SUPPORTING OPEN ARCHITECTURE WITH PROFINET

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ABSTRACT

Supporting Open Architecture is a key to most major automation and control suppliers. In every industry, there is a desire to make a unified control system architecture that can easily integrate control system equipment from multiple suppliers. Whether it is a Navy military application or an industrial application, the needs are almost identical. Some of the keys to providing this transparency among control systems are utilizing an open standard that can pull together communications from multiple suppliers.

In this paper, SIEMENS will demonstrate the capabilities of utilizing an open standard, which is PROFINET. By adhering to the PROFINET standards, Open Architecture is achieved at many levels in a naval application. Open Architecture is intended to yield modular, interoperable systems that adhere to open standards with published interfaces. As will be demonstrated by this paper, PROFINET provides these capabilities and more.

By implementing PROFINET as the infrastructure for OA, the military community will see significant increases in its opportunities for innovation and competition by providing an architecture to bring disparate systems from multiple vendors together under a common platform. There will also be the ability to reuse system components, so that reengineering is not always required for every system. In addition, PROFINET will facilitate rapid technology insertion, by allowing for the best product to be used for a particular application. PROFINET also helps to reduce maintenance constraints by providing for increased diagnostics. Because of the need for OA to deliver increased war fighting capabilities in a shorter time at reduced cost, utilizing PROFINET will pull information from multiple systems together more quickly than past systems. Because of the modular concepts, PROFINET will allow for continuous innovative design.

KEY WORDS

Open, Architecture, Siemens, Military, PROFINET

1. INTRODUCTION

Open Architecture as defined on the World Wide Web is:
"An architecture whose specifications are public. This includes officially approved standards as well as privately designed architectures whose specifications are made public by the designers. The opposite of open is closed or proprietary. The great advantage of open architectures is that anyone can design add-on products for it…"[1]

Open Architecture solutions provide several advantages for a ground vehicle, marine or industrial application. First and foremost is that that there is assurance that all of the components, whether from one or more vendors, will operate together. For an automation product, this provides a tremendous reduction in integration time and test. Second, an open architecture solution allows a choice of best in class products to be used for the project. Another major advantage is that components will probably be available for a long time, whether from the same vendor or another, which means that the automation solution will have longevity, or in financial terms a good return on investment (ROI).

In addition to technical considerations and interoperability, other considerations such as market trends and market expectations, are needed to ensure longevity.

This paper explains how PROFINET, one of the industrial communications protocols, meets the requirements of an open architecture solution and is in line with current market trends and expectations.

2. A PROFINET OPEN ARCHITECTURE SOLUTION

2.1 MARKET TRENDS IN AUTOMATION

According to a study by the ARC Advisory Group [2], the current trend and future of automation is in Ethernet based solutions. There is an expected annual increase of 27.5% through year 2012. By the year 2012, the number of Ethernet-Based device networks is expected to reach four million. See Figure 1.

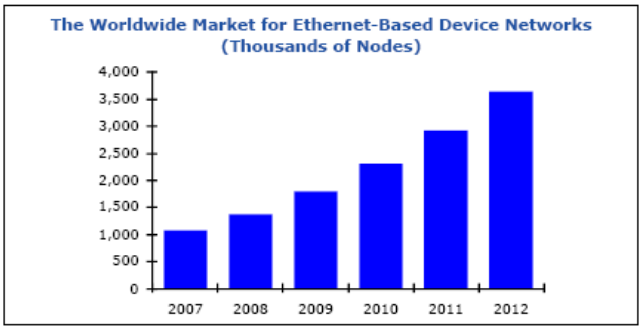

Figure 1: Growth of Ethernet-Based Device Networks

With this data, selecting an Ethernet-Based automation solution would be a good choice to ensure longevity of products and support.

2.2 PROTOCOL STANDARDS

The PROFINET protocol operates via several Ethernet standards which make it a good choice for an open architecture solution based upon the fact that an open architecture solution is based upon standards and the future of automation market analysis shows Ethernet-Based Device networks growing significantly. These protocol standards are [3]:

- IEEE 802.3 – ETHERNET
- IEEE 802.1Q – VLAN Tagging
- RFC 791 – Internet Protocol

- RFC 768 – User Datagram Protocol
- RFC 793 – Transmission Control Protocol
- IEC 61158 – Fieldbus Standard
- IEC 61784 – Fieldbus Profiles

The PROFINET protocol also conforms to the 7 layer Open Systems Interconnect model (OSI) with the PROFINET services residing at layer 7. Figure 2 shows the PROFINET OSU model.

ISO/OSI			
7b	PROFINET IO Services PROFINET IO Protocol		PROFINET CBA acc. IEC 61158 Type 10
7a		Connec-tionless RPC	DCOM Connection - oriented RPC
6		empty	empty
5			
4		UDP	TCP
3		IP	
2	Real-Time Enhancements acc. to IEC 61784-2 IEEE802.3,Full-Duplex,IEEE802.1Q,Priority Tagging		
1	IEEE 802.3 100 Base TX , 100 Base FX		

Figure 2: PROFINET Open Systems Interconnect Model [3]

Based upon the number of International communication standards that PROFINET uses, it is obvious that the PROFINET protocol meets the requirements of an open architecture.

2.3 MULTIPLE PRODUCT SUPPLIERS

As mentioned previously, another advantage of an open architecture solution is that products are available from several vendors. Even though PROFINET is relatively new as an automation communications protocol, there are products from more than twenty suppliers listed on the PROFI website (www.profibus.com). Additionally, more that 1.6 million nodes of PROFINET have been sold as of the end of 2008. This represents an increase of 40% from the previous year. Figure 3 shows the growth chart that is anticipated for PROFINET nodes. [4]

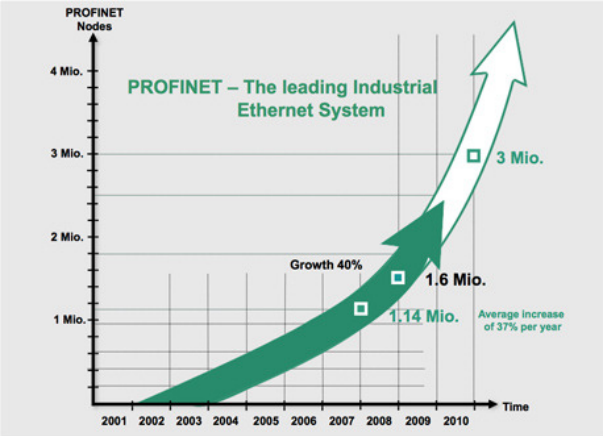

Figure 3: PROFINET Nodes and Anticipated Growth [4]

One of the things that is helping PROFINET is the area of multiple vendors is that it provides on Ethernet the distributed control features that the PROFIBUS Fieldbus protocol has provided for years. PROFIBUS is the most successful Fieldbus protocol in the world with more than twenty-eight million nodes sold. [5]

With this many vendors producing products, a solution using a PROFINET architecture will be supported for many years and will be capable of being enhanced based upon future requirements of the vessel.

2.4 BENEFITS OF USING PROFINET

The previous sections of this paper have provided facts that prove that PROFINET meets the requirements of an Open Architecture solution. Other than just meeting the definition of an Open Architecture solution, PROFINET itself must provide benefits to the user and be capable of performing the automation task that is required by the marine vessel. The following is a list of benefits that PROFINET provides [5]:

- Long runs of hardwired sensor signals are eliminated (with smart instrumentation hardwiring is eliminated) which reduced installation time and costs
- Good asset management due better control and diagnostic functionality
- The ability to choose best in class (high quality) products due to the interoperability with products from multiple suppliers
- The ability operate safety and motion products on the same network
- The ability to integrate PROFINET devices on an existing enterprise-wide network and have global accessibility to them
- Unlimited enterprise-wide node count (based upon product capabilities and network design)
- Compatible with TCP/IP, internet, and web compatibility with Real-Time determinism (RT and IRT)
- Installation and diagnostics can be performed with familiar IT tools
- Networks may be constructed using wireless technology
- Integrates easily with existing automation networks (such as PROFIBUS using link technology products) which protects the existing automation investment
- PROFINET solutions are modular in design which make them scalable and expandable which saves cost during commissioning and future expansion
- The ability to operate I/O devices and peer communication on the same network infrastructure
- PROFINET contains a topology feature that provides the ability for a PROFINET network to automatically configure the network address of a replacement component which reduces maintenance time

From this list of benefits, it is obvious that PROFINET is a prime choice for an automation system.

2.4 KEY FUNCTIONAL ELEMENTS OF PROFINET

PROFINET provides the usual functionality of a Fieldbus network such as communicating with distributed racks on input and output modules. Additionally, PROFINET provides some key functional elements that make it a good automation choice for marine systems. Some of these elements include performance, reduced maintenance time, fast start-up, and connectivity of subsystems from different suppliers.

In the area of performance, PROFINET products primarily operate on 100 megabit networks but some products, such as the SIMATIC WinAC product, will operate on gigabit networks. This ability alone provides very good performance based upon the amount of bandwidth that networks of this speed provide. However, PROFINET provides additional performance capability.

For PROFINET networks and components that control I/O devices, there are two communication options; Real-Time (RT) and Isochronous Real-Time (IRT). On an RT network, the Ethernet packets are sent as high priority. This means that when a PROFINET packet enters an Ethernet switch that supports Quality of Service (QoS) Ethernet packets, the switch will forward the PROFINET packet to its destination before "normal" Ethernet packets such as those used for web functionality or communications with file servers or printers. This means the automation solution get priority on the network. A PROFINET RT solution can exchange data as fast a 1 millisecond. Figure 4 shows an example of PROFINET RT communications.

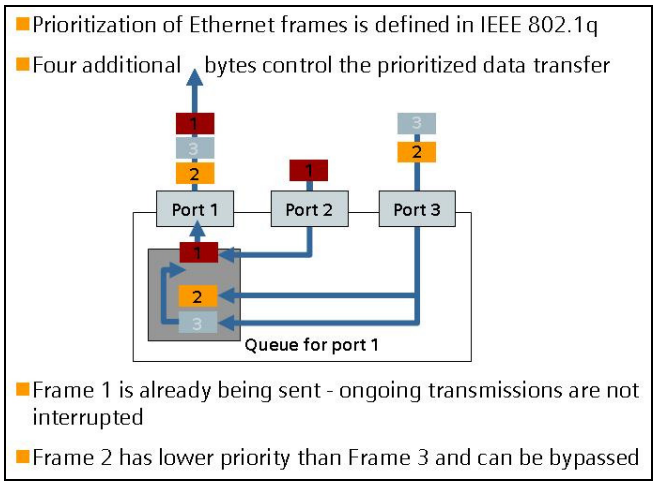

Figure 4: PROFINET RT Packets Entering an Ethernet Switch

Even better performance is achieved using PROFINET IRT. PROFINET IRT requires an Ethernet switch that understands the PROFINET IRT Ethernet packets. PROFINET IRT packets are sent using reserved bandwidth so the packets "cut through" the Ethernet switch ahead of RT and normal packets during the reserved bandwidth time. PROFINET IRT networks can operate as fast as .25 milliseconds. PROFINET IRT is typically used for motion control applications. Figure 5 shows the IRT protocol operation with PROFINET RT and normal Ethernet packets.

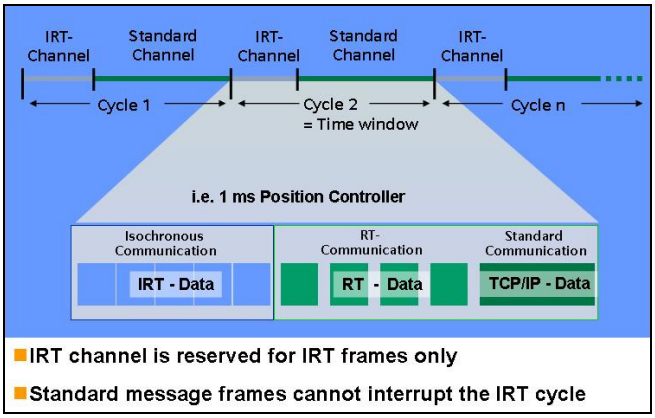

Figure 5: PROFINET IRT Reserved bandwidth

PROFINET solutions can provide reduced maintenance time for maintenance personnel. This is very important when retuning a subsystem to service after component failure or damage. A part of the PROFINET protocol is a Link Layer Discovery Protocol (LLDP) or topology feature which enables each PROFINET node on a network to indentify its network neighbor by type, PROFINET name, and IP address. When a component fails and a replacement is placed installed with a null configuration, the null configuration is an indication to the PROFINET CPU to "auto-configure" the device. Based upon the stored configuration of PROFINET names and IP addresses, the required configuration of the new device can be determined and the CPU will automatically assign the PROFINET name to it, assigns the IP address to it, and, depending on the device, will configure it like the original component that failed or was damaged. This means that maintenance personnel can return a PROFINET network to service

faster and without using software tools. Figure 6 show how this is accomplished.

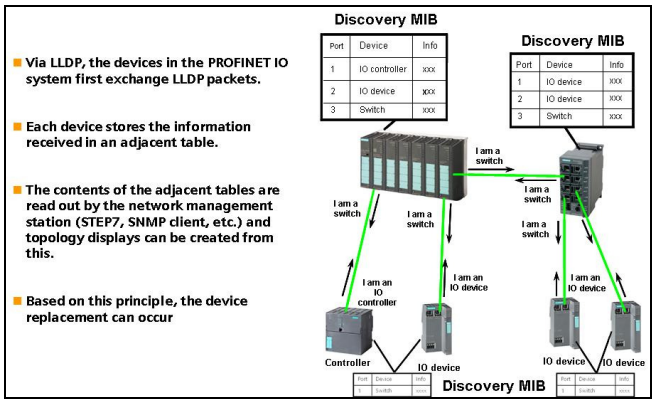

Figure 6: PROFINET LLDP used for Reconfiguration

Fast startup is another common requirement for equipment aboard ship. Depending on the situation, such as battle damage, it is essential that critical equipment become operational as soon as possible. Within number of device limits, PROFINET provides the ability for network components to become operational in a little as 500 milliseconds.

It is not uncommon for both marine and industrial customers to purchase equipment subsystems from several suppliers. Once installed in factory or aboard ship, these subsystems must communicate with each other in order to perform an overall complex automation function. PROFINET provides a solution to enable these subsystems to communicate. The solution is called PROFINET Component Based Automation commonly referred to as PROFINET CBA. During the project specification phase, the communication data structure for each subsystem must be defined. Each subsystem supplier then configures the communication data structure for the PROFINET controller of their subsystem to the defined data structure. Once configured, a PROFINET "component" is created using the configuration software for the PROFINET controller. The subsystem is then delivered with the PROFINET component file for the subsystem. A graphical software utility, for example SIMATIC iMAP, is used to import these component files and then graphically configure the communications between subsystems. The communication parameters are then downloaded to the PROFINET controllers of each subsystem and communications begin immediately. A communication "lifestate" is added by default to each PROFINET component so each PROFINET controller can easily obtain the status of communications with other subsystems. The major benefit of this solution is that the communications between subsystems can be achieved in minutes with no programming. PROFINET CBA communication packets can be either Real-Time or normal priority. PROFINET CBA RT communication packets (referred to as PROFINET CBA cyclic communications) can, depending on the specifications of the PROFINET controller, be exchanged in a fast as one millisecond. Normal priority PROFINET CBA communication packets (commonly referred to as PROFINET CBA acyclic communications) can be exchanged as fast a 500 milliseconds. Figure 7 provides an example of configuring PROFINET CBA communications between a conveyor and lift table using the SIEMENS SIMATIC Step7 software.

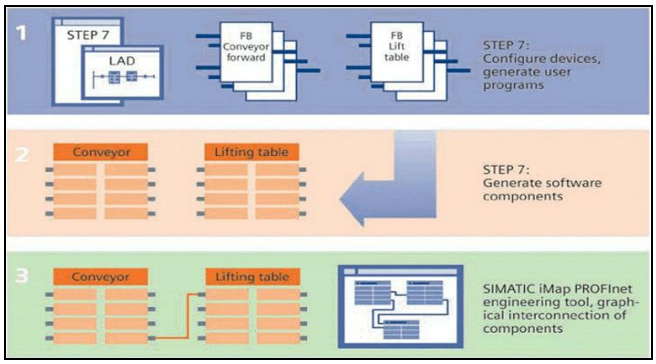

Figure 7: PROFINET CBA Configuration Process

2.5 EXAMPLE PROFINET ARCHITECTUE

Figure 8 shows an example PROFINET based system architecture.

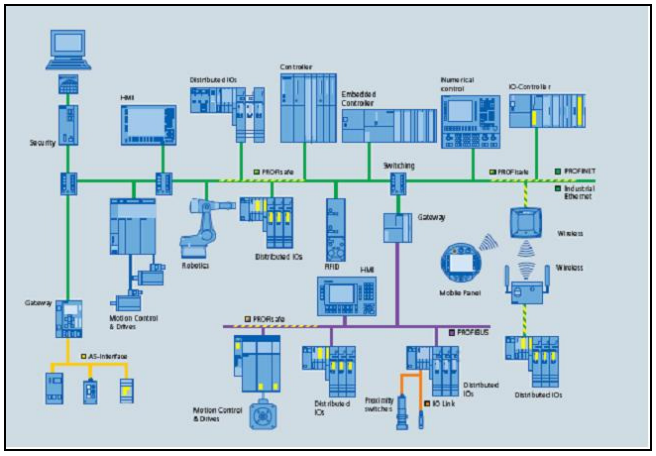

Figure 8: Example PROFINET Architecture

In Figure 8, the following components are shown that may be necessary for configuring a functional automation system.

- An Ethernet network is shown with Ethernet switches
- An Ethernet security device is connected to prevent unauthorized access to the Ethernet/PROFINET network by local or remote PCs
- HMI devices are connected to the PROFINET network to provide human operators the ability to interact with the shipboard equipment
- Multiple PROFINET automation controllers are connected to the Ethernet network
- PROFINET CBA can be used to communicate between these PROFINET automation controllers
- Distributed input and output racks (distributed I/O) are connected to the Ethernet network and can be located throughout the vessel
- Each distributed I/O rack is controlled/monitored by a PROFINET automation controller and uses the PROFINET RT protocol to ensure real-time control
- Distributed I/O is also connected to a wireless Ethernet network
- A wireless HMI device is shown and operated using the same access point as the wireless distributed I/O
- A Radio Frequency Identification system functions on the same network infrastructure
- For personnel safety system, the safety controllers communicate using the same network infrastructure
- Control of robotics equipment is achieved using the same Ethernet network infrastructure
- Motion control, such as controlling the propulsion of an electric ship, is also achieved on the Ethernet network and would use PROFINET IRT for deterministic control
- Communication with non-PROFINET equipment is achieved using gateways (sometime referred to a PROFINET links). In the example architecture, devices from the industry standard Actuator-Sensor Interface (AS-I) network and

PROFIBUS devices are also being used

From this example, one can easily see that a PROFINET architecture has the functionality to meet the complete automation requirements of a factory or a marine vessel.

3. CONCLUSION

As summarized in this paper, a PROFINET solution meets the defined requirements of an open architecture system by utilizing communications services based upon published standards. Additionally, the capability to easily use best in class products from several suppliers assures that an automation solution will provide required functionality.

Based upon research data, an Ethernet-based automation solution like PROFINET is in line with expected automation market trends which will ensure longevity and the ability to add future functionality to the automation solution.

PROFINET also provides functionality that is critical to control the operation of industrial and marine equipment such as real-time performance, automatic reconfiguration after component replacement, fast startup, and the ability for equipment subsystems to communicate with no programming, only graphical configuration.

Finally, a PROFINET architecture supports all of the required functionality to create an automation solution such as HMI communications, motion control, network security, distributed I/O, wireless communications, and integration with non-PROFINET networks such as PROFIBUS.

PROFINET is a good choice for an open architecture solution.

4. ACKNOWLEDGEMENT

Although not always mentioned, the specifications for several industrial automation products from Siemens Energy and Automation, Inc. were used for technical information in this paper.

REFERENCES

[1] Webopedia – Copyright 2009 WebMediaBrands, Inc.

[2] ARC Advisory Group – January 18, 2008

[3] The Rapid Way to PROFINET – Manfred Popp, Karl Weber – Copyright by PROFIBUS Nutzerorganisation e.V. 2004

[4] SIEMENS AG – Copyright 20002-2008 – www.automation.siemens.com

[5] www.profibus.com

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Wayne Cantrell is an automation Systems Engineer for Siemens Energy and Automation, Inc. in Johnson City, TN, USA. Wayne designs, reviews, and approves automation system architectures for marine and other industries. He has a Bachelors of Science degree in Computer Science from East Tennessee State University.

During his career, Wayne has been a system test technician for Sperry Univac, a technician for manufacturing and hardware/software/environmental design testing of automation equipment for Texas Instruments, Inc., and a test, applications, and systems engineer for the process automation industry for Siemens.

For his marine experience, Wayne has been a systems engineer and business manager for a marine automation group. He has experience with machinery control systems, power generation, and propulsion systems using diesel and gas turbine engines.

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