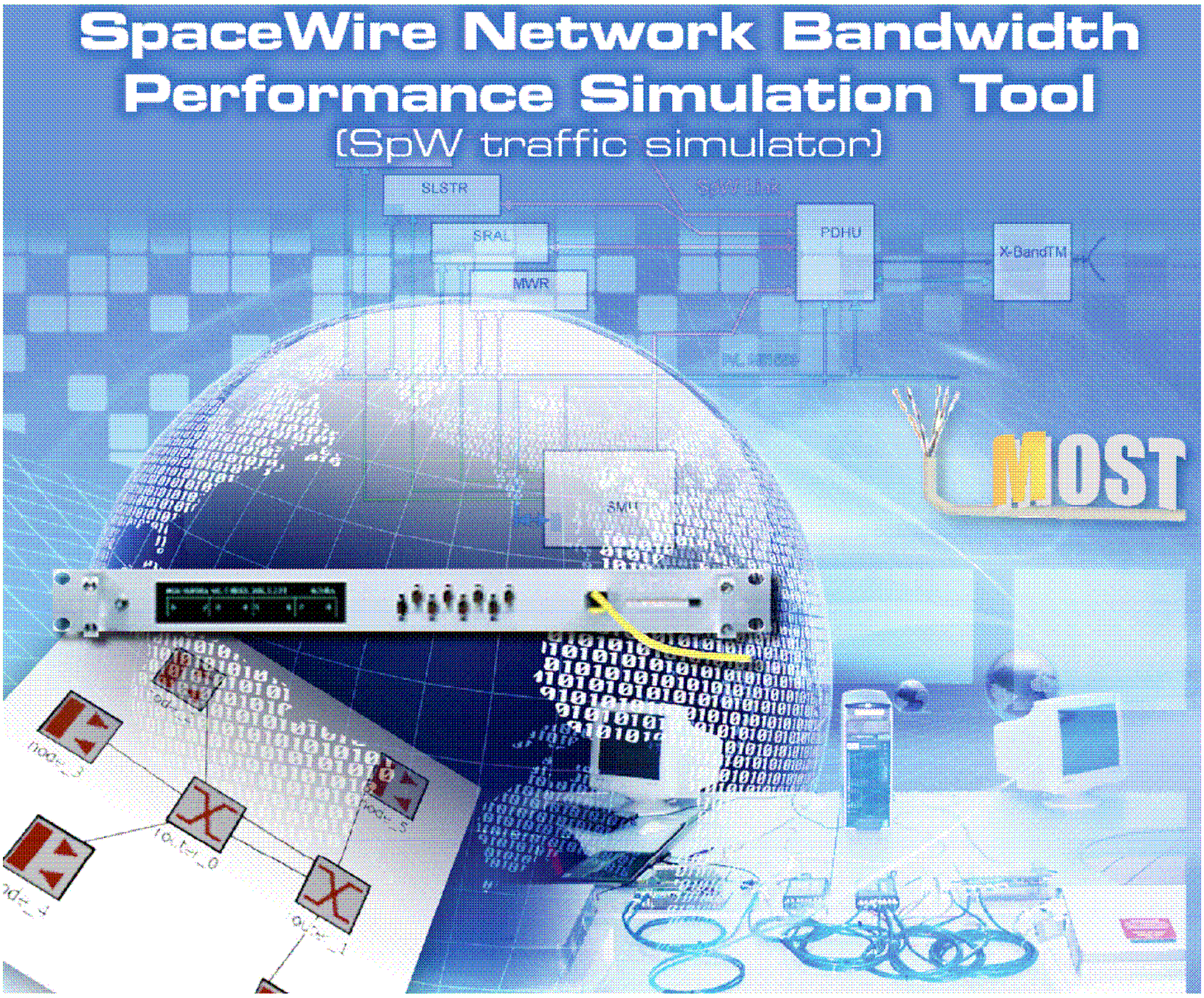
Modeling Of Spacewire Traffic

- ESA study Contract No. 23037/10/NL/LvH –

Executive Summary & Final Report



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OVERVIEW

The Spacewire technology allows embarking high speed data networks on-board spacecraft and becomes widely adopted by agencies and industries missions. Need for new tool to support conception, development and validation of such high speed data network has increased with Spacewire standard development. In that frame, the Modeling Of SpaceWire Traffic simulator (MOST) has been created by TAS-F in year 2006, with development based on OPNET toolkit dedicated to network modeling. The MOST library contains SpW nodes, routers and links which are selected by the user to build the SpW network topology thanks to drag & drop actions. Configuration is done at network level thanks to a set of attributes attached to each network component that can be tuned by the user. In 2006, MOST provided only a router model and one basic node model, with producer/ consumer application and a limited SpW protocol model.

In the frame of the ESA study No. 23037/10/NL/LvH, Thales Alenia Space has specified, implemented and validated MOST upgrades from the initial version in order to provide a representative and powerful simulation tool.

The Building Block (BB) concept has been adopted since the beginning in the specification phase in order to identify in the node layout the different communication layers and in order to offer to user a flexible simulation tool. For example, the “SpW standard BB” (or CODEC) is the SpaceWire node interface which ensures node physical connexion to the SpW network with the character management. This “SpW standard BB” is clearly separated from the protocol “RMAP BB”. As a result, one BB can be enhanced anytime without impacting others BB.

MOST library has been upgraded with implementation of representative models of SpW component as the SMCS116SpW, the SMCS332SpW, the RTC and the router SpW-10X. Modelling of these components is based on their data sheets (ref to the MOST URD). Those components make use of also developped procol BB as the RMAP, the CCSDS PTP, and, the SpW protocol.

Validation of MOST development has been run through simple test cases (reference to MOST Test Report). In addition, an HW cross validation has been done on a mock-up with 4Links support for HW traffic analysis. A representative on-board network topology has been tested on a mock-up and output comparison with MOST simulation run have provided successful results, showing how MOST traffic behaviour is well representative of HW.

MOST demonstration performances based on two study cases testing has shown MOST capacity to provide a representative and detailed assessment about traffic behavior, MOST ability to test complex network topology with several configurations setting, and, MOST capacity to provide a large set of observables for detailed results report.

MOST specification, development and validation done in the frame of the ESA study 23037/10/NL/LvH has allowed to deliver a representative and powerful SpW network traffic simulation tool which presents great interests for both system engineers and spacewire experts. Indeed, MOST offers the possibility to build SpW network model, selecting and configuring SpW component, and it allows to test defined design without waiting for HW. MOST allows to keep control on traffic load and to identify weak parts of the network topology, giving load margins and traffic performances. MOST allows failures simulation and gives the possibility to run various scenarios. As a result, MOST supports design risks decrease and also secures planning thanks to early verification. Thanks to a Building Block approach in the node model layout, MOST also gives opportunities for SpW experts who can easily test protocol or component changes.

Identification and specification of powerful MOST upgrades to be done have been taken into account in the MOST specification and annoted as “Extended” requirements. In order to take benefit of the work done and to go on supporting either current programs for SpW network topology design and validation, or, SpW WG standard evolutions, Thales Alenia Space would be very interested to pursue MOST development consolidation for ESA.

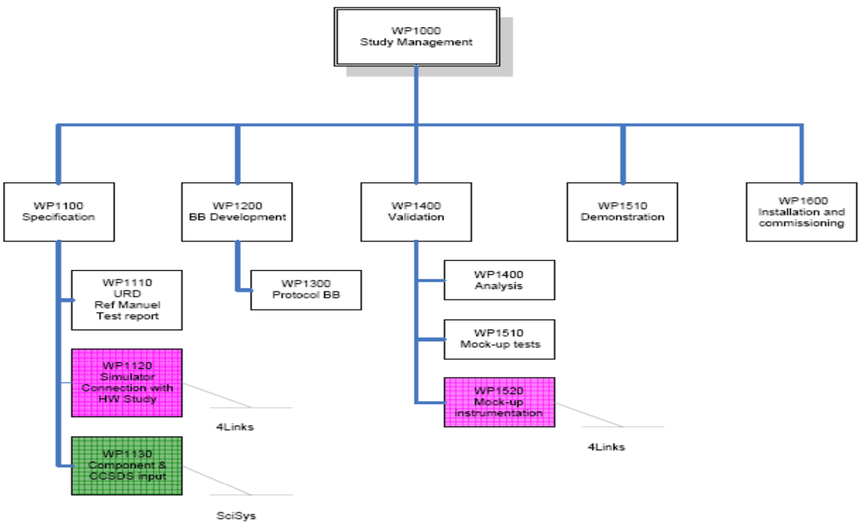
CONTRACT EXECUTIVE SUMMARY

The ESA study No. 23037/10/NL/LvH consists in the specification, the development, the validation and the delivery of a representative and powerful Spacewire Traffic simulator dedicated to both system engineers and to SpW experts, either to support SpW network design or to test SpW Building Blocks evolutions (protocols or components).

The ESA study No. 23037/10/NL/LvH is a 12 month contract between Thales Alenia Space France and the European Space Agency.

Two sub-contractors of Thales Alenia Space have been involved in this study:

- Scisys has provided input for the specification of the SpW component models.
- 4Links has first provided an analysis for the simulator connection possibilities with HW. In the validation phase, 4Links has supported the MOST HW cross validation with their own measure instrumentation.



The study has been splited into five phases:

– The first phase was dedicated to the specification of the SpW building blocks models to implement with regard to SpW component datasheet.

– The second phase was dedicated to the building blocks implementation,

– The third phase was dedicated to the validation of implemented Buiding Blocks,

– The fourth phase was dedicated to the simulator performances demonstration,

– The fifth phase was dedicated to MOST installation and delivery.

The following documentation has been delivered in the frame of this study:

– The MOST User Requirement Document (URD) specifies MOST building blocks models based on the SpW standard, the protocols, and the SpW component datasheet. Requirements issued are annotated “Mandatory” or “Extending” in order to provide a comprehensive specification of MOST models whatever the time frame allocated for the development in the current study. “Mandatory” requirements have been selected with the goal to select features with direct impact on the traffic.

– The MOST Reference Manual gives a complete presentation of MOST and include the detail presentation of MOST models. It includes feedback from development or validation phases through the Build Block presentation.

– The MOST Validation test report provided at the MTR presents building blocks validation. It includes also the HW cross validation report which show how MOST is representative of the HW measurement. It is presented a comparison between MOST output and HW mockup test measures based on a common network topology and test scenarios specification.

– The MOST Demonstration report gives a presentation of simulation outputs from two representative study cases selected to test the MOST performances.

– The MOST User Manual is split in two parts and addressed both type of users. In the first part the system engineers are guided to easily build SpW network topology and run simulations at network level. In the second part, the SpW experts are initiated to building blocks structures and node layout in order to be able to create new BB or even change one existing model

MOST source code has been delivered (Cdrom) and is installed on a dedicated laptop.

FINAL REPORT

1.1 Objectives

The objective of the Spacewire traffic simulator ESA study was to specify the modelling of SpW component based on their data sheets, to develop and validate the models implementation, and, finaly, to make a demonstration of the simulator tool performances.

The project had to be conducted over 12 months, and, goal was to deliver the SpW traffic simulator named “MOST” installed on a dedicated laptop, with a reference manual gathering the detailed descriptions of models, the user manual and the performances demonstration report.

In the frame of this study, five main milestones were foreseen as contratcual milestones: the User Requirement Review to validate the specification phase, the Mid Term Review to validate the modelling implementation, the Preliminary Acceptance Review to validate the MOST performances and attached documentation, the Final Acceptance Review to validate MOST delivery and installation on customer laptop.

1.2 Main Achievements

1.2.1 MOST : a powerful SpW traffic simulator

MOST is a progressive simulation tool for spacewire network traffic.

It supports system engineers in the designing phase (for topology definition and SpW components selection), in making predictions, and in the validation phase (thanks to a complete set of observables).

It offers to experts and component designers the possibility to build new spacewire building blocks and to test them without waiting for HW implementation.

MOST has been developed on OPNET (Open NETwork modeler). This object oriented SW allows SpW devices configuration thanks to a set of attached attributes. Its graphical editor provides a full set of possibilities to display and analyse simulation output. The user can work at Network level to build a network topology. The user can also access to the Node and Process levels to make change on existing spacewire component from MOST library or even to build new components, changing one building block design.

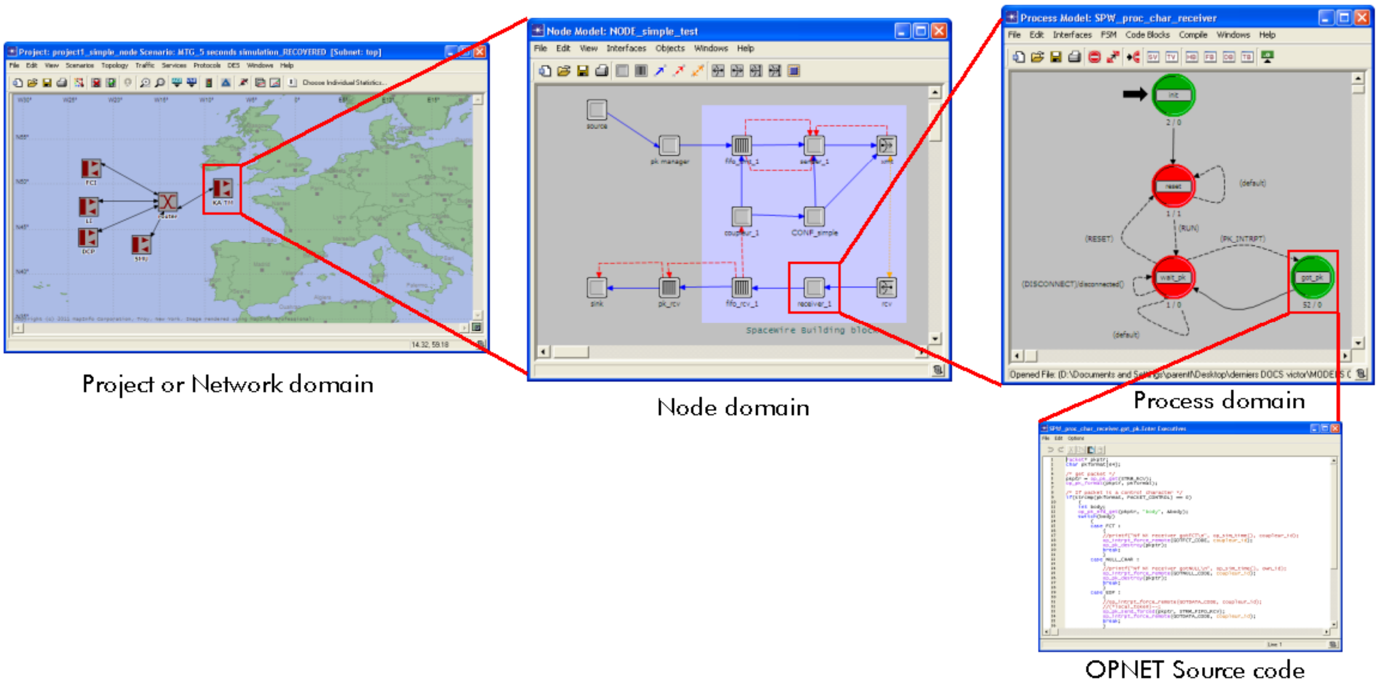


Figure 1: the MOST library is accesible from the OPNET network level to build SpW network topology and specify the configuration. At node and process level, MOST Building Blocks are accessible for SpW experts who would like to test new protocol or SpW component evolutions.

SpaceWire Nodes, Links and routers, are available in the MOST library to be selected by a user who wants to build and test a network topology at Network level.

The designer builds the network model, picking the components in the library and connecting them by using the graphical editor. Each network item (node, router and links) can be parameterized, setting values in a pre-defined set of attributes (data rates, routing table, buffer sizes etc …).

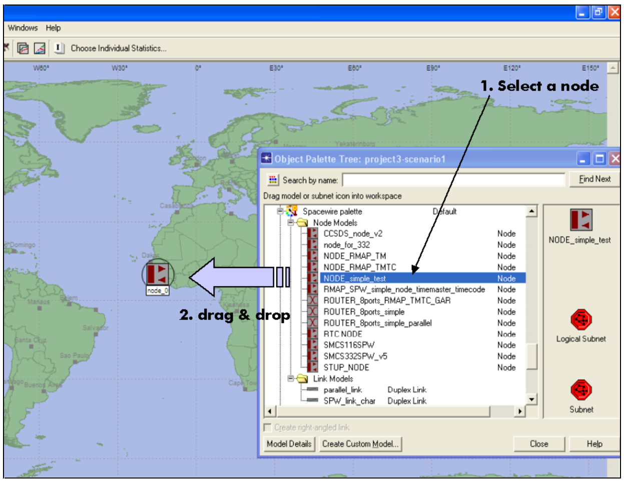


Figure 3: Drag and drop from MOST library allows to select SpW component and build the SpW network topology to test.

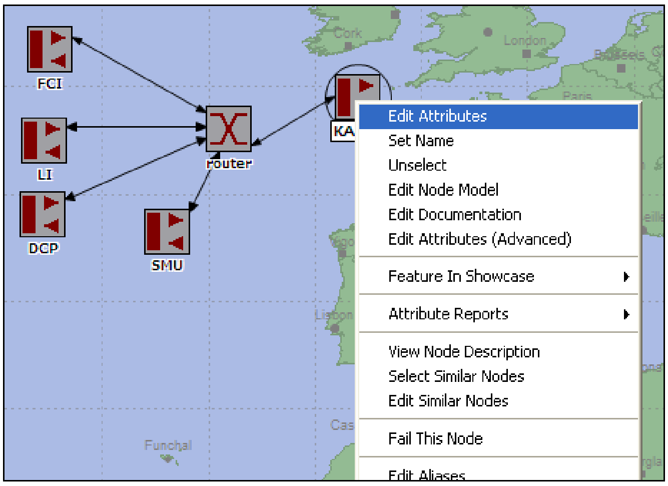


Figure 4: the SpW network configuration is done by tuning node attributes

Nodes are available in the MOST library. Node architecture shows the building blocks connection, implementing at least: the “SpW standard BB” and the chosen application layer.

MOST has been developed with respect to requirement to be an open and living tool.

An incremental development has been applied, each step enriching the simulator by modeling new SpaceWire features and appending SpW component. MOST allows to modify and test one specific component in its library.

The Building Block concept allows analysis and test of specific changes in a BB at any communication layer, without impacting the others. SpW devices Models are one specific set of BB (application layer) and can be enhanced anytime, such to follow evolutions of the embedded design (incremental approach, models refining).

The “SpW standard BB”, or CODEC, is the SpaceWire node interface which ensures node physical connexion to the SpW network and character management.

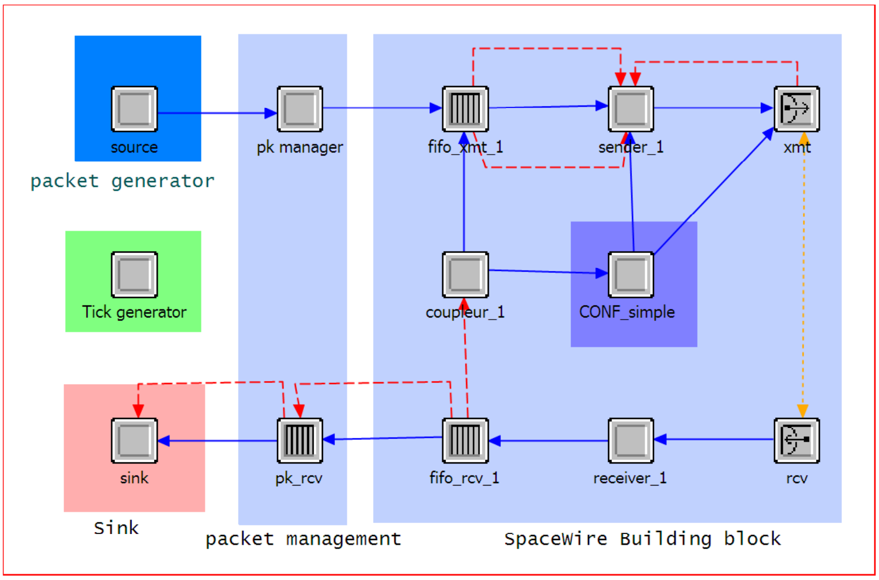


Figure 5 – SpaceWire node architecture

Opnet offers a powerful tool to analyse simulation output. It provides various way to display each type of data.

Spacewire traffic analysis is done based on observation of statistic parameters as: the End-to-End delay, the bottleneck observation, packet size, packet latency or jitter, number of sent and received packets, the evaluation of the sustained bandwidth or also buffers occupation.

Observables are selected by the user and it can be choose to observe one data at one node level or at network level.

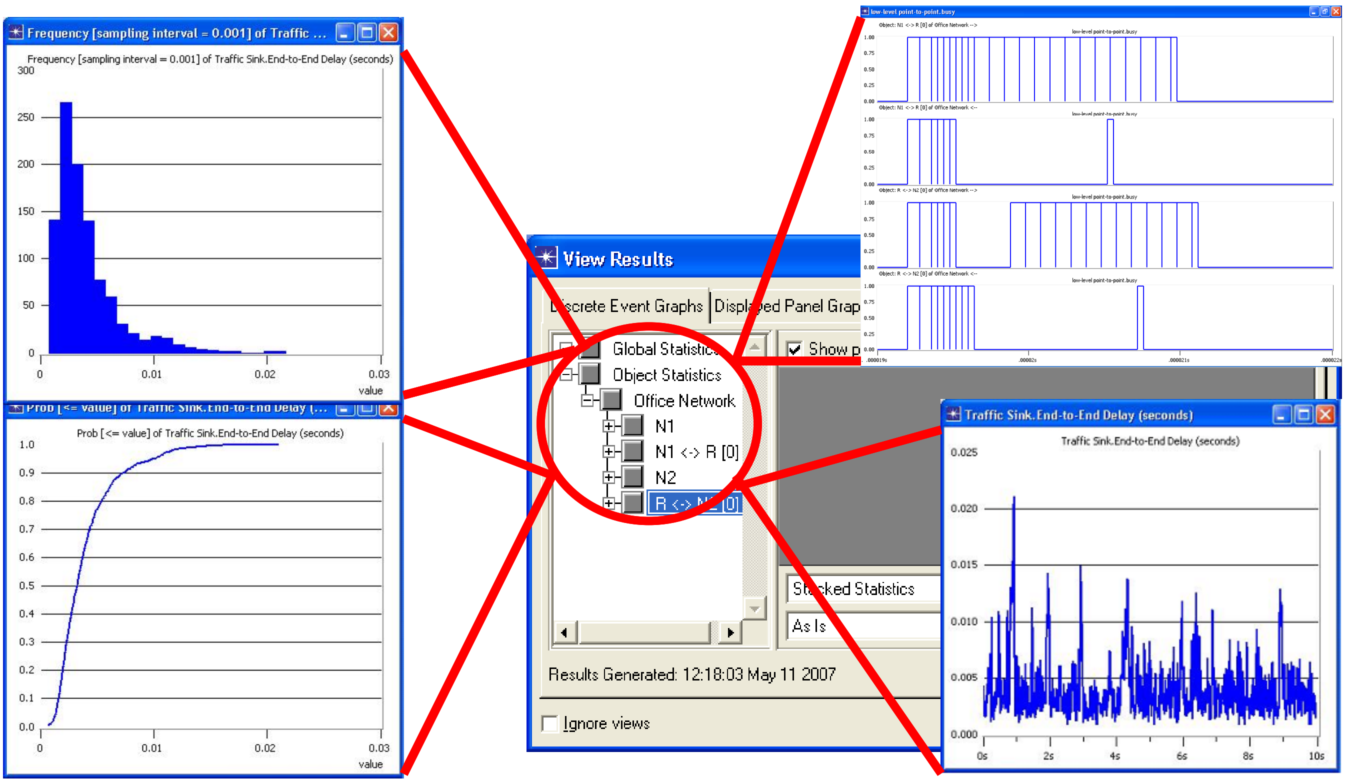


Figure 6 : MOST offers a large set of simulation output

1.2.2 MOST output are HW representative

One MOST HW cross-validation has been run successfully in TAS-F premises during one week long, with the support of 4Links for the mock up instrumentation.

From this cross-validation tests, it has been shown the correct performance of MOST against a HW network, where real outputs and real statistics have been achieved. Besides of this, it has been shown the capabilities of MOST to be adjusted and tuned up in order to be compliant to some practical results thanks to its modular design. Output from MOST were comparable to the ones from 4Links, where HW simulations analysis of the network traffic has been presented for all tests scenarios. Through this tests, it has been verified the correct performances of the simulator with a complex network and with high data flows.

Cross validation has been done by comparing HW provided results to simulator's. This validation consists in implementing a reference network topology with HW bricks (nodes and routers) and then modelling this same topology with MOST.

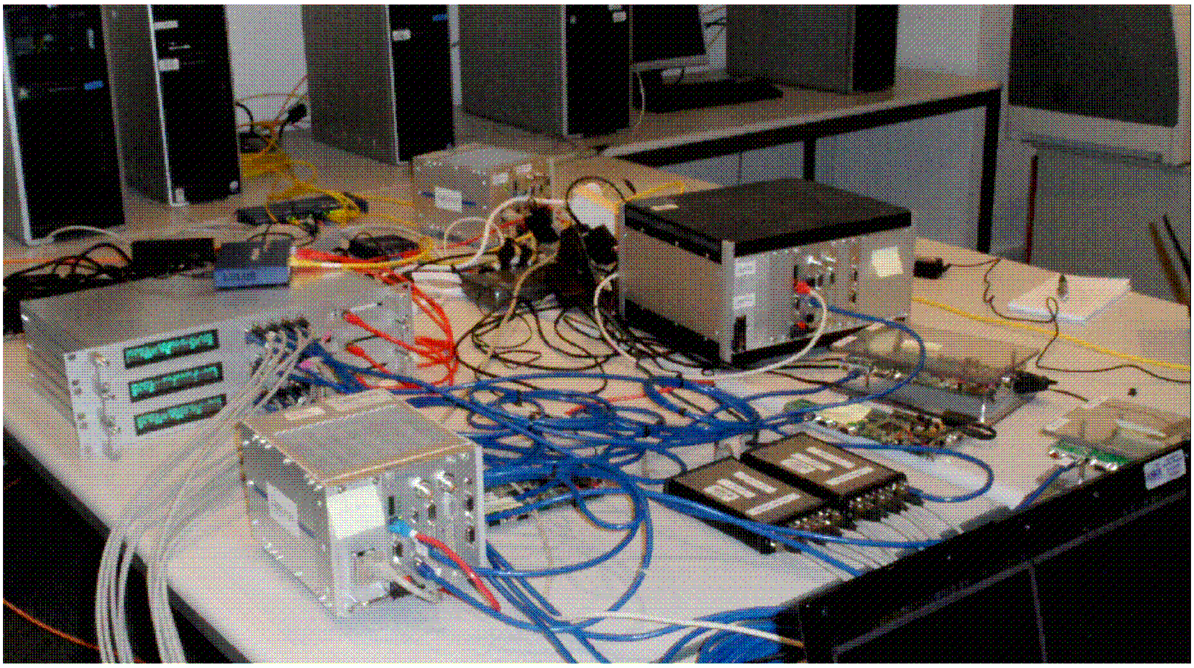


Figure 8: HW mock-up with Gaisler Leon board and Rasta system, and 4Links traffic recorders

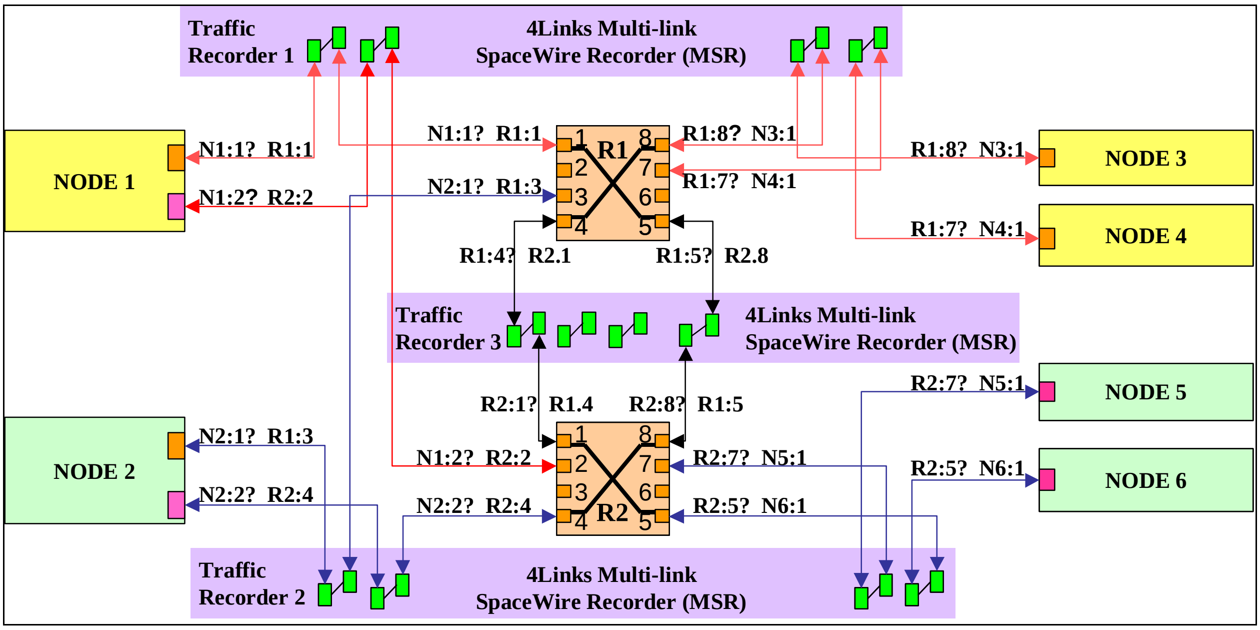


Figure 9: HW cross-validation network topology with 4Links Traffic recorders

1.2.3 *MOST performances demonstration*

MOST performances have been successfully tested through two study cases: the earth observation study case, and, the robotic study case. Goal was to make use of all the MOST tool possibilities based on complex network topology and various scenarios, allowing different configuration setting and deep analysis of the network topology & configuration performances (margins/bottlenecks/buffer status).

<u>Study case #1: spacecraft on-board representative SpW network</u>

The Study case #1 objective was to test a representative embedded on-board spacecraft SpW network, which mixes critical data with less critical data, but which cannot be lost.

The selected network topology makes use of specific SpW component available in the MOST palette as the SMCS116SpW and the RTC.

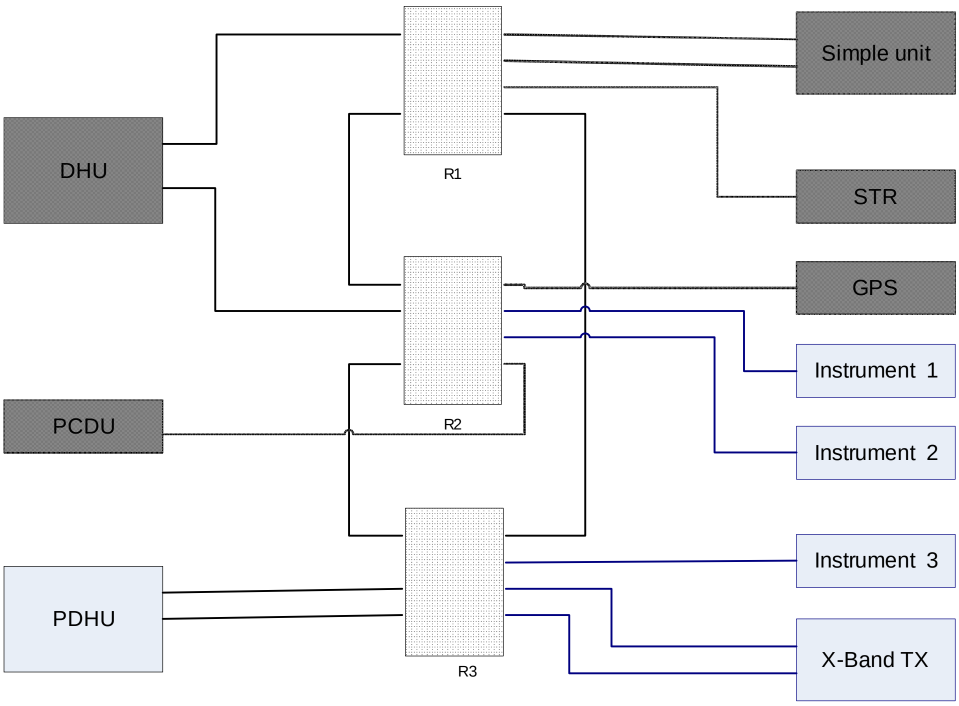


Figure 10: study case #1 is a complex and representative on-board SC SpW network topology

The SpW network topology includes both Platform units and instruments, which is current trend for new on-board architecture, compared to current and old designs where payload and platform where controlled by dedicated data busses. As a result, critical data items from the PF are mixed with large non critical data from the PL (Science data):

– Platform presents Hard real-time constraints, and matches DH cycle (~ 10 Hz). The Data Handling Unit (i.e. Central On board computer) controls avionic units, sending commands and collecting HK.

– Payload presents lower real-time constraints: Transfer of Low rate cyclic images (but large data units) or asynchronous mission data, Takes autonomous decisions impacting traffic (future)

From this study case, the correct behaviour of the data flow from a network involving critical and non-critical devices has been shown. The analysis includes end-to-end delay and bandwidth utilizations analysis.

The packets traffic has been shown, and the analysis has given results proving that no packet(s) loss occurred in the selected topology and scenario, while the delivery is on time thanks to expected results, in all cases. Commands and housekeeping data exchanges have been analysed, showing that delays are pending on the routers latencies and the packets sizes.

The effects of the traffic burst created by the PDHU on the network mainly affects the global end-to-end delay of the packets. Perturbations are mostly due to traffic peaks between the PDHU and the X-Band TX, during download sessions.

Study case #2: Robotic SpW network topology

The Study Case #2 objective was to test a representative robotic SpW network topology, mixing critical data, with hard real time constraints (e.g. motors control), and large amount of non critical data generated continuously by non vital source (e.g. cameras). This study case was also selected to test the impact of the network degradation on the SpW traffic performances. Non-degradation and progressive degradation of the network have been considered in various scenarii.

The robotic network topology is centered on two nodes playing a central role: the Mission Controller (CDMU) and a Supervisor (Tasks Controller).

– The CDMU (Control Data Management Unit) is the central computer of the vehicle and it interfaces the Supervisor. It collects HK and Images of the working scene and also ensures communications with ground. It sends/receives discrete commands/acquisitions and also sends complex directives to the Supervisor.

– The Supervisor is the time master and it controls the robot moves according to command targets, derived from the directives of the CDMU. It synchronizes robot activities via time-code. It commands robot devices and collects robot devices data .

– Three cameras: two cameras (Visual Monitoring Cameras VMC) provide continuously images of the scene to allow control of the robot activities by the ground – non critical data, 20 to 25 images/second. One Robot Control Camera provides critical data and medium message, with middle frequency.

– Three actuator/sensor couples (Joint Controllers) are used to control the two rotation axis (encoder): they Receive & execute motor commands, and, Return position data on a cyclic basis (or on request)

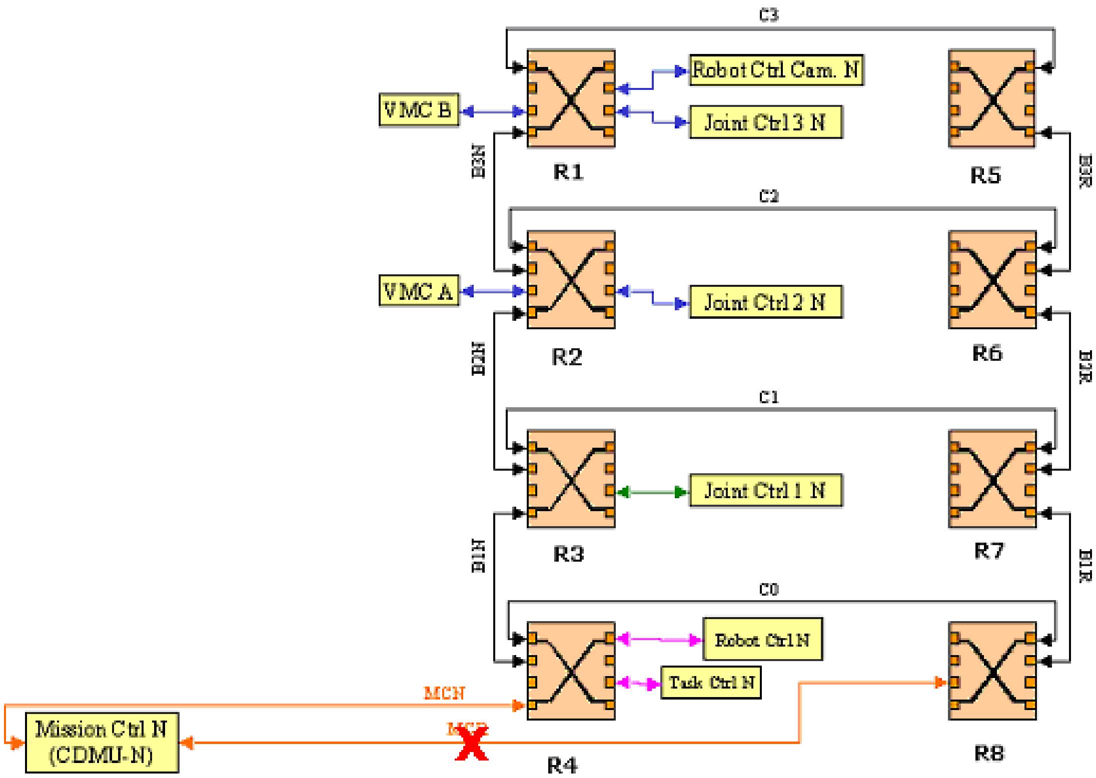


Figure 12: study case #2 represents a robotic network topology, mixing hard real time constraints traffic and a large amount of non critical data

The analysis has been focused on the behaviour of the data flow in all these cases, dealing with collisions, busy ports and GAR function from the routers.

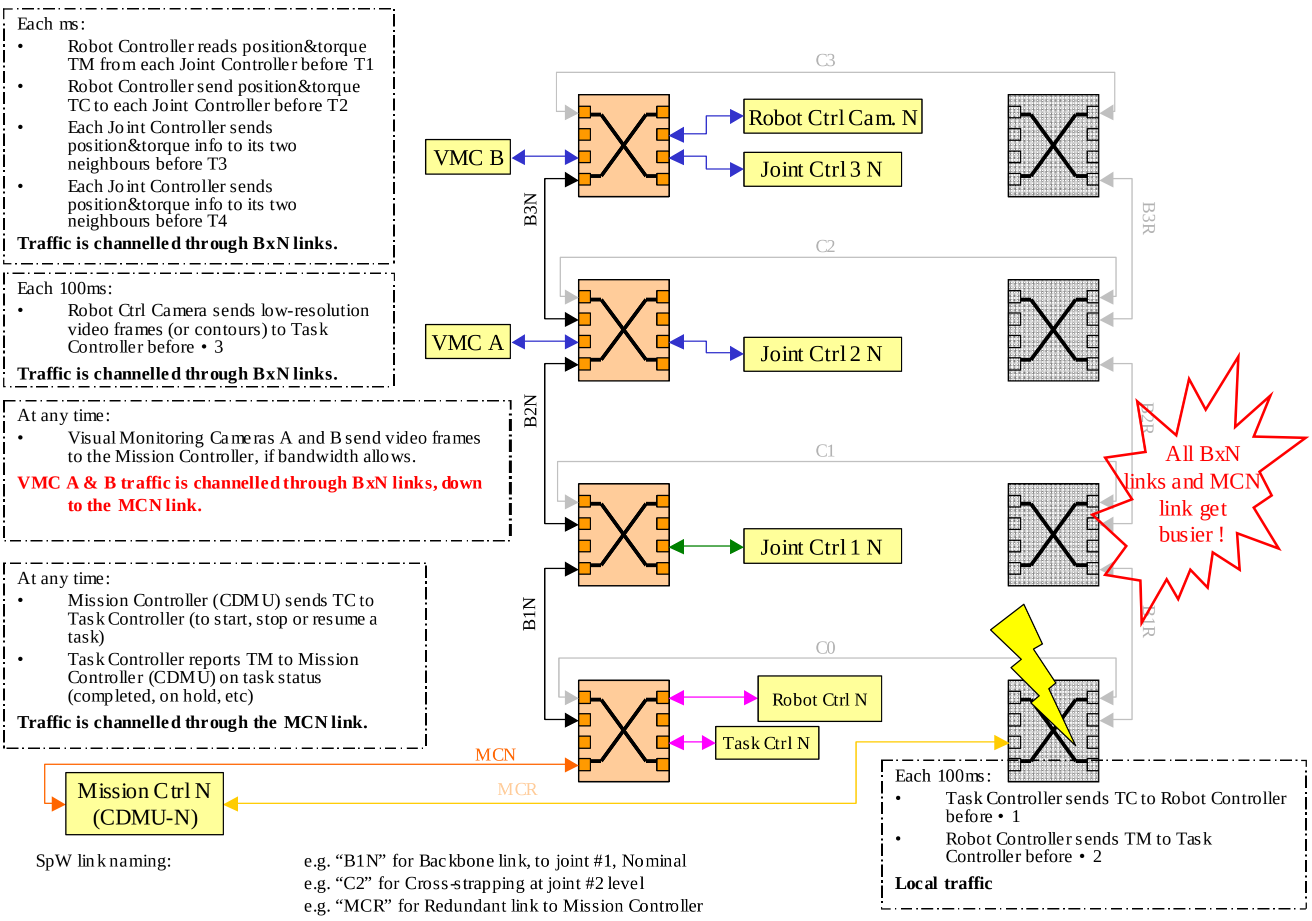


Figure 14: Packets loss is observed when network degradation occurs

Over the degradation scenarios, bottleneck occured on every router where the redundant way is unavailable, so that packets shared the same nominal channel to arrive to their destinations. The network degradation has been observed with packets loss. Through the end-to end delay analysis it is observed that even in case packets arrive up to their destination, the system performance is degraded because deadlines are not met. This traffic view allows the designer to modify nodes or network characteristics, as packets MAX sizes for example, to find out the best compromise meeting system requirements at best

1.3 Conclusion & perspectives

In the frame of ESA study [AD1], Thales Alenia Space has developped a Spacewire traffic simulator named "MOST" (standing for Modelling Of Spacewire Traffic) and a successful performances demonstration allows to consider MOST as a major contribution for the SpaceWire standard and associated technologies development.

MOST performances demonstration, based on representative study cases, has allowed to show how the simulator can be used for current mission to support SpW network topology design and configuration. The MOST library has offered the possibility to include various SpW component in these topologies, as the 10X router, the SMCS116SpW, and the RTC. Thanks to a HW cross validation on a mock-up, it has been demonstrated how MOST outputs are representative. The graphical editor provides a full set of possibilities to analyse and to display outputs on synthetic graphical views.

In addition, it has been shown how MOST offers the possibility for spacewire experts to test SpW component design without waiting for HW development. Building block concept provides a progressive tool, which allows to modify one communication layer from a given node without impacting the whole design. As a result, MOST can be used to test new spacewire technology or even SpaceWire standard evolutions. Upgrading the application layer of nodes lets also project teams refine the network design and configuration, by including the node behaviour in term of data generator and consumer and by modelling nodes local constraints.

A complete documentation is delivered with MOST to describe into detail MOST models and give to users, in addition to the User Manual, a complete view of MOST performances and possibilities. From this documentation, current MOST version limits are identified in order to point at powerful upgrades to be done if MOST is selected to support current project with SpW network on-board. In addition, the "Extended" requirement from the MOST URD issued specify the upgrades that can be done to complete SpW component models wrt their data sheet.

Main upgrades are can be summarized with the following list (please, also refer to [AD2]MOST URD, reference 100435046D and associated compliance matrix included in [AD4]):

- Upgrade the generic packets generation mechanism with several data sources per node
- Upgrade the reception mechanism - a treatment delay
- Upgrade of the messages handling - Elaboration of a generic GDF file structure (packets detailed description)
- Upgrade of the End To End statistics computation – attached per source ID
- Upgrade the SpW router 10X model
    - timecode handling – selection of output ports
    - Parallel ports implementation
    - configuration command interpretation – handler for address 0
    - Disable on silence feature & "Start on request" features
    - Router delay computation thanks to input/output data rates
- Upgrade the SpW RTC model with DMA and virtual channel mechanisms
- Upgrade the SMCS116SpW model with RAM interface implementation
- Upgrade the SMCS332SpW model with COMI implementation
- Packet Utilization Standard implementation – PUS above PTP

DOCUMENTATION

[AD1] ESTEC Contract No 4200023037

[AD2] MOST URD, reference 100435046D

[AD3] MOST Test Report, reference 100435115D

[AD4] MOST Reference Manual, reference 100435074I – This document include the demonstration report and the user manual. This document also includes the Compliance Matrix with regard to the URD.

END OF DOCUMENT