Towards SpaceWire Plug-And-Play ECSS Standard

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Background

1. SpaceWire:
    a. initiated by ESA
    b. allows embarking high speed data networks on board spacecraft
    c. widely adopted by ESA missions and other agencies and industries
2. SpaceWire: highly flexible and capable communication system
    a. physical and data-link layers of the ISO Open Systems Interconnection (OSI) basic reference model
    b. + a number of features which fit into the ISO network layer
    c. a certain degree of interoperability, further extended by PID, RMAP and CPTP
3. Limitation: SpaceWire networks must still be designed, constructed, and configured carefully for a given application

“Network Discovery Protocols” R&D contract

1. SpaceWire working group on Plug And Play (PnP)
    a. European and US experts from industry as well space agencies
    b. draft protocol specification for network discovery and the detection of configuration changes in the network
    c. objective: support rapid integration of future spacecraft subsystems
2. Current draft SpaceWire PnP protocol
    a. based on the syntax and synchronisation rules of RMAP
    b. quite advanced
    c. must be completed and validated through breadboarding, verification, and demonstration
    d. in view of its standardisation in the frame of ECSS
3. “Network Discovery Protocols” R&D contract
    a. kicked off in October 2011
    b. funded under the ESA TRP
4. overall goal: further define design, breadboard, test, and validate a SpaceWire PnP protocol
    a. detail design and description
    b. implementation derived from existing SpaceWire equipment (FPGA and SW)
    c. functional tests and overall demonstration

Objectives

1. SpaceWire does not offer a standard mechanism for detecting the topology of a network, or what devices are attached to it. Nor does it offer a standard mechanism for configuring the various aspects of a SpaceWire network, such as links and switches. SpaceWire also lacks standard features to assist detection or configuration beyond the network, in the service domain. It is the aim of the SpaceWire-PnP protocol to add these features, within the scope of what is practical.
2. The first objective of this activity is to design a SpaceWire Plug And Play protocol that fulfils all these needs and to describe it in a form as close as possible to current ECSS writing rules in order to prepare for later standardisation of this protocol at European level.

Objectives - Basic Principles of Plug-And-Play

1. provide standardised, interoperable mechanisms for performing key functions associated with SpaceWire networks
2. 'Plug And Play' originates from the commercial electronics market
    a. a range of techniques were developed to improve the user experience of device integration
    b. for space users, interface two or more arbitrary devices without the need for configuration
3. Plug-And-Play generally involves two key aspects:
    a. Automatic discovery and configuration of hardware and software systems in response to changes in physical interfacing or availability, including whilst the system is running ('hot plugging'); in other words, the capability to detect any connection or disconnection of Plug-And-Play enabled devices.
    b. Detection, registration, and configuration of the services that a newly connected Plug And Play enabled device provides; as well as detection and de-registration of the services that a newly disconnected Plug-And-Play enabled device was providing.

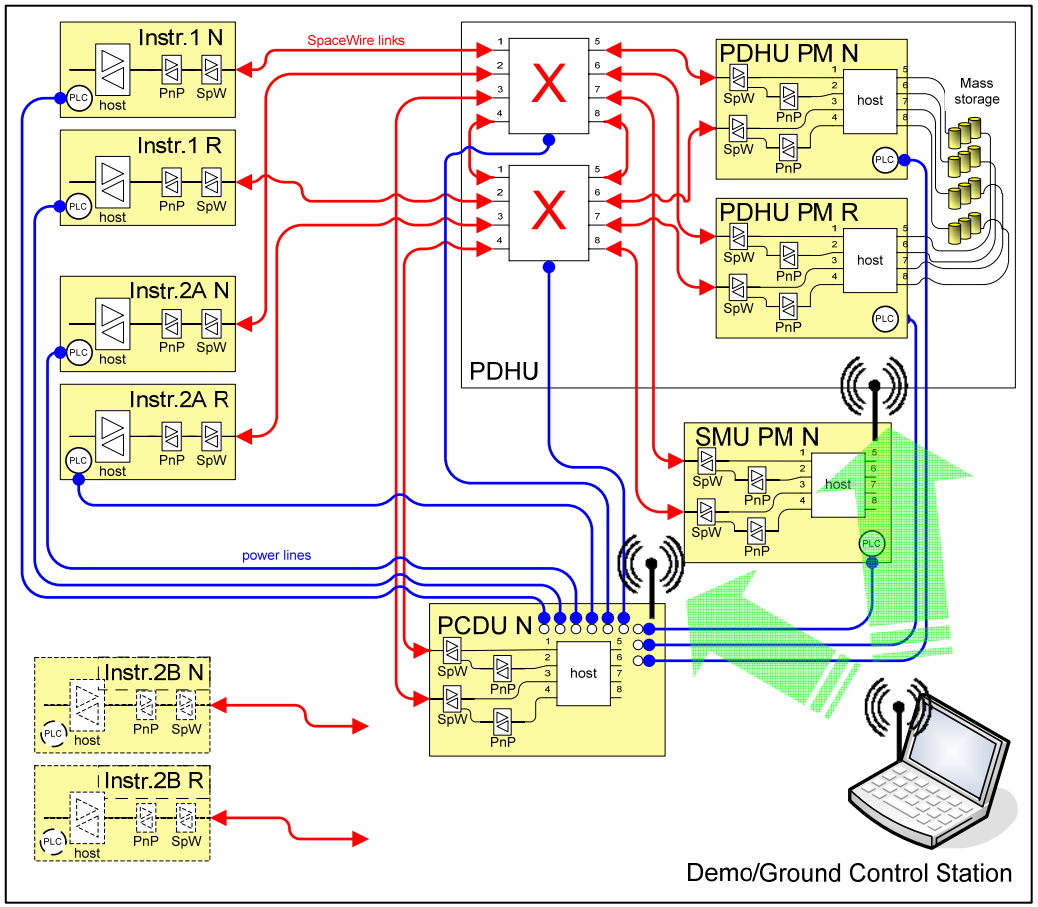
Objectives - Full Compatibility with the Current SpaceWire Standard Suite

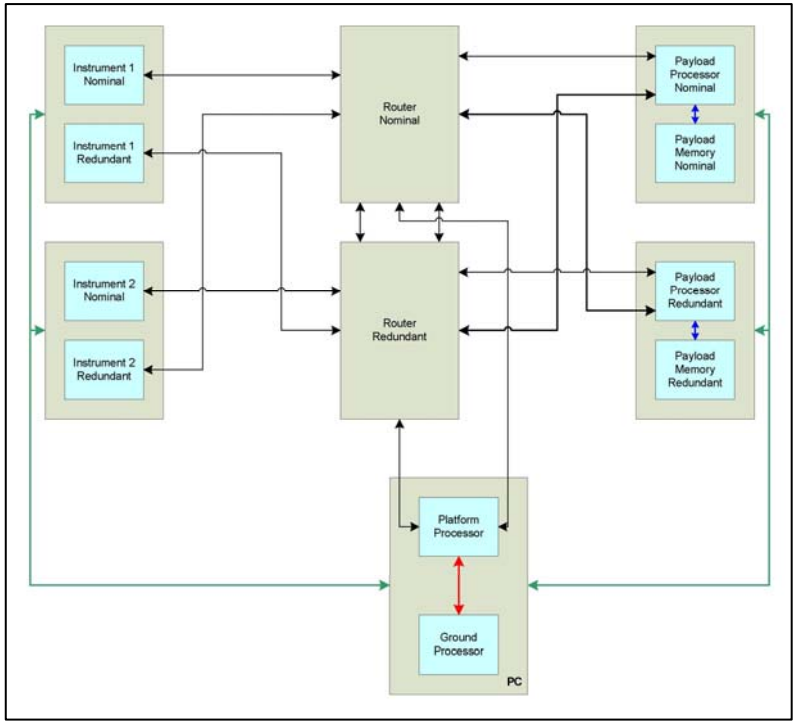
1. The overall goal of the SpaceWire-PnP standard is interoperability at the Network Level
    a. services to discover, identify and configure the features of a SpaceWire network
    b. Nodes and switches as defined by the next revision of the SpaceWire standard (Revision 1, end of 2012)
2. SpaceWire-PnP should not require devices to support more of the SpaceWire standard than is required to achieve their objectives
    a. if something is optional in the SpaceWire standard, SpaceWire-PnP should not require that it be implemented

Objectives – Validation (1/2)

1. The second objective of this activity is to implement and test the SpaceWire network discovery and configuration capabilities of the Plug-And-Play protocol and techniques over a real SpaceWire network
    a. testing of each protocol feature whenever possible
    b. demonstration of the overall capabilities of the protocol
    c. *From the testing and demonstration, recommendations for improvements will be derived which will support the process of standardisation of the SpaceWire Plug-And-Play protocol.*
2. For the validation of these new features at breadboard level, the test setup should be mainly based on existing SpaceWire equipment modified and upgraded with the Plug-And-Play capabilities.

Objectives - Validation (2/2)

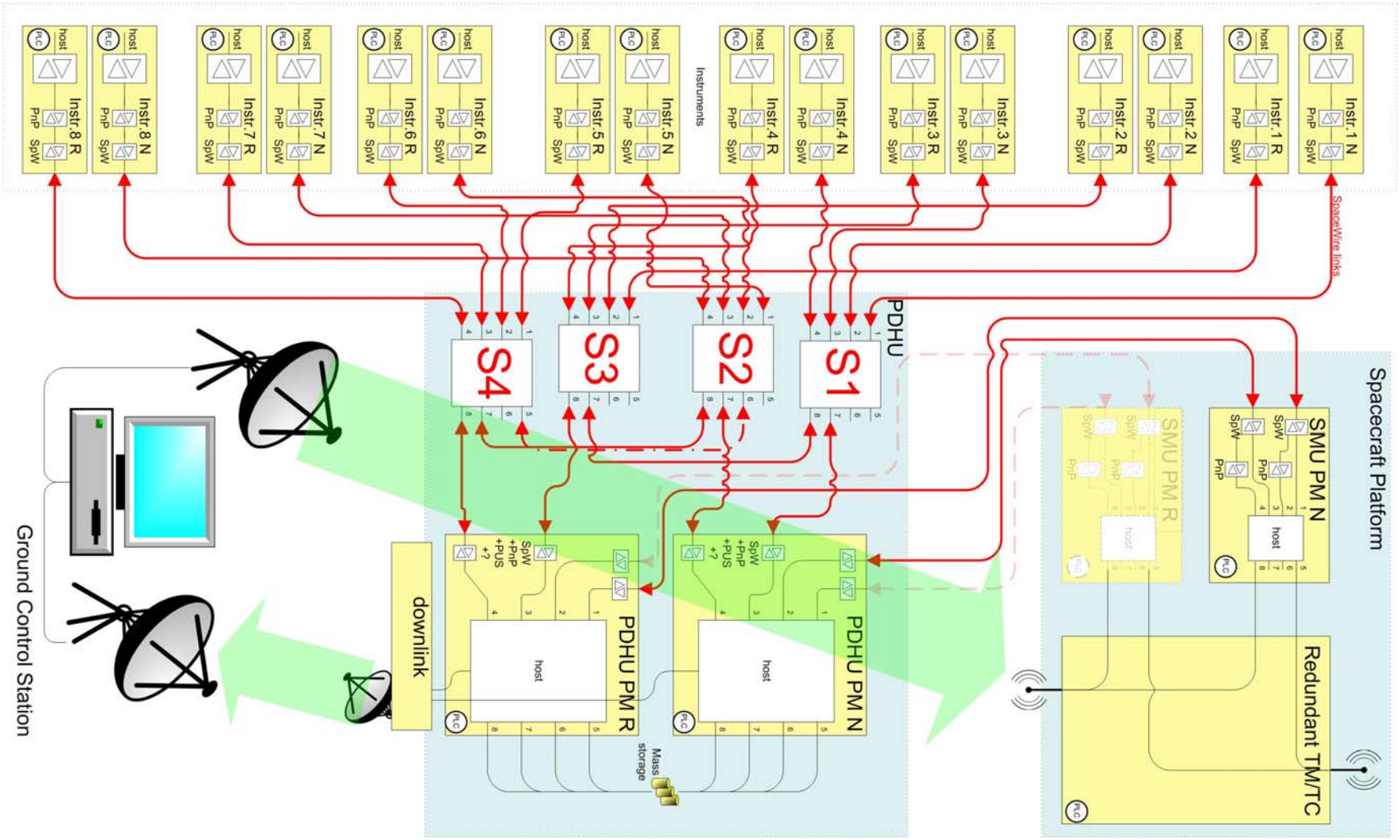




Considerations on Network Discovery

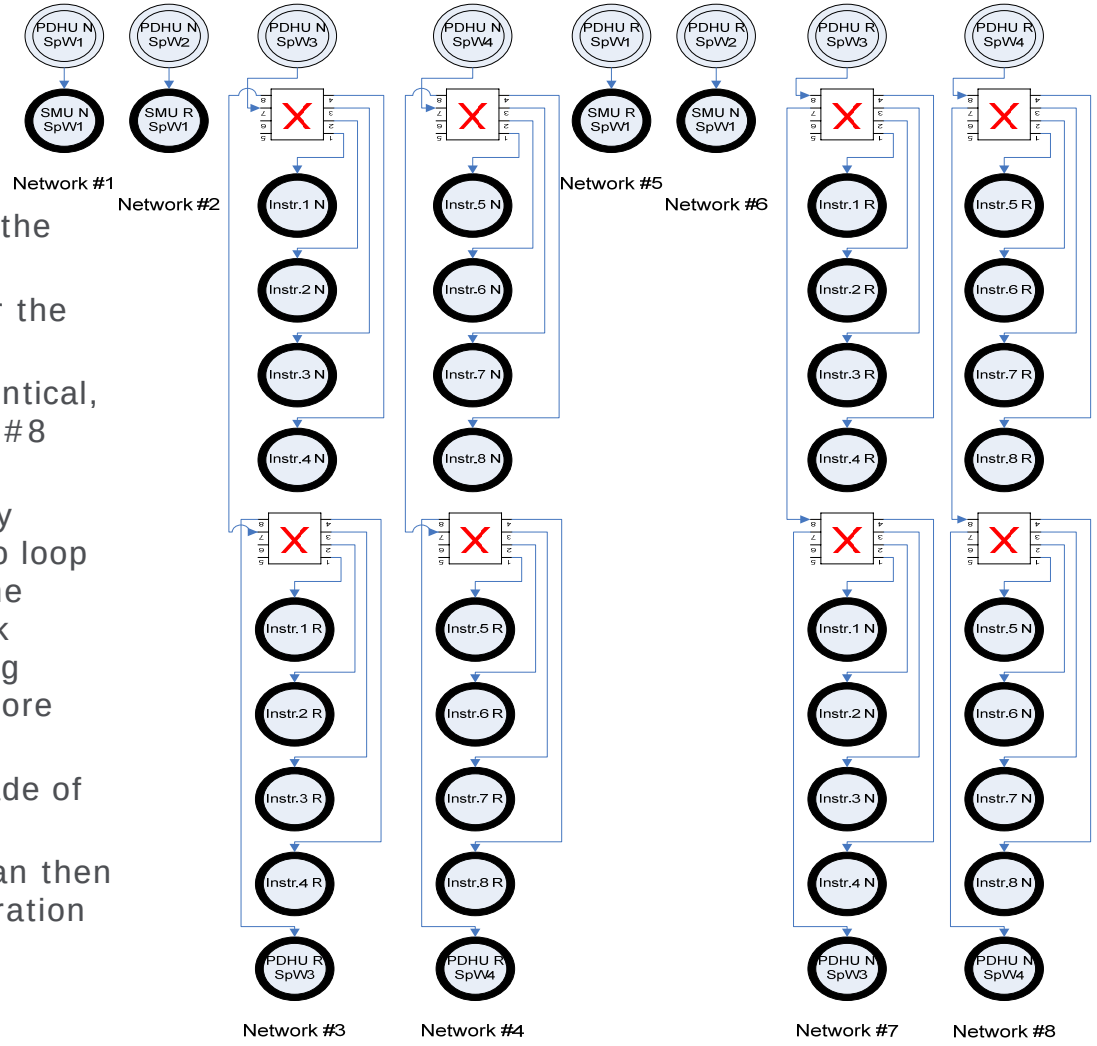
1. Plug-And-Play
    a. Network discovery (simple & universal ?)
    b. Discovered network configuration (complex: engineering culture and system dependent)
2. Network Discovery or at least the discovered network topology, has a great influence on network configuration
    a. Discovered network topology depends on definition of node (unit or SpW I/F inside a unit)
3. Definition of node
    a. International telecommunication standards (mainly ITU)
    b. Theoretical considerations on configuration port
    c. Examples from current missions, based on legacy data handling (SW) architecture

Network discovery - Linear networks



Network discovery - Linear networks

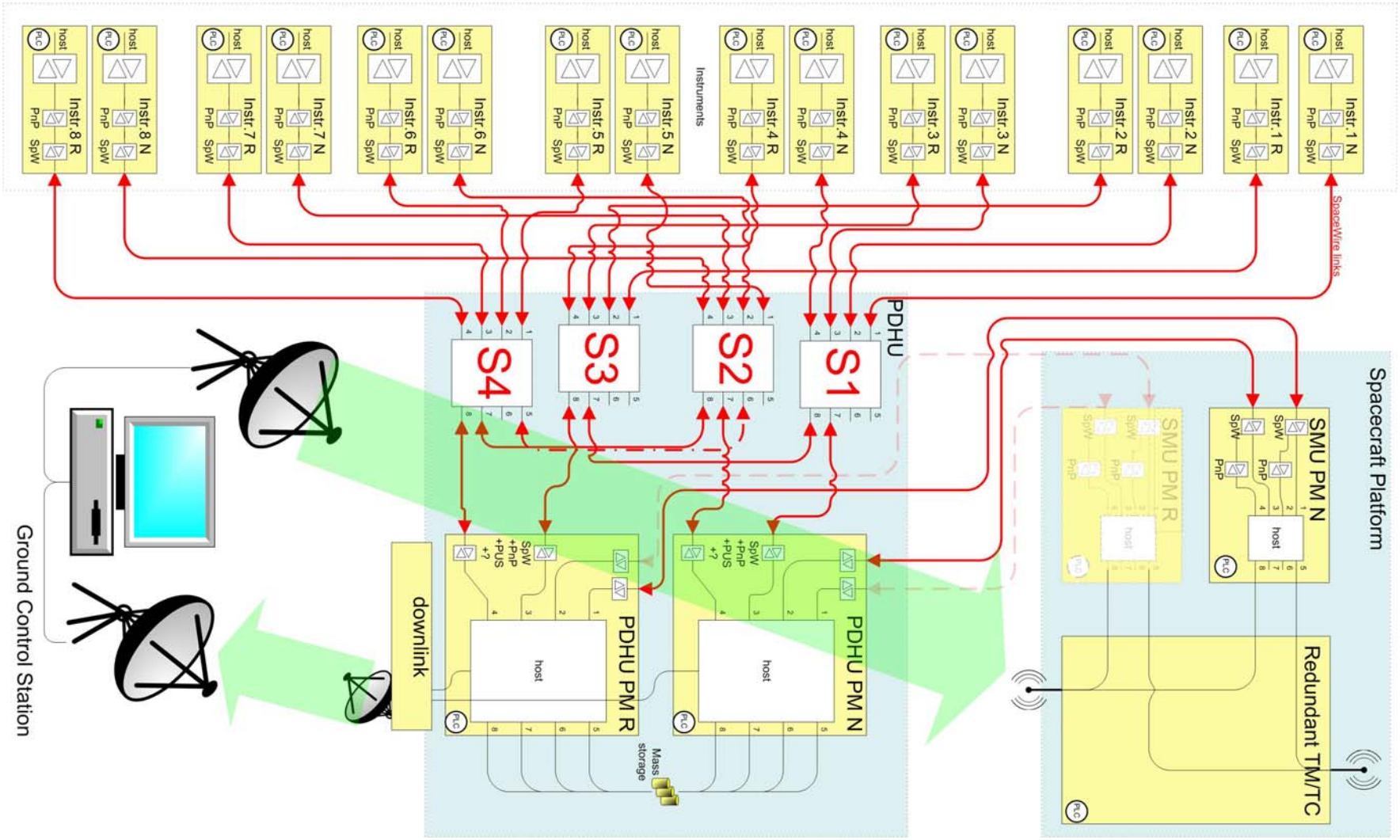
1. the SpaceWire link in dotted lines between the two central switches (S2 and S4) is not connected
2. the network is discovered from each of the Payload Data Handling Units (PDHU)
3. according to the algorithm baselined for the SpW PnP protocol
    a. networks #4 and #7 are identical, as well as networks #3 and #8
    b. although the on-board data systems network seems very complex, there is actually no loop in the explored networks; the second phase of the network discovery algorithm (merging nodes or networks) is therefore not required in this case
4. This on-board data system is in fact made of six linear networks.
5. The SpaceWire Plug-And-Play service can then proceed with the discovery and configuration of the services provides by each of the terminal nodes in each network.



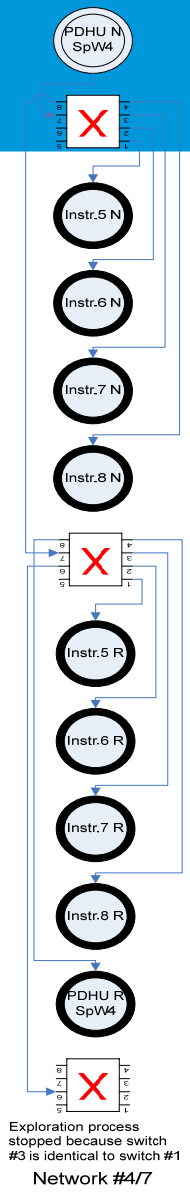
Network discovery - Linear networks

1. The configuration of logical addresses for these six networks is straightforward
    a. they contain no loop
    b. configuration can be fully handled by the SpaceWire Plug-And-Play service
    c. the six networks being independent, the same logical address may be assigned to the four SpaceWire interfaces of the PDHU, which might reduce the complexity of the applications running on other terminal nodes (instruments and Spacecraft Management Unit – SMU)
    d. the same applies to the two SpaceWire interfaces of the SMU
    e. for the same purpose, it is also possible to assign the same logical address to the Nominal and Redundant SpaceWire interfaces of each instrument, provided that the switching tables in each switch is carefully designed.
2. With this scheme, it is even possible to allow GAR between the two switches to enable SpaceWire-level automatic FDIR.

Network discovery – Non-linear networks with simple loops 1/2



Network discovery – Non-linear networks with simple loops 2 / 2

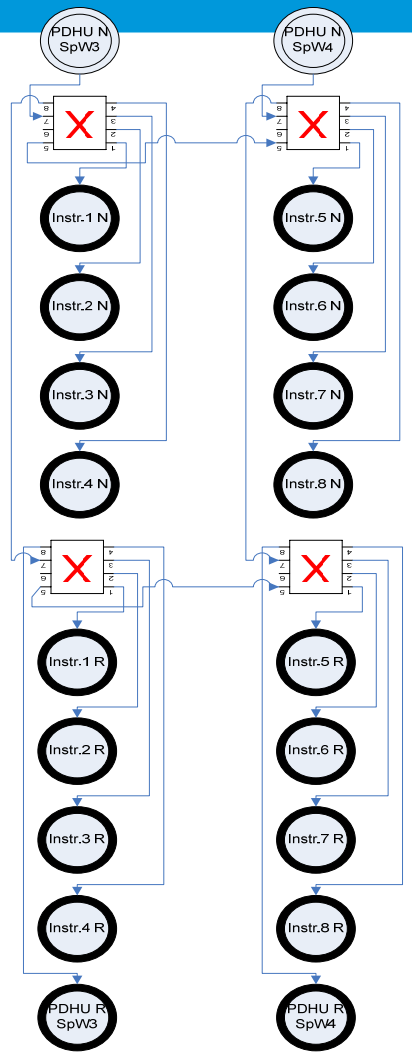


Network #4/7

1. We now assume that a second link is connecting the two central switches (the SpaceWire link in dotted lines between switches S2 and S4 in Figure 2 is now connected) in order to accommodate more data rate between these two switches.
2. A simple loop is introduced in network #4/7.
    a. Since this loop involves only two switches, the node merging phase of the network discovery algorithm is straightforward
    b. and the assignment of logical addresses can follow the same pattern as described for the previous case (linear network).

Network discovery – Non-linear networks with complex loops 1/2

1. If we want to increase even more the possibility of using redundant paths in case of failure, we can connect switches S1 and S2 together via an additional SpaceWire link, as well as switches S3 and S4. This introduces a complex loop and increases significantly the number of possible paths from one terminal node to another, e.g. from an instrument to the PDHU.
2. A reasonable network discovery algorithm would now consider this physical network as only one logical network, assigning different logical addresses to each of the terminal nodes, and therefore to different SpaceWire interfaces of the same spacecraft unit (e.g. the PDHU), although this might not be the preferred option for the system spacecraft designer.
3. This advocates for the SpaceWire Plug-And-Play services to be complemented with some tools allowing Computer Aided Design (CAD) of SpaceWire networks.



Network #3+4

European Space Agency

Conclusion

1. Once designed, formally verified, breadboarded, and validated, the Plug-And-Play services and protocol developed in the frame of the “Network Discovery Protocols” ESA R&D contract will be handed over to the SpaceWire Working Group for endorsement. They will then be subject to formal standardisation by the European Cooperation for Space Standardisation (ECSS).
2. This paper also showed the need for the SpaceWire Plug-And-Play services to be complemented with some tools allowing Computer Aided Design (CAD) of SpaceWire networks. Such tool should be specified by the SpaceWire Working Group. Its breadboarding and validation could possibly be supported by ESA R&D activities.