APPLICATION OF THE SPACEWIRE PLUG-AND-PLAY PROTOCOL

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ABSTRACT

The proposed SpaceWire Plug-and-Play (SpaceWire PnP) protocol [SpaceWire PnP working group 2007] provides an infrastructure for network management. The protocol defines a set of common features (i.e., parameters and behaviors) to facilitate recognition of and interaction between SpaceWire PnP devices. Network management involves the automatic discovery of arbitrary network topologies, the configuration of device parameters to establish communication, and the timely detection of changes to the network. Network discovery entails the recognition of the type of each device (i.e., router or node) encountered, the identification of key device characteristics, and the mapping of the connections between devices. The facilities provided by the SpaceWire PnP protocol can be used for network discovery and configuration in several different ways depending upon the specific network management approach. The SpaceWire PnP protocol provides mechanisms for arbitration between multiple network managers to prevent collisions and minimize network traffic in dynamic ad-hoc networks. It also provides support for both polled and asynchronous notifications of changes to the network. Lastly, it offers standard

support for accessing device configuration parameters including those required for Plug-and-Play and those defined by the ECSS-E50-12A SpaceWire standard [ESA 2003] (e.g., routing table, logical address, etc.). We describe each SpaceWire PnP feature and give an example of its use in network management.

1 OVERVIEW OF THE SPACEWIRE PNP PROTOCOL

The SpaceWire PnP protocol provides facilities for identifying and configuring SpaceWire PnP-compatible devices (nodes or routers). The protocol defines exchanges of packets (Read, Response, Write, Reset and Notification) between network managers and network elements to perform network management operations. Each packet is tailored to an operation by the associated data type.

To avoid limiting the functionality of higher-level network manager applications, the SpaceWire PnP protocol is based on a "let software do it" philosophy. For example, Write and Reset transactions do not include acknowledgement packets, so a follow-up Read transaction is necessary to confirm success.

1.1 DATA TYPES AND PARAMETERS

Each SpaceWire PnP data type combines one or more SpaceWire PnP parameters into a convenient structure associated with a specific purpose. A SpaceWire PnP data type is used as the cargo of a SpaceWire PnP packet. Table 1 – SpaceWire PnP Data Types identifies the device parameters included in each data type.

		Data Type														
		Device Description	Active Ports	Device Identifier	Valid Logical Addresses	Arbitration Mode	Port Table Entry	Link Speed Table Entry	Routing Table Entry	Network Manager Identification	Notification Table Entry	Detachment Timeout	Notification Information	xTEDS File	Error	Return Address (implicit)
Device Parameters (Read-Only)																
Parameters	Device Class	√														
	Vendor Identifier	√														
	Subsystem Identifier	√														
	Version	√														
	Ports	√														
General Use Parameters (Read-Only)																
	Incoming Port Number	√														
	Active Ports	√	√										√			
xTEDS Parameters (Read-Only)																
	xTEDS File													√		
Network Discovery Parameters (Read-Write)																
	Device Identifier	√		√												
	Granted Port Number									√						

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		Device Description	Active Ports	Device Identifier	Valid Logical Addresses	Arbitration Mode	Port Table Entry	Link Speed Table Entry	Routing Table Entry	Network Manager Identification	Notification Table Entry	Detachment Timeout	Notification Information	xTEDS File	Error	Return Address (implicit)
	Network Manager Logical Address									√						
Event Notification Parameters (Read-Write)																
Parameters	Detachment Timeout											√				
Parameters	Notification Table Size	√														
Parameters	Notification Table Entry – Acknowledgement Timeout										√					
Parameters	Notification Table Entry – Router Identifier										√		√			
Parameters	Notification Table Entry – Notification Address										√					
Network Configuration Parameters (Read-Write)																
Parameters	Logical Address	√			√											
Parameters	Valid Logical Addresses				√											
Parameters	Arbitration Mode					√										
Parameters	Port Table Entry – Arbitration Priority						√									
Parameters	Port Table Entry – Link State						√									
Parameters	Port Table Entry – Link Status						√									
Parameters	Port Table Entry – Link Speed							√								
Parameters	Port Table Entry – Maximum Link Speed							√								
Parameters	Routing Table Entry – Port Association								√							
Parameters	Routing Table Entry – Header Deletion								√							
Parameters	Routing Table Entry – Arbitration Priority								√							
Parameters	Routing Table Entry – Packet Distribution								√							

Table 1 – SpaceWire PnP Data Types

1.2 PACKET TYPES AND BEHAVIORS

A network manager transmits a SpaceWire PnP Read packet to request a specific SpaceWire PnP data type. The SpaceWire PnP device that receives the SpaceWire PnP Read packet transmits a SpaceWire PnP Response packet to the network return address contained in the Read packet. The SpaceWire PnP Response packet contains the requested data type or the Error data type.

To reduce the chance of conflicting values being written to a device, SpaceWire PnP Write transactions are conditional. The write request fails if the current values of any of the parameters associated with the specified data type do not match the default (reset) values (see Section 2.2.2). A network manager transmits a SpaceWire PnP Write packet containing the specific SpaceWire PnP data type to be modified. The SpaceWire PnP device that receives the SpaceWire PnP Write packet checks the device parameters associated with the data type to determine if all current values are the default (reset) values. If all the parameter values are default, the device replaces them with the packet contents. Since SpaceWire PnP Write packets are not acknowledged, the network manager should confirm the success of the write transaction by reading the data type.

A network manager transmits a SpaceWire PnP Reset packet to reset a specific SpaceWire PnP data type. The SpaceWire PnP device that receives the SpaceWire PnP Reset packet initializes the writable device parameters associated with the data type to the default (reset) value (the network manager issuing the Reset packet does not need to know the default value of the parameters). SpaceWire PnP Reset packets are not acknowledged, so the network manager should confirm the success of the reset transaction by reading the data type.

The SpaceWire PnP Notification packet is optionally transmitted by a SpaceWire PnP router when a notification event is detected. The Notification packet contains the Notification Information data type. The router independently notifies each network manager that has identified itself in the router Notification Table. To ensure reliable event notification, a SpaceWire PnP router can optionally retransmit notification packets periodically until a Read packet requesting the Notification Information data type is received from the network manager.

1.3 SPECIAL CONSIDERATIONS

To identify an unknown device, a network manager reads the Device Description data type. The SpaceWire PnP Device Description data type contains detailed information about the responding SpaceWire PnP device. Since the network manager doesn't know whether the unknown device is a node or a router, the SpaceWire PnP protocol requires that SpaceWire PnP devices support a common packet structure based on the ECSS-E-50-11 Draft B Protocol Identification specification [ESA 2005] augmented with a leading-zero path address.

SpaceWire PnP Read, Write and Reset packets arrive at the destination device with a prefix consisting of single-byte path address (value 0) and a single-byte logical address (value 254 decimal). SpaceWire PnP routers pass the packets to the router configuration port (port 0) for handling. SpaceWire PnP-compatible nodes must accept such packets, but the handling method is implementation-defined.

2 NETWORK MANAGEMENT

Network management can be viewed as consisting of initialization and maintenance phases. Each of these phases performs both network discovery and configuration.

Network initialization can interweave the network configuration and network discovery activities (discover a network element, configure it, and then proceed with discovery). Alternatively, it can be decomposed into a distinct network discovery phase followed by a network configuration phase.

Network maintenance naturally combines the network configuration and network discovery activities when a single network element is added, but can be treated similarly to network initialization when an entire subnet is added.

2.1 NETWORK DISCOVERY

Network discovery is the process of identifying the network topology. It is accomplished by exploring the network, identifying each network element encountered and mapping the connections between the network elements.

The SpaceWire PnP protocol provides the tools for network discovery, but leaves implementation to higher-level network manager applications.

2.1.1 DEVICE RECOGNITION

Device recognition involves two aspects of device identity: (1) the characteristics of the device (e.g., this device is a SpaceWire PnP router with eight ports) and (2) the name of the device (e.g., this is SpaceWire PnP router 25). While the device characteristics are inherent attributes, the device name may be assigned by the discoverer and is a potential source of confusion.

As a network manager explores the network and recognizes each device, it must resolve issues of conflicting identity (devices with the same name) and connectivity (separate links between the same devices, one link identified twice, etc.).

The Device Description data type establishes the detailed description of a SpaceWire PnP device needed for device recognition. The Device Class parameter provides a generic categorization of the device while the Vendor Identifier, Subsystem Identifier and Version parameters combine to form a “fingerprint” for identifying the device in a device database.

The Device Identifier parameter is the primary means of uniquely identifying a specific SpaceWire PnP device on a network-wide basis. Since the defined default (reset) state of the Device Identifier parameter is zero, a non-zero value indicates that the device has been recognized and claimed by a network manager. The assigned Device Identifier value should be unique within the set of devices discovered by that network manager. However, to avoid identity confusion, the Device Identifier must be network-unique, so higher-level network manager applications must communicate with each other to resolve name-space partitioning and device ownership issues. Note that SpaceWire PnP routers with Event Notification support offer a means for each network manager to uniquely identify each router independently using the Router Identifier field in the Notification Table.

2.1.2 IDENTITY RESOLUTION

The SpaceWire PnP protocol provides the Network Manager Identification parameters to aid the network manager applications in finding each other. The Network Manager Identification parameters (Granted Port Number and Network Manager Logical Address) are labeled to indicate their defined purpose, but can be used in any way desired by higher-level network manager applications. The Granted Port Number and Network Manager Logical Address parameters each offer similar capability implemented in different ways.

The Granted Port Number parameter is defined to contain the router port that should be used to send a packet to the network manager that owns the SpaceWire PnP router device. If the owner network manager is directly attached to that router device, then the Granted Port Number parameter value is the full path address to the network manager. If other SpaceWire PnP router devices exist between the initial router device and the owner network manager, they are presumed to be owned by the same network manager and the Granted Port Number parameter value of each router device provides a partial path address to the network manager (note that the Network Manager Logical Address parameter can be used to confirm the presumption of common ownership of intermediary router devices by comparing the logical address values). A second network manager wishing to communicate with the owning network manager can interrogate each device in the chain of Granted Port Number parameter values to determine the complete path address. Note that all intermediary router devices must be SpaceWire PnP compatible (i.e., support the Granted Port Number parameter) for proper functioning of this mechanism.

The Network Manager Logical Address parameter is defined to contain the logical address that should be used to send a packet to the network manager that owns the SpaceWire PnP router device. The owning network manager is presumed to have established valid routing table entries in all router devices between the initial router device and itself. Note that intermediary router devices can be non-compliant with SpaceWire PnP.

2.1.3 TOPOLOGY MAPPING

Topology mapping builds a database (a map) of the network connections. Each network entity and its interconnections are uniquely identified such that all paths between any two network elements are known. A complete and accurate topology map is critical when assembling path addresses between two nodes of a SpaceWire network. A SpaceWire network based on logical addressing can tolerate lesser global topology detail for node-to-node traffic (the routing table in each router must still be locally accurate), but needs a detailed map for router configuration traffic since SpaceWire routers do not have logical addresses.

2.1.4 DYNAMIC NETWORK CHANGES

An important aspect of the SpaceWire PnP protocol is support for dynamic changes to the network topology. The network topology changes when a network element is attached or detached. The change may be minor (a single node) or major (an entire network region, or subnet). If the change is an attachment, the new network region must be mapped and configured (or reconfigured) to merge it with the existing

network topology. If the change is a detachment, the network topology must be pruned to the new boundary.

The Event Notification capability of SpaceWire PnP routers eliminates the need for periodic polling of each router to detect changes to the network. It increases network responsiveness to changes by directly notifying interested network managers as soon as the event is detected. It also reduces the network traffic associated with event detection by limiting interaction to the router that detected the event.

An attachment event occurs when a router port becomes active while in the detached state. A detachment event occurs when a router port stays inactive for a configurable period while in the attached state. The Detachment Timeout parameter establishes the delay between a router port becoming inactive and recognition of the detachment event. Since a port may become inactive due to transient conditions such as error recovery, etc., the Detachment Timeout acts as a filter to reduce the responsiveness of the router to such situations. A notification event is either an attachment event or a detachment event that occurs while the SpaceWire PnP router is configured to issue Notification packets.

When a SpaceWire PnP router detects a notification event, it transmits a Notification packet to each network manager that has configured an entry in the router Notification Table (the packet contains the router identity, the current state of the router ports and the Notification Table entry index).

The Notification Table contains an entry for each network manager supported by the SpaceWire PnP router (the Notification Table Size parameter indicates the number of entries available in the table). Each entry contains a Notification Address field, a Router Identifier field and an Acknowledgement Timeout field. The Notification Address field contains the network address of the network manager to receive the Notification packet. The Router Identifier field is included in the Notification packet to indicate to the associated network manager which router sent the packet. The Acknowledgement Timeout field supports reliable delivery of Notification packets by allowing the associated network manager to specify a delay period before the router retransmits the Notification packet (a Notification Information Read transaction indexed to the Notification Table entry is used to acknowledge the Notification packet).

2.2 NETWORK CONFIGURATION

Network configuration optimizes network behavior. During or after network discovery, the configuration of each network element can be adjusted to conform to the needs of the network applications. The degree of customization performed is dependent on the capabilities of each network element and the choices made by the network architect.

The SpaceWire PnP protocol defines the tools for determining the basic capabilities and customizing the behavior of each network element. Higher-level network manager applications can make use of the basic SpaceWire PnP configuration features to provide additional functionality.

2.2.1 CONFIGURATION RESOURCES

The ECSS-E50-12A SpaceWire standard defines various device configuration parameters (e.g., routing table, logical address, etc.). The SpaceWire PnP protocol defines additional parameters required for Plug-and-Play applications and offers standard support for accessing both types of parameters. The parameters are defined in an abstract manner to allow flexibility of implementation. Any parameters required by the SpaceWire standard and certain SpaceWire PnP parameters needed for network discovery are considered mandatory for SpaceWire PnP compliance. Other SpaceWire and SpaceWire PnP parameters are either mandatory or optional depending upon perceived utility in most SpaceWire applications. Some mandatory parameters could be rendered unnecessary since an implementation might choose to limit the number of allowed values to as few as one.

The Port Table and Routing Table each contain a mix of mandatory and optional parameters. The Port Table fields Link State, Link Status, Link Speed and Maximum Link Speed are mandatory while the Arbitration Priority field is optional. The Routing Table fields Port Association and Header Deletion are mandatory while the Arbitration Priority and Packet Distribution fields are optional.

The optional Arbitration Mode parameter supports routers that implement more than one of the arbitration methods defined by the SpaceWire standard. Similarly, the optional Port Table Arbitration Priority field supports routers that implement priority arbitration between input ports and the optional Routing Table Arbitration Priority field supports routers that implement priority arbitration based on packet addresses.

2.2.2 CONFLICT RESOLUTION

Device configuration can be complicated in complex SpaceWire networks that have multiple simultaneously active network managers. The SpaceWire PnP protocol defines parameters and associated behavior to aid higher-level network managers in resolving collisions between multiple network managers.

Competing network managers that attempt to configure the same network element parameter inevitably create confusion and contention. The SpaceWire PnP protocol provides the conditional-write behavior as a partial solution. The conditional-write behavior is a classic atomic test-and-set mechanism with the test condition predefined by the network element implementation. The current parameter value must match the default (reset) value for the write transaction to succeed. After the parameter value is changed to a new value (and the new value doesn't match the default value), all attempts to overwrite the value will fail. Only a Reset packet selecting the parameter can affect the value.

The conditional-write behavior enforces serial access to a parameter, but does not address a conflict between network managers over ownership of that parameter. Higher-level network manager applications must define a protocol for resolving such conflicts.

The simplest conflict resolution protocol is that device parameters only be reset by the network manager that successfully wrote the current value. A network manager can access the parameter only after the previous network manager has finished using it (a fault in the owning network manager that causes it to leave a shared parameter in a

non-default state must be resolved by a higher-level mechanism, e.g., a time-limit convention between network managers sharing the parameter). While feasible for network discovery, a first-to-use arbitration scheme may not satisfy the optimization needs of the network. A role-based or region-based mechanism can be used to avoid conflicts during network configuration.

With an accurate network topology map, a network manager responsible for configuring the logical address assignments (Routing Tables for routers and Valid Logical Addresses for nodes) can perform that role independently of network managers with other roles (Device Identifier assignment, Link Speed configuration, etc.). Since all network manager roles cover the entire network, each network manager can independently discover the network topology. The only negotiation necessary between network managers is over the roles to be performed by each.

Similarly, with the topology map of a network region and an allocation of Device Identifiers and logical addresses from the network namespace, multiple network managers can independently configure the separate network regions. The non-trivial problem of partitioning the network topology into regions (while avoiding overlaps and gaps) is the most difficult aspect of region-based conflict avoidance. The SpaceWire PnP Network Manager Logical Address parameter can be used to mark region assignments by indicating the network manager responsible for configuring the associated network element.

3 CONCLUSION

The SpaceWire PnP protocol defines capabilities that support discovery and configuration of a network of compatible devices. It is based on a philosophy of providing basic facilities and leaving as much behavior to higher-level network manager applications as possible. The SpaceWire PnP packets and behaviors are transparent to legacy SpaceWire routers (except when addressed to a legacy router).

In addition to the Plug-and-Play facilities that are the primary focus, most features defined by the ECSS-E50-12A SpaceWire standard are explicitly supported by the SpaceWire PnP protocol. The Plug-and-Play features support device identification and event notification, both critical to network discovery and maintenance.

Support for contention resolution between multiple active network managers is included, but the detailed mechanism is relegated to the network manager applications. Similarly, some features are optional to facilitate development of minimal products.

4 REFERENCES

[1] SpaceWire Plug-and-Play Specification: http://tech.groups.yahoo.com/group/SpaceWirePnP/files/Draft%20Specification/

[2] SpaceWire Specification: http://spacewire.esa.int/content/Standard/ECSS-E50-12A.php

[3] SpaceWire Protocol ID Draft Specification: http://spacewire.esa.int/content/Standard/Draft_ECSS-E50-11.php