Proposed SOIS Plug-and-Play Architecture and Resulting Requirements on SpaceWire Mapping

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Distributed, Real-Time, Embedded Systems

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Overview

- Existing CCSDS SOIS Architecture

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  - ⇨ Example Switching on of a Device

- Requirements on SpaceWire Mapping

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Existing CCSDS SOIS Architecture
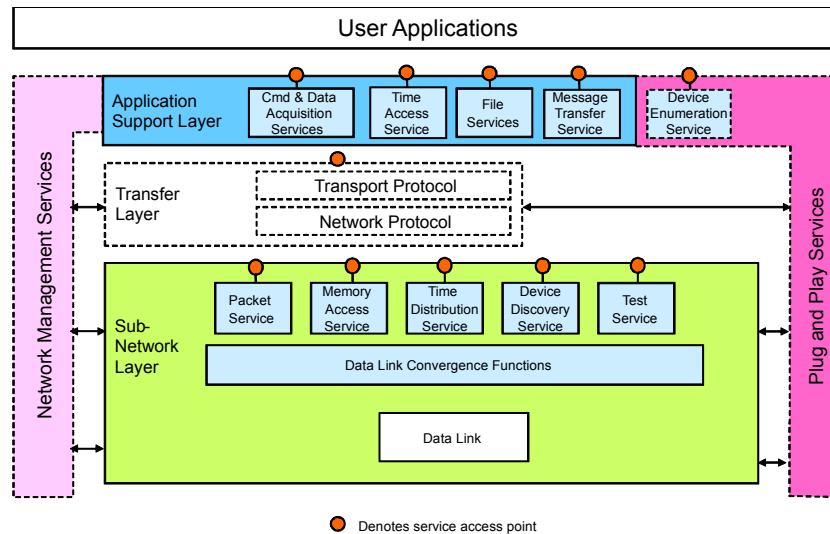
- **Command and Data Acquisition Services**, that provide mechanism for commanding of and acquiring data from devices within a spacecraft;
- **Message Transfer Service**, that provides transfer of messages between software applications within a spacecraft;
- **Packet Service**, that provides transfer of packets between data systems within a subnetwork of a spacecraft;
- **Memory Access Service**, that provides access to memory locations of a data system from another data system within a subnetwork of a spacecraft.

Existing CCSDS SOIS Architecture

- The first set of standards is currently being reviewed by the various Space Agencies.

- ECSS are currently developing protocols to provide the mappings onto SpaceWire and MIL-STD-1553B and a similar exercise is planned in 2008 for CAN.
  - ⇨ For SpaceWire, the RMAP protocol is suitable for the SOIS Memory Access Service and the SpaceNet project is producing a specification and prototyping a SpaceWire packet protocol for the SOIS Packet Service.

- However, these standards only address a static or top-down configured communications architecture. In addition, support for "wireless" capabilities is being considered and by their nature can result in a more dynamic communications architecture.

- To address these issues, it has been identified that the SOIS architecture needs extending to support "plug-and-play" concepts and a "Birds-of-a-Feather" (BoF) grouping has been organised to address this.

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Plug-and-Play Requirements

- Definition of "Plug-and-Play"

- SOIS Plug-and-Play Use Cases

- SOIS Plug-and-Play Requirements

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Definition of "Plug-and-Play"

- **"Plug and play** is a computer feature that allows the addition of a new device, normally a <u>peripheral</u>, without requiring reconfiguration or manual installation of <u>device drivers</u>. ... Modern plug-and-play includes both the traditional boot-time assignment of I/O addresses and interrupts to prevent conflicts and identify drivers, as well as <u>hotplug</u> systems such as <u>USB</u> and <u>Firewire</u>." – www.wikipedia.com

- In the context of the Spacecraft domain, **Peripherals** should include:
  ⇨ onboard computing modules (processing, IO and mass memory)
  ⇨ devices traditionally associated with avionics
    ↳ simple (e.g. thrusters, magnetometers, thermistors)
    ↳ more complex (e.g. star trackers)
  ⇨ simple instruments

- **Plug-and-Play** doesn't extend to full integration of whole sub-systems (as this includes software not device integration)
  ⇨ However, it does have a role in simplifying integration at the subnetwork layer

- **"SOIS Plug-and-Play** is the mechanisms necessary to establish communication services between two data systems in a spacecraft's onboard (sub-)network, without requiring reconfiguration or manual installation of device drivers by any user (higher-level service or OBSW application)." – Stuart Fowell!

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SOIS Plug-and-Play Use Cases

- **Dynamic Spacecraft Network Reconfiguration** – activation of redundant devices upon a flying spacecraft in response to faults. A Fault Detection, Isolation and Recovery (FDIR) system application simply powers up replacement. Reconfiguration happens automatically (bottom-up), rather than hierarchically (top-down)

- **Spacecraft Integration & Test** – Electrical Ground Support Equipment (EGSE) connection to Spacecraft under test using wireless technologies

- **Rapid Spacecraft Assembly of Devices** – to reduce/eliminate the need for aspects of Spacecraft database for configuring OBSW

- **Biometric Health Monitoring of ISS/Orbiter crew** – characterised as facilitating the incorporation of heterogeneous sensing and control devices in a wireless, heterogeneous communications network

Use Cases out-of-scope for SOIS Plug-and-Play (though that is not to say that SOIS Plug-and-Play may not have a role to play within them):

- **Onboard Software Upgrade or Reconfiguration** – covering mode changes or software updates. This is purely a software change with no new data systems introduced

- **Rapid Spacecraft Assembly of Subsystems** – SOIS Plug-and-Play simplifies at the subnetwork integration of subsystems, but also requires exchange of info. using perhaps a s/w framework or middleware, beyond the present scope of SOIS. However, a s/w framework would exchange messages using Message Transfer Service so SOIS Plug-and-Play aids but does not fully solve this

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SOIS Plug-and-Play Requirements

Support mechanisms to:

- discover new data systems added to a SOIS subnetwork;
    - ⇨ powered up, mechanically inserted, electing to enter e.g. sending announcement packet

- discover old data systems removed from a SOIS subnetwork;
    - ⇨ switched off, failed, mechanically removed, out of range, electing to withdraw

- discovery of capabilities of added data systems;

- reconfigure SOIS communication services to allow communication to and from added data systems;

- reconfigure SOIS communication services to disallow communication to and from removed data systems;

- to notify users (applications and higher layer services) of added and removed data systems and their capabilities.

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Tentative SOIS Plug-and-Play Architecture

- Plug-and-Play Technologies and Studies

- Proposed SOIS Plug-and-Play Architecture

- Example of Switching on of a Device

Plug-and-Play Technologies and Studies

- **USB 2.0** – ubiquitous serial bus for data exchange between host computers (typically PCs) and a wide range of simultaneously accessible peripherals

- **IEEE 1451** – a standard for a Smart Transducer Interface for Sensors and Actuators, designed to ease connectivity of sensors and actuators into a device or field network

- **1-wire** – a device communication bus system from Dallas Semiconductor that provides low-speed data, signalling and power over a single wire

- **wireless technologies** – by their very nature of integrated independent data systems, wireless technologies support plug-and-play concepts

- **BioNet** – BioNet is a network-transparent device-driver and application-client framework. It is a general middleware solution for the integration of disparate data-producing endpoints over heterogeneous wired and wireless networks

- **SpaceWire Plug-and-Play Prototyping** – primarily focussed on SpaceWire network mapping and router (re-)configuration

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Proposed SOIS Plug-and-Play Architecture
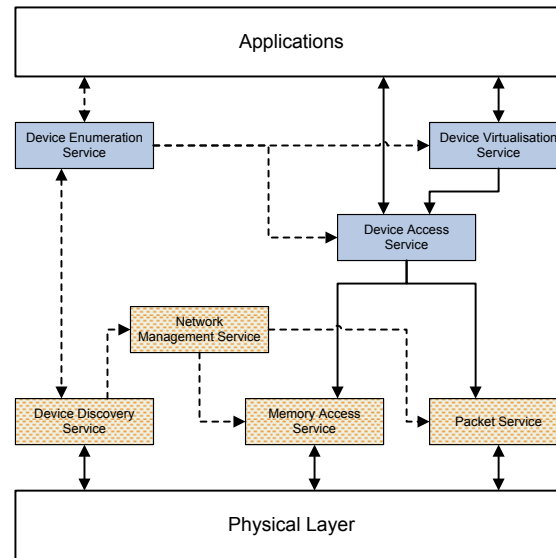
- **Device Enumeration Service**, which is responsible for managing the discovery of a new device and its insertion into the SOIS communications architecture.
- Subnetwork **Device Discovery Service** is used to discover new devices.
  - ⇨ This may implement a specific discovery mechanism, e.g. by broadcasting for new devices, or react to a subnetwork-specific event, e.g. a trigger that a new device has been powered up or inserted into the subnetwork.
  - ⇨ Also responsible for allocating or obtaining a subnetwork-specific address for the new device.
  - ⇨ Allows the Subnetwork Layer Services to be reconfigured to allow communication from within the SOIS communications architecture with the new device.
- Subnetwork **Network Management Service** is responsible for any reconfiguration of the Subnetwork Layer services that may be required
  - ⇨ e.g. updates to SpaceWire Router GAR Tables.
- **Electronic Data Sheet** (EDS) defines the device type and capabilities (e.g. functions, protocols and classes-of-service supported).
  - ⇨ Together with the subnetwork-specific address of the new device, allows the Command and Data Acquisition Services and/or Message Transfer Service to be reconfigured to allow application-level communication with the new device.
  - ⇨ Either Subnetwork Memory Access or Packet Service will be used to obtain the device's EDS.

Example of Switching on of a Device

1. Device is powered up.

2. Subnetwork Device Discovery Service discovers the device and either discovers its address or allocates it.

3. Subnetwork Network Management Service performs any necessary configurations to allow communication with the device from any other data system in the subnetwork.

4. Device Enumeration Service is notified of the new device, including its address. The Device Enumeration Service uses the Subnetwork Memory Access Service to read the device's EDS to discover its capabilities, e.g. device class. The device may be configured to a default setting.

5. Device Enumeration Service configures the Device Virtualisation Service and Device Access Service so that users may command and acquire data from the device.

6. Finally, Device Enumeration Service notifies a registered OBSW application that a new device has been plugged into the system.

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Requirements on SpaceWire Mapping

- Given the current status of the SOIS Plug-and-Play initiative, anything said here must be considered speculative!

- To date the SpaceWire community have focused on network mapping and discovery of attached and detached nodes. These map nicely to the functionality of the SOIS Device Discovery Service.

- The Device Enumeration Service will require a standardised mechanism to discover the capabilities of a node is required, i.e. provision of the device's EDS.
  - ⇨ RMAP provides a generalised method that can be used to access the EDS data.
  - ⇨ Where is EDS located, what address is it at? Is this standardised or perhaps dynamically obtained?
  - ⇨ The content of the EDS (structure, types, etc.) remains to be defined. Probably it will not be specific to SpaceWire.

- So far, SOIS Plug-and-Play Architecture has primarily focussed on SpaceWire. It must encompass other bus types, both wired and wireless. The diverse requirements and technologies must be taken into account in the difficult balancing act between the contradictory requirements of the genericity of the SOIS architecture and the resource constraints of actual spacecraft.

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And finally...

- The next CCSDS SOIS meeting is 1st-5th October 2007 at Heppenheim, Germany (nr. ESOC, Darmstadt)

- Dedicated session on SOIS Plug-and-Play BoF to define Concept, Use Cases and Requirements

- Starting point is this Paper

- All comments and feedback gratefully received and attendees welcome

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