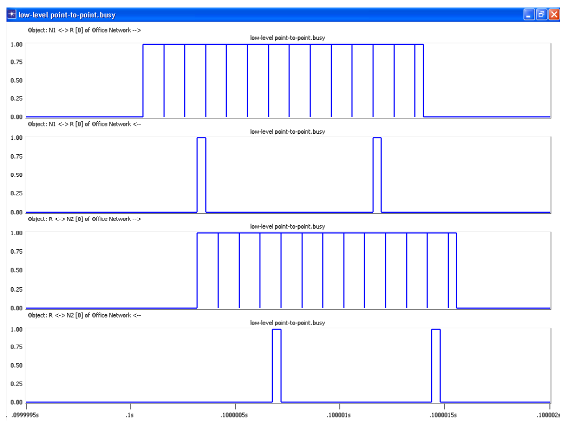

Figure 8 : Breadboarding network traffic simulated on MOST

MOST helps to identify slowing down factors observing the network behaviour in terms of data flows and allows to identify bottlenecks.

Avionics mock-up particularities

The internal avionics mock-up is based on an existing avionics software mock-up completed with SpaceWire nodes in such a way that it can be adapted to any SpaceWire network architecture.

Two high level protocols used for the mock-up have been tested :

- Remote Memory Access Protocol (RMAP),
- Packet Utilization Standard (PUS) protocol (including CCSDS protocol).

On the one hand, RMAP protocol is reserved to the routers during initial configuration and for their updates, if needed.
On the other hand, PUS protocol has been used to the traffic management and monitoring. Thanks to PUS protocol, our high level protocol includes a dedicated FDIR definition in order to make a failure monitoring from On-Board Computer. That permits to improve the control of the network health state without use of analyzers on each link, because it is unwieldy and expensive to have an analyzer for each link. The aim of this monitoring is to identify the lost packets, lost time-codes, EEP, bottlenecks … then to find, and even to track, the problem origin. It is why it is important to establish a strategic protocol to visualize the network behaviour with information exchanges which are correctly defined upstream.

This way, the avionics mock-up includes the PUS protocol based on following services : telecommand verification (1), HouseKeeping and diagnostic data reporting (3), event reporting (5), memory management (6), time management (9), on-board operations scheduling (11), on-board monitoring (12), large data transfer (13), packet forwarding control (14), test (17), on-board operation procedure (18), event action (19) and equally TAS PUS services dedicated to SpaceWire.

In the avionics software architecture, a virtual router has been implemented at middleware layer level to manage a redunded SpaceWire port at node level. This way, a specific routing table will be configured and updated, if needed. It permits to route packets to the redundant SpaceWire port if the nominal portfails.

At user application level, the avionics software mock-up has been developed to be in accordance with Spacecraft On-board Interface Services (SOIS) which are based on CCSDS_850.0-G-1 informational report. In fact, mandatory (and some optional) features of SOIS services have been implemented :

- at application support layer: network management, command/data acquisition, time access and message transfer services,
- at sub-network layer of the avionics software: packet, memory access and time distribution services,
- including the SpaceWire mapping in data link layer convergence functions (redundancy, prioritization and protocol multiplexing functions).

That provides a set of services to SpaceWire users compliant with CCSDS SOIS standard and completes the avionics software architecture.

Benefits

MOST brings support all along the project life, consolidating the design from early steps of the definition by an incremental approach. Once qualified, this tool will permit to support design/development of SpaceWire network in phase A/B, to verify FDIR concepts (at network level), to extend its use towards verification/validation in phases C/D, and if needed towards maintenance in phase E (including anomaly cases).

So network can be specified and breadboarded reusing the existing mock-up. That means it is possible to evaluate specification of :

- any SpaceWire network,
- any monitoring strategy to detect any bottleneck or permanent failure of a piece of the network,
- and any SpaceWire high level protocol (RMAP, CCSDS, PUS, …), synchronized or not.

Together they bring a continuous support for future developments during specification, design, development, assembly and validation phases of future projects.

Up to now, the network is synchronized via time-codes which provide features to build a high level protocol dedicated for the synchronization of SpaceWire networks. In a next future, MOST simulator and mock-up could test the feasibility of a synchronous and adaptive SpaceWire high level protocol.

Conclusion

The spacecraft avionics mock-up constitutes the best way to :

- build easily a representative SpaceWire mock-up for any space system application,
- specify any SpaceWire network including monitoring strategies (e.g. status and error messages),
- evaluate any high level protocol for any network architecture.

Moreover, it is important to guarantee that SpaceWire simulation run on MOST tool is deeply representative and efficient in order to provide a support for any project. In case we want to optimize the network performances, the nominal campaign of scenarios can be appended with specific elements, e.g. :

- some anomaly cases which are impossible to set in use on hardware bench, in order to verify FDIR concepts at network level,
- eventual improvements on SpaceWire high level protocol in order that SpaceWire networks become more robust : adaptive synchronous protocol.

This breadboarding mock-up and its possible SpaceWire improvements are an opening on the creation of hardware benches in order to realize a specific platform dedicated for SpaceWire networks. This SpaceWire platform could be able to optimize the design, development, and test of networks entirely SpaceWire.