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System Approach for a SpaceWire Network

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SYSTEM APPROACH FOR A SPACEWIRE NETWORK

- INTRODUCTION
- SIMULATION
- BREADBOARDING
- INTERFACES STANDARDIZATION
- FAILURE DETECTION
- CONCLUSION

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INTRODUCTION

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SpaceWire for Space Application

- SpaceWire technology is today affordable and can be used for many space applications. Indeed Standard flight computers or flight units provide such SpaceWire interfaces

- However when designing a SpaceWire network for a space application, how to guarantee that network is reliable in term of failure Detection&Recovry and enough performing in term of bandwidth ?

- When starting a new satellite design based on SpaceWire network , and in order to secure the development, Thales Alenia Space consider needed to follow a system approach or a top down approach:
  - To settle SpaceWire network performances requirements
  - To define and validate the FDIR concept of the network
  - To prevalidate the bandwidth performances and real time constraints
  - To standardize the interfaces to ease the compatibility between modules

Objectives

For this purpose, THALES ALENIA SPACE (TAS) has developed RD effort on several directions :

- **Development of simulation tool (MOST) in order to validate bandwidth performances of a network early in the project**
- **Development of an internal Avionic mockup with the objectives :**
  - **The mock up will be scalable and adaptable to cover new future mission**
  - **To Adapt the existing TAS avionics software in order to handle SpaceWire**
  - **Use SOIS services to handle SpaceWire**
  - **Use standard interfaces as PUS or RMAP for SpaceWire exchange**
  - **To Evaluate Failure Detection capability and FDIR**
  - **To Design a synchronous protocol in order to secure CC messages on the network**

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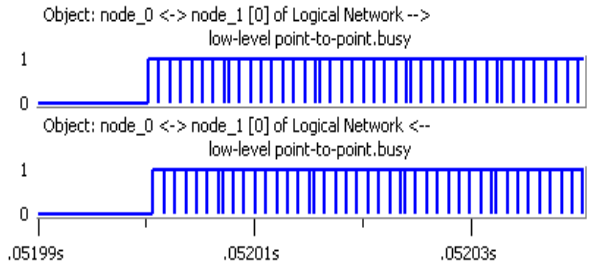
MOST SIMULATION TOOL

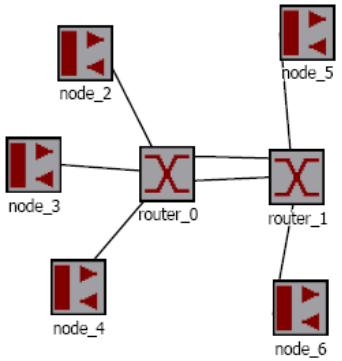
MOST simulator

- A tool has been designed to support design/development of SPACEWIRE networks :MOST for Modelling Of Spacewire Traffic
- MOST is primarily intended to simulate SpaceWire traffic
- MOST has be developed with the following objectives :
  - Build any network topology involving routers and nodes
  - Low effort in simulating new cases due to components' library
  - Simulate node behavior as data generator / consumer
  - Parameterize data production process
  - Execute scenarios (including error cases)
  - Execute recording and analyses visualizing a high debit traffic which uses routing
  - Produce reports of traffic analysis, based on drawings (evaluates peaks and margins, shows long term evolutions of resources, identify saturations cases)

MOST brings support all along the project life



- During early steps of projects, MOST mainly plays a part in the following design activities :
  - Phase A and before : performs evaluations, starting from a preliminary specification of network and nodes
  - Phase B : consolidate design by enhancing and completing nodes' models behavior in term of data provider and consumer



- During development steps of a project, MOST participates to :
  - Phase C, D : design, validation and investigation
- During maintenance step of a project, MOST takes part to :
  - Phase E : investigations, eventual support to very specific operations

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MOCK UP DEVELOPMENT

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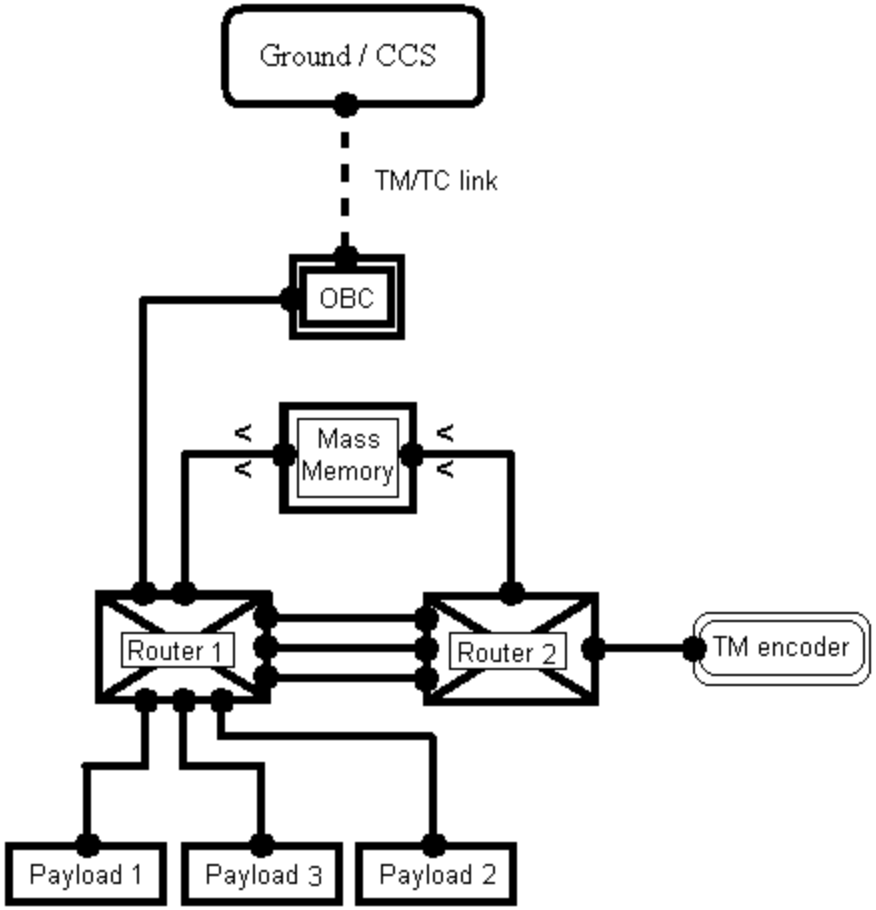
SpaceWire Network Mock Up



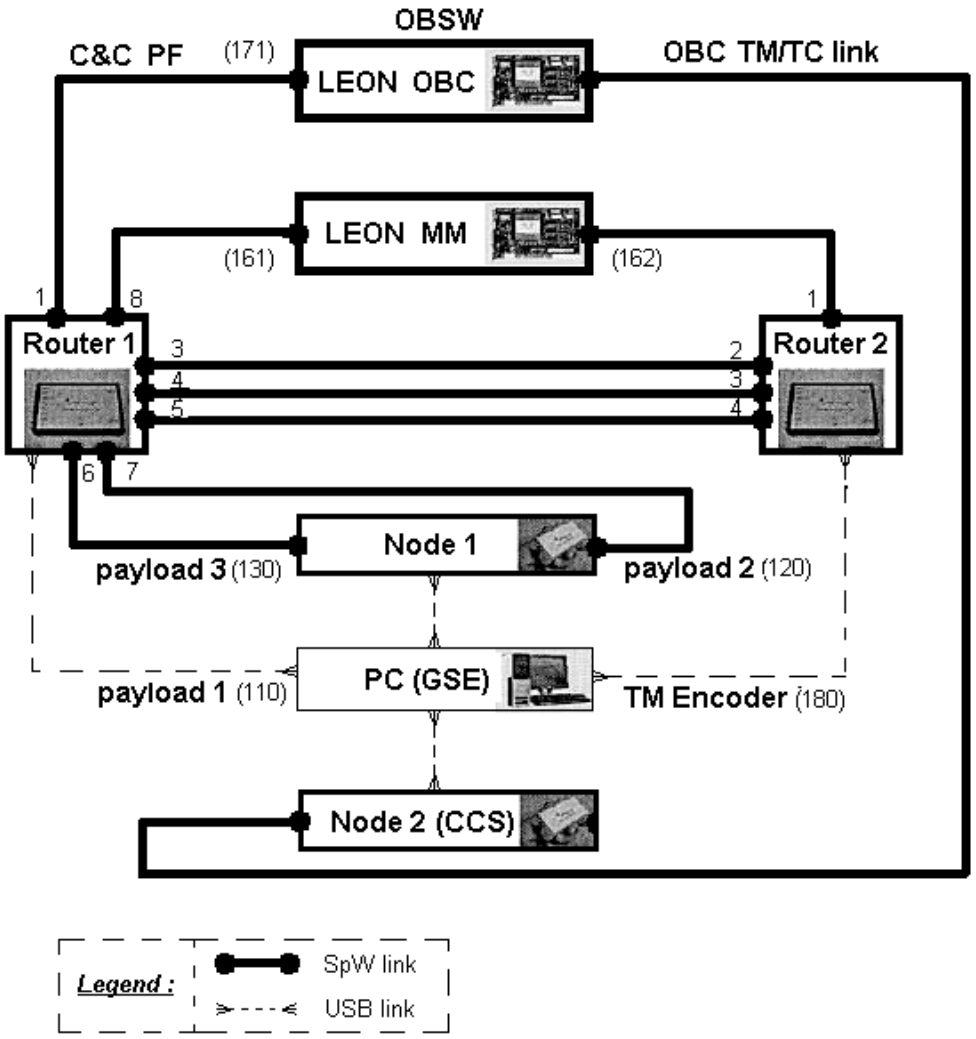
Experiment specification defined by :

- Topology,
- Scenarios and network characteristics,
- Ways to monitor the network state,
- Ways to detect failures and bottlenecks,

Based on :

- LEON boards,
- Bricks & routers,
- TAS Avionics Software Mock-up.

SpaceWire Network Architecture



Reuse of avionic software & development of applications :

- For each LEON board
  - Simulated CDMU behaviour
  - Simulated mass memory behaviour
- Behind each brick and router
  - Simulated payload behaviour
  - Simulation of TC subsystem

Particularities of this network :

- RMAP for initialisation & router status
- Exchange based on PUS
- Time-code for synchronisation
- Group Adaptive Routing
- FD monitoring to analyze a network
- Intensive use of router

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MOCK UP / MOST COMPARISON

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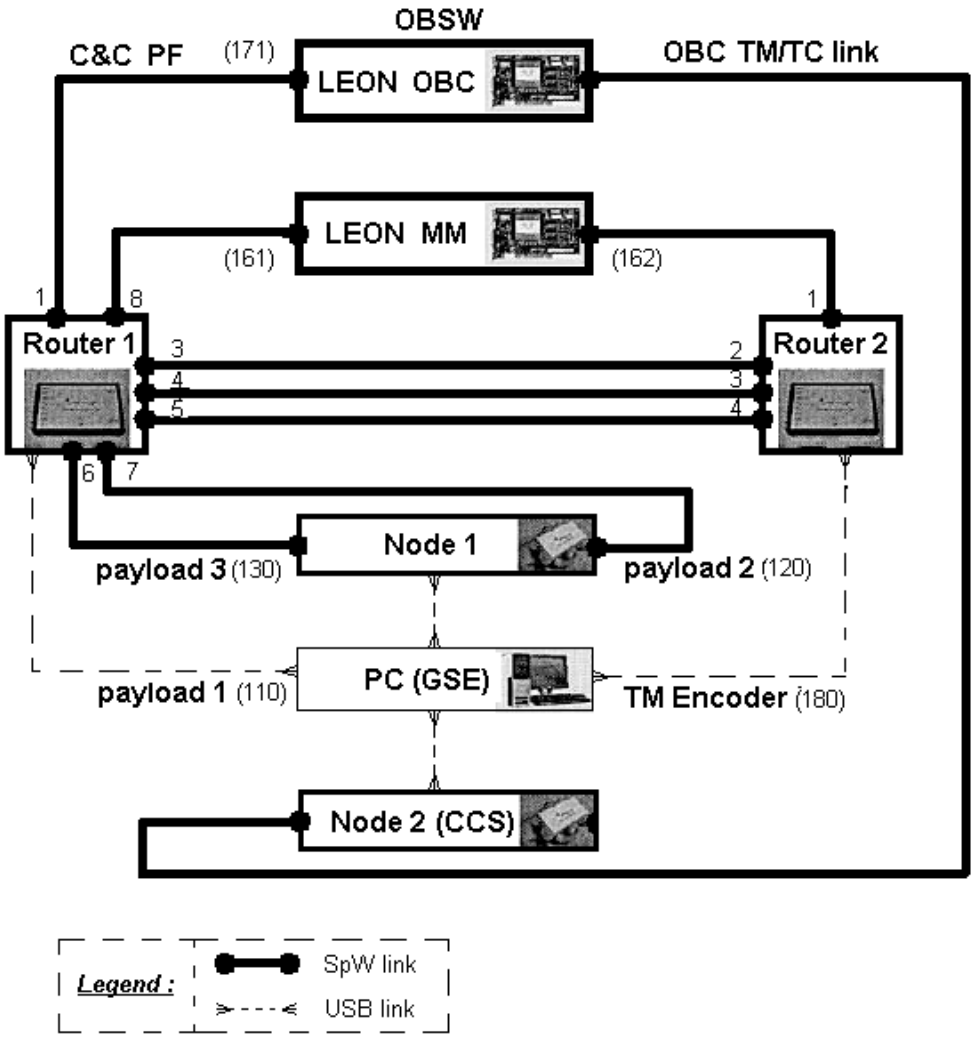
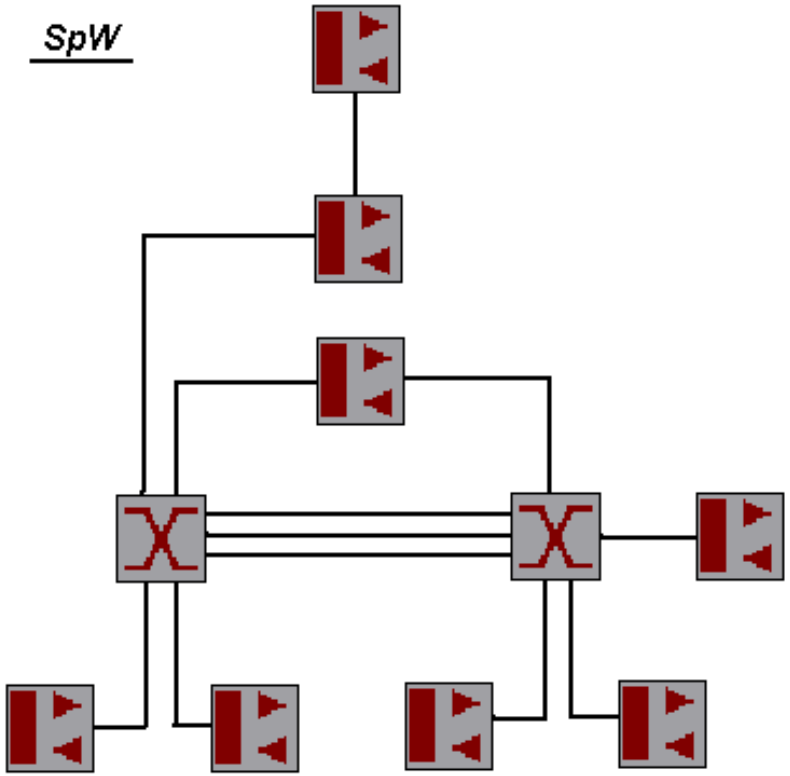
Cross-Checking : MOST Simulator vs Mock-Up



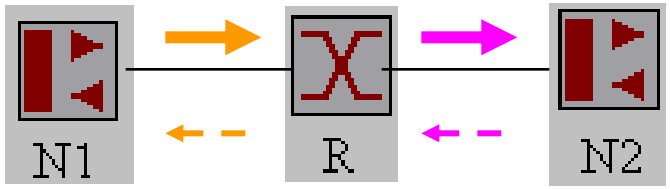
MOST model :

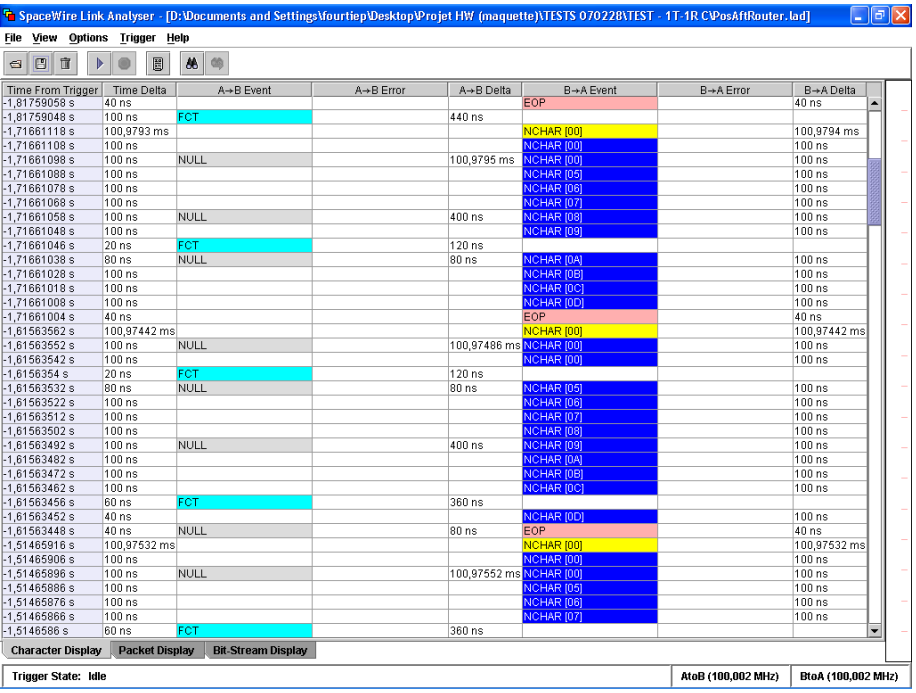


MOST : Modelling Of Spacewire Tool

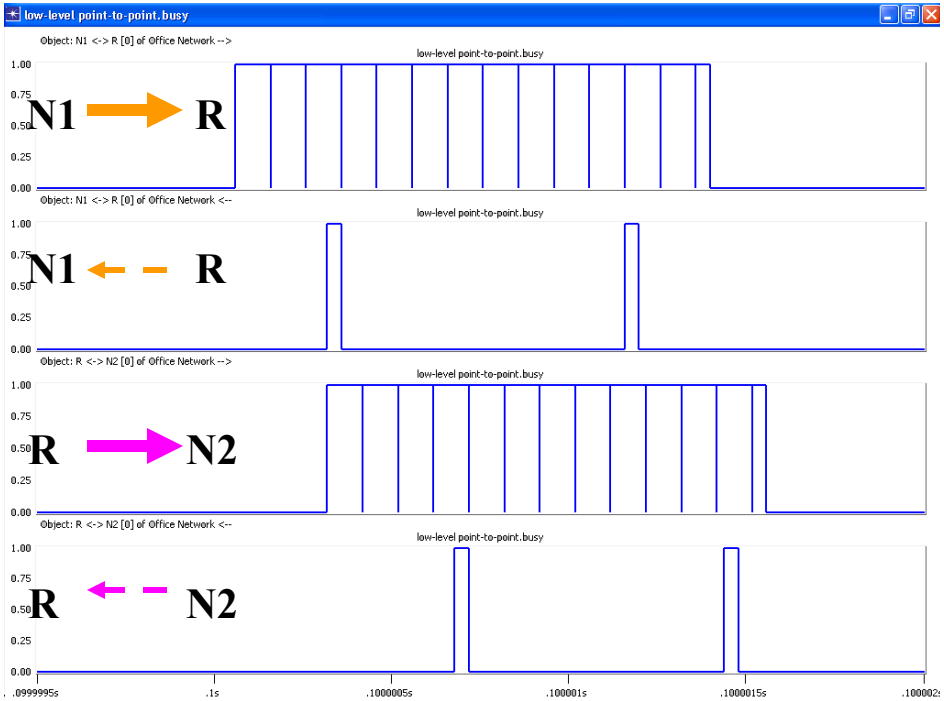
Cross-Checking of results (1)

- **The main verified features are :**
  - SpaceWire standard features
  - Bottlenecks and failures





Data traffic on SpaceWire link analyzer



Data traffic on MOST simulator

Comparison table

TESTS :	Validate	Not Validate	Not Done
Graphical reading of results	√		
Generation time	√		
Generation delay	√		
Generation cycle	√		
Transmit frequency	√		
Interval time of a byte	√		
Number of sent or received packets	√		
Number of sent or received bytes	√		
Packet size	√		
Byte size	√		
EOP size	√		
Generation of a EOP at end of packet	√		
Number of FCTs at the hardware initialization	√		
Generation of a FCT at each 8 characters √			
RMAP principle	√		
Logical & path addressing	√		
GAR functionality principle	√		
Header deletion	√		
Time code (except for a lost time-code)	√		
Time-out functionality principle & anomalies			√
Switch time & router latency & jitters & skews			√
Blocking level			√

Limitation at HW level :

- **Link analyzer : precision of 20ns**
  - Difficulty to compare simulation with test in some cases :
  - Switch time & router latency & jitters & skews (specific instrumentation would be needed)
  - MOST developed based on data sheet

- **Impossible to create all anomalies at hw level**
  - **Benefits thanks to MOST simulator :**
  - Creation of anomaly cases (e.g. EEP, parity error, no EOP generation …)

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S/W architecture

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Avionics Software Architecture (1)

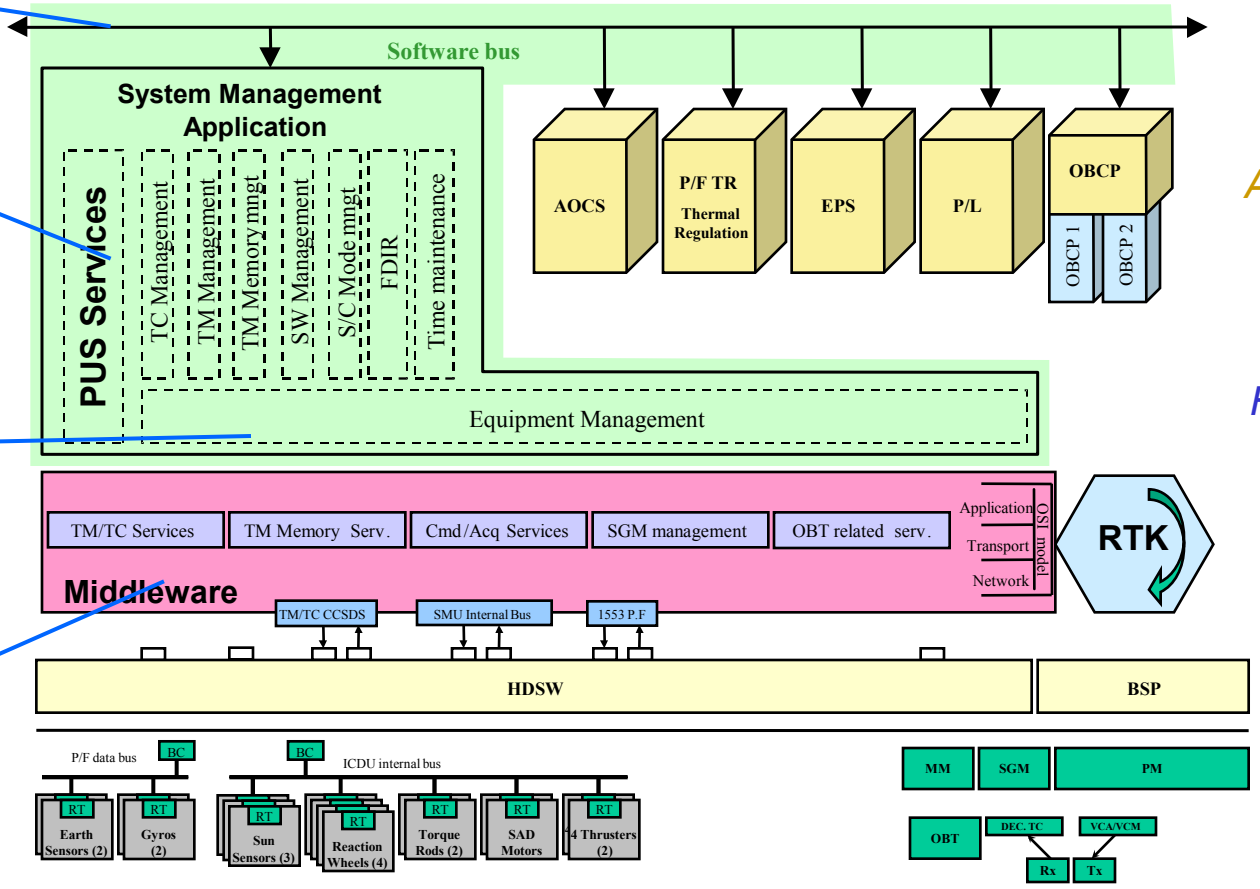
❑Mock up is started from standard TAS avionic baseline :

Software bus For Plug&play of applications

Use of PUS standard for ground/board interface

Centralised management of all equipments status

Middleware for high level I/O abstraction



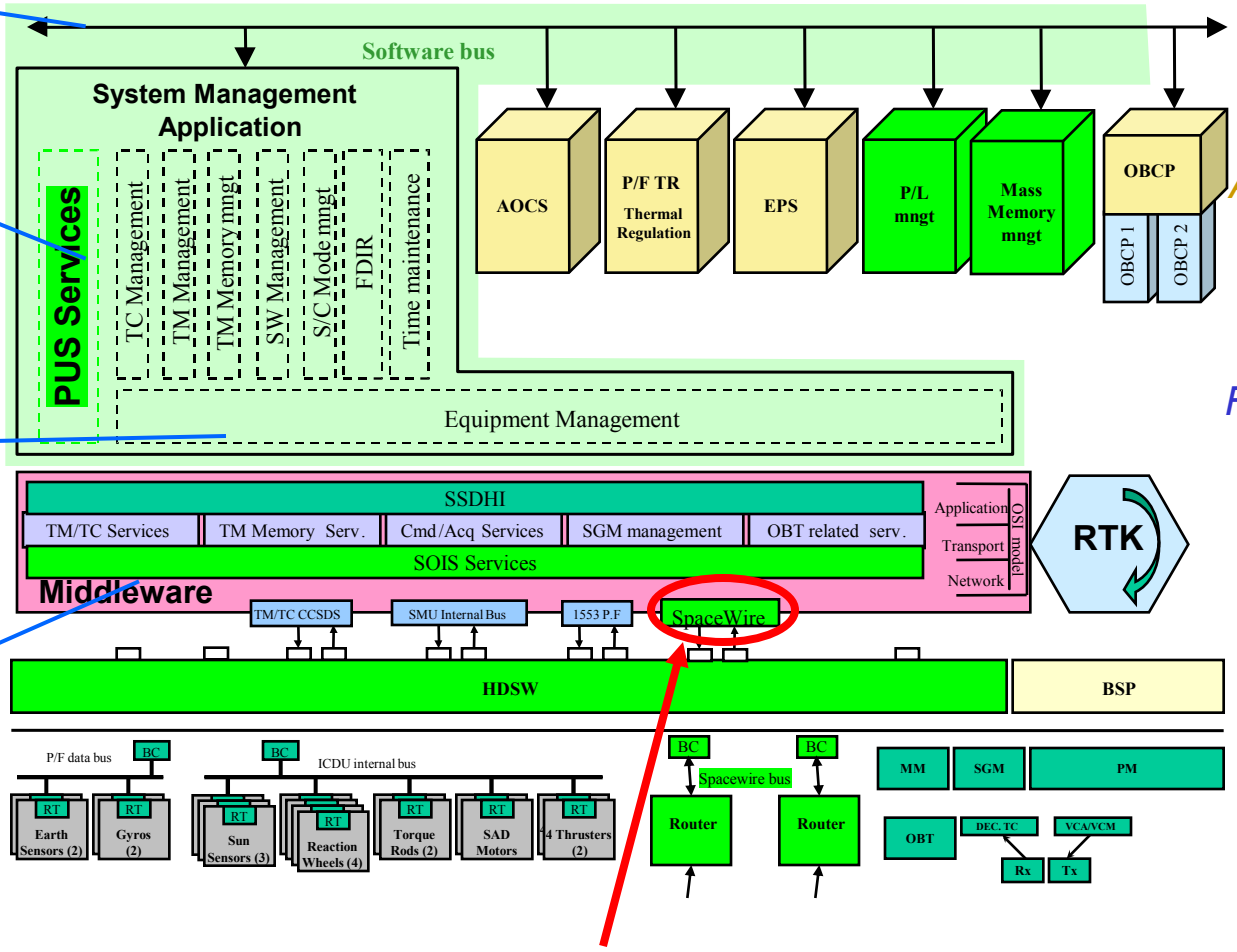
Avionics Software Architecture (2)

Software bus For Plug&play of applications

Use of PUS standard for ground/board interface

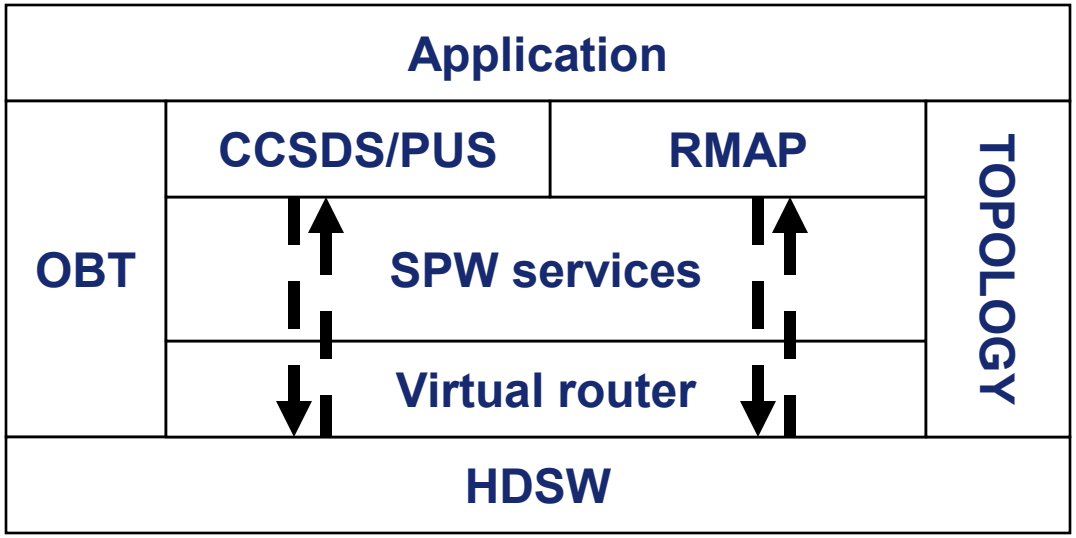
Centralised management of all equipments status

Middleware for high level I/O abstraction



Compliant with PUS & RMAP standards

Software architecture :

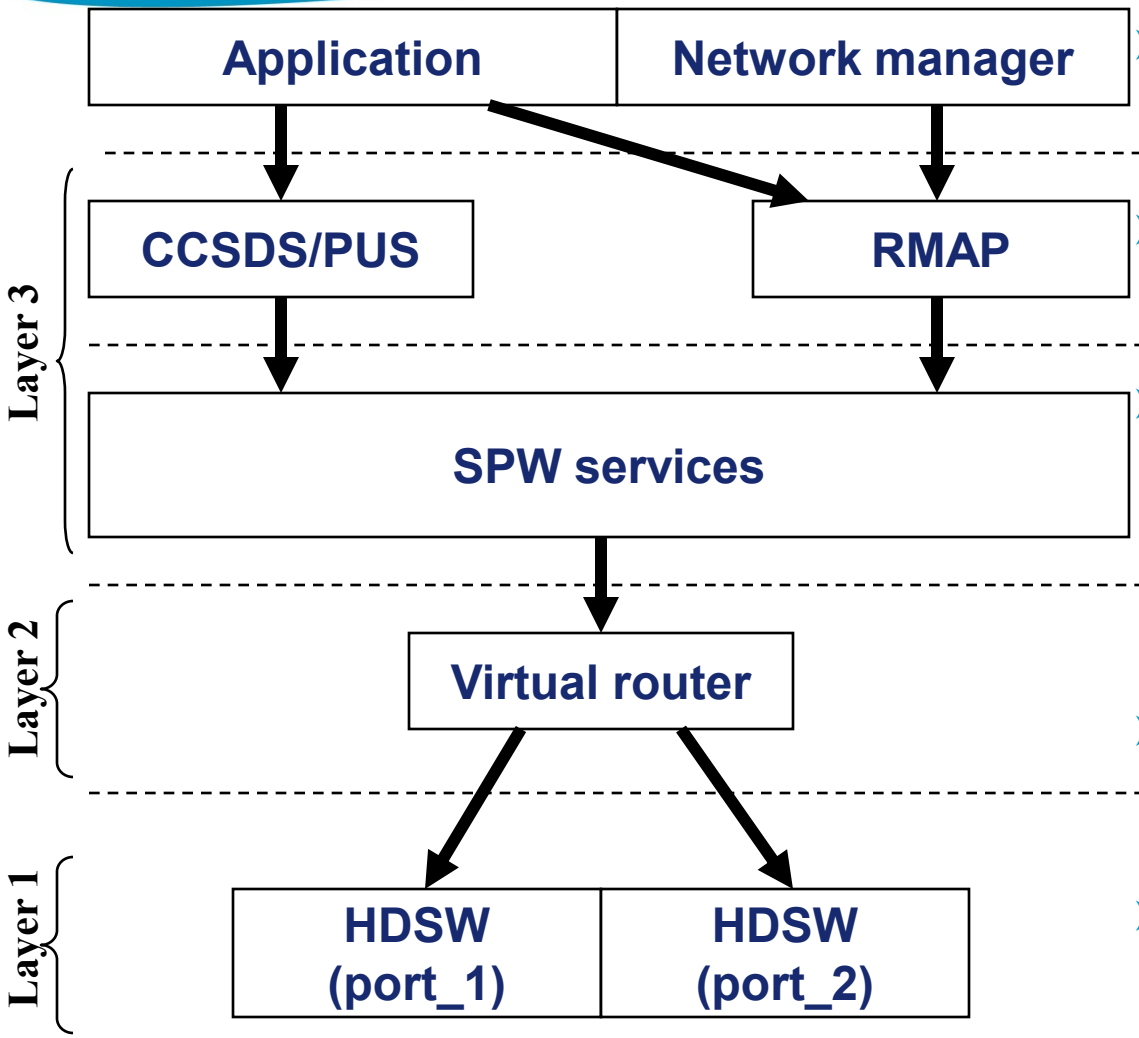


Virtual router principle :

- From SPW server, application selects the SpW port on which its packets will be sent thanks to a virtual router.
- The virtual router is configured by a routing table informing on :
  - Destination address
  - Associated SpW interface port
  - Deletion header
- The virtual router works as a real router.

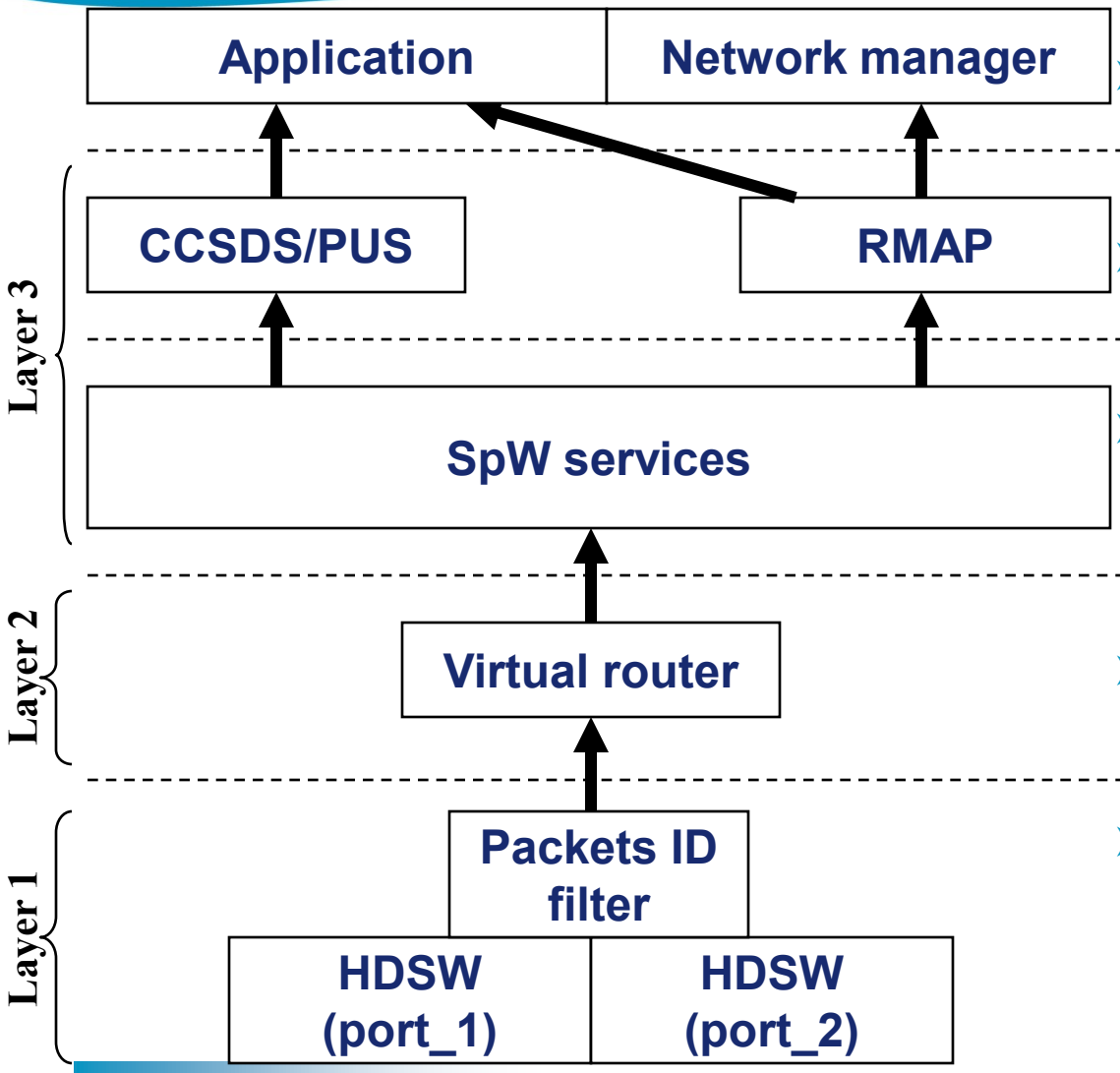
Interest :

- Manage the redundancy at node level



- Generate PUS or RMAP packets
- Fill RMAP Table with all RMAP requests
- Correlate destination node with its headers via a specific routing table (dest logical address, priority, physical output port, deletion header flag)
- Route to a SpaceWire ports
- Send packets

Virtual routers – (ANNEX)



- Recover packet data
- Retrieve data to appropriated destination
- Decapsulate received packets
- Route packets to application layer
- Receive PUS or RMAP packets
  - (RMAP commands are treated at HW level)
  - (RMAP reponses are treated at application & network manager level)

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INTERFACE STANDARDIZATION

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Packet format : SpaceWire

CCSDS packet format

Packet Header (48 Bits)							Packet Data Field (Variable)			
Packet ID				Packet Sequence Control		Packet length	Data Field Header (Optional)	Application Data	Spare	Packet Error Control
Version Number (=0)	Type (=1)	Data Field Header Flag	Applica-tion Process ID	Sequence Flag	Sequence Count					
3	1	1	11	2	14					
16				16		16	Variable	Variable	Variable	16

CCSDS packet format

Packet Header (48 Bits)						Packet Data Field (Variable)			
Packet ID				Packet Sequence Control		Packet length	Data Field Header (Optional)	Application Data	Spare	Packet Error Control
Version Number (=0)	Type (=1)	Data Field Header Flag	Applica-tion Process ID	Sequence Flag	Sequence Count					
3	1	1	11	2	14					
16				16		16	Variable	Variable	Variable	16

CCSDS Secondary Header Flag	TC Packet PUS Version Number	Ack	Service Type	Service Sybtype	Source ID	Spare
Boolean (1 bit)	Enumarated (3 bits)	Enumarated (4 bits)	Enumarated (8 bits)	Enumarated (8 bits)	Enumarated (n bits)	Fixed BitString (n bits)

PUS packet format (TC)

CCSDS packet format

Packet Header (48 Bits)							Packet Data Field (Variable)			
Packet ID				Packet Sequence Control		Packet length	Data Field Header (Optional)	Application Data	Spare (Optional)	Packet Error Control
Version Number (=0)	Type (=0)	Data Field Header Flag	Applica-tion Process ID	Sequence Flag	Sequence Count					
3	1	1	11	2	14					
16				16		16	Variable	Variable	Variable	(Optional)

Spare	TM Packet PUS Version Number	Spare	Service Type	Service Sybtype	Packet Sub-Counter	Destination ID	Time	Spare
Fixed BitString (n bits)	Enumarated (3 bits)	Fixed BitString (4 bits)	Enumarated (8 bits)	Enumarated (8 bits)	Unsigned Integer (8 bits)	Enumarated (n bits)	Absolute Time	Fixed BitString (n bits)

PUS packet format (TM)

PUS Advantages/Constraints

PUS advantages :

- Packet format used for ground / board communications (ECSS-E-70-41)
- PUS may become a reference standard for board to board communication (e.g. formation flying)
- Packets which shall be received and sent by CDMU to a unit are already in PUS format : central s/w is a “mail box” which transmit message to the unit or to ground
- Possibility to use ACK function in order to Guarantee packet transfer

PUS constraints :

- Not adapted to store information into registers (contrary to RMAP)
- Not useful to configure Routers and module ports and to interrogate their status
- Some overhead reduce the bandwidth
- If used to manage an instrument, all the instruments of the spacecraft should use it for harmonization purpose of the spacecraft

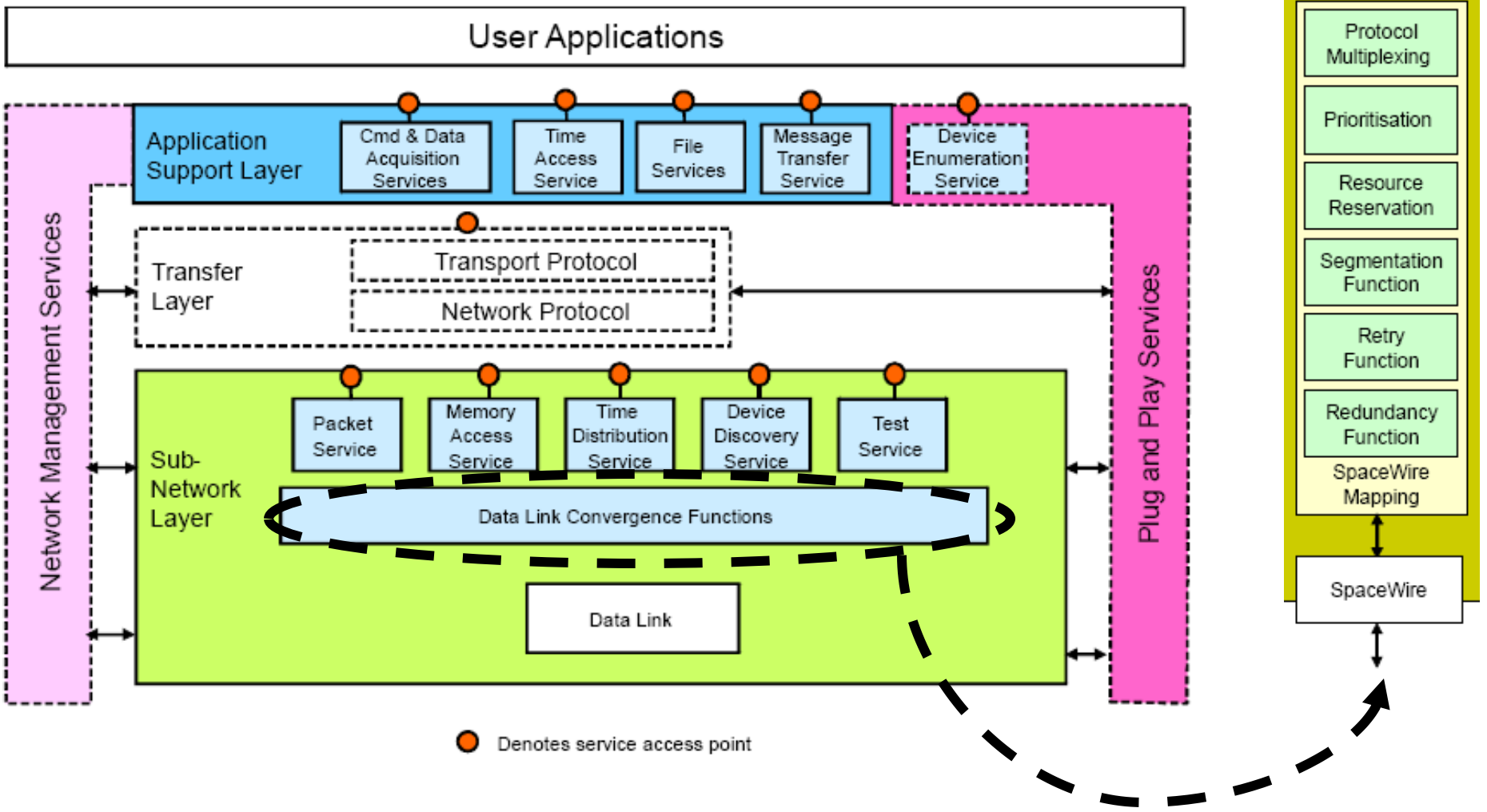
RMAP Advantages/Constraints

RMAP advantages :

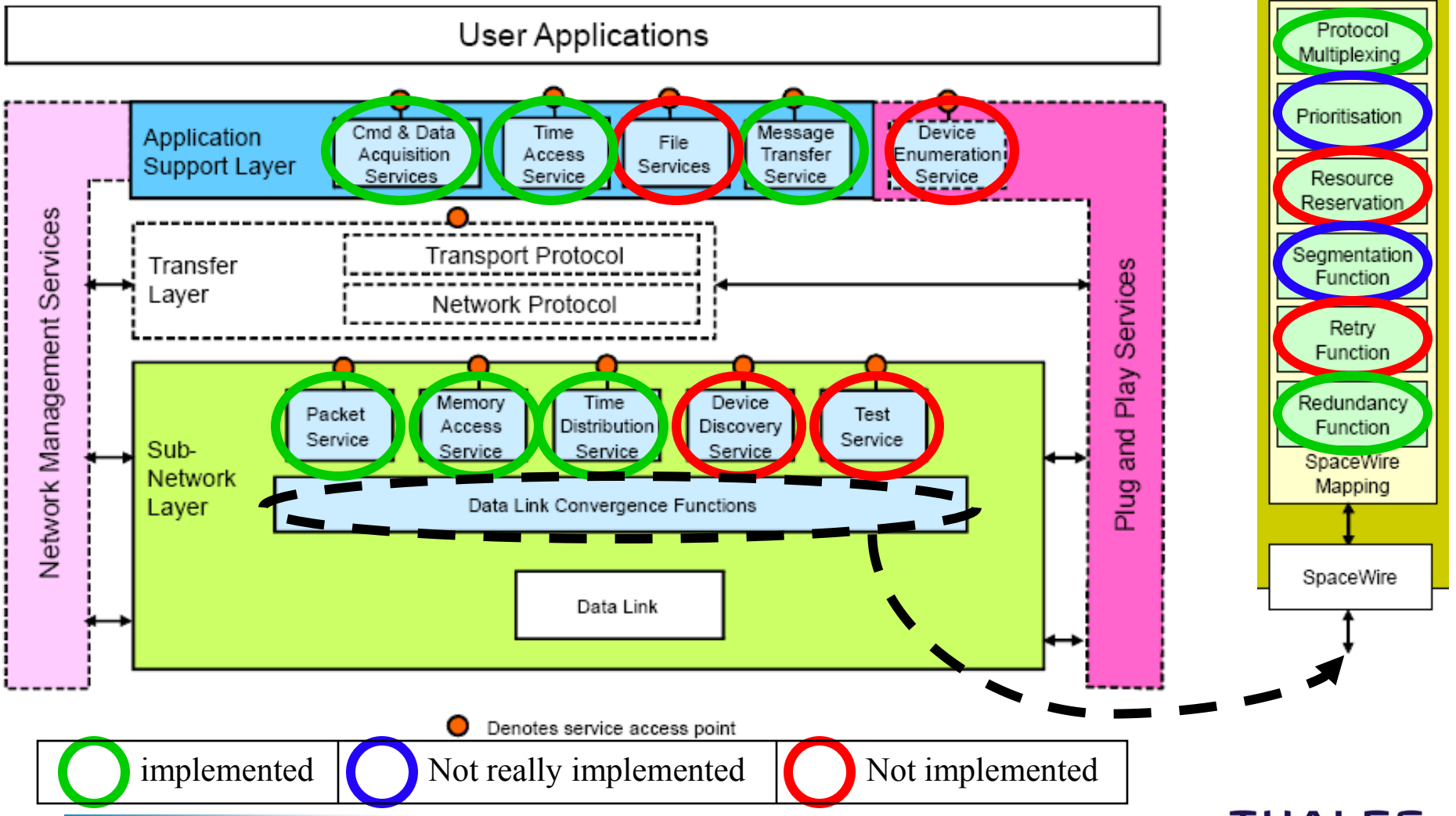
- Permit to configure Routers and module ports and to interrogate their status
- Store information at drivers level (Mass Memory principle)
- Guarantee packet transfer using ACK option

RMAP constraints :

- Not used for ground/board TM/TC communication (contrary to PUS)



SOIS services applied to TAS Avionics Software



Used ways :

- **RMAP commands to interrogate Router and module ports status**
- **RMAP READ commands (with data length = 0) to evaluate network bottlenecks (PING principle as Internet)**
- **HK packets generated by each modules transmitted to CDMU containing the following informations :**
  - Mode & status of SpaceWire units
  - Number of EEP
  - Number of lost HK packets
  - Number of lost Science packets
  - Number of lost time-codes
  - Number of synchronization packets
  - Number of sent packets by each units
  - Evolution of the traffic fluidity onto the network
- **In future, it should be possible to define a specific protocol in order to detect and recover failures via specific procedures.**

THALES ALENIA SPACE believe that system approach is mature enough to start major development of spacecraft based on SpaceWire network

- **Remaining open points to get the SpW more reliable :**
  - **standardize a synchronous protocol to get SpW behavior more predictable**
  - **standardize FDIR mechanism**