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Real-Time Ethernet IP – ProfiNet Technology

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Figure 1 – Ethernet is ubiquitous in the enterprise

Twenty years ago, there were competing network protocols in the enterprise (office) network space. Today, no one would believe that, because there is only one network protocol that is used in 99%-plus of all enterprise networks. That network is Ethernet running TCP/IP.

WHAT IS ETHERNET?

Ethernet is ubiquitous. Our computer networks all are run on Ethernet, even our video games and HD video devices in our homes are Ethernet enabled. So it is very important to understand what Ethernet is, how it works, and what it can and cannot do. This is especially important in the industrial environment, as Ethernet becomes common on the plant floor.

Ethernet is a family of frame-based, or data packet based, networking technologies that are part of the IEEE 802.3 standard. There are several varieties of Ethernet. Originally based on a coaxial cable format, like the old analog cable TV cable, Ethernet cabling became based on twisted pair technology adapted from telephony (see Fig. 1), because this kind of cable was already run in many offices and was understandable to most cable installers. Thus, 10Base-T was developed as a star topology, similar to telephony, and this was continued in 100Base-T and other higher throughput formats.

Ethernet networks consist of nodes, switches, routers and repeaters. Switches, especially smart managed switches, have made it possible to have Ethernet networks consisting of a nearly infinite number of nodes.



Figure 2 - Smart switch manages Ethernet traffic

Ethernet nodes send each other data packets. As with other IEEE 802 LANs, each Ethernet node is given a MAC (media access control) address. The MAC addresses are used to specify both the destination and the source of each data packet. All packets are broadcast, that is, they are sent to all nodes. Data in the packet causes the node for which the packet is intended to wake up and grab the data. Adapters come programmed with a globally unique address. Nearly all generations of Ethernet use the same frame formats and can be readily interconnected using bridges.

SPEED AND DETERMINISM

But here's the problem. Since Ethernet is broadcast, all of the packets go to all of the nodes. Managed switches, such as the Advantech EKI-6558TI (shown in Figure 2), help by directing the data packet to only the designated receiving node or nodes, but the fact remains that collisions between data packets are a serious problem. They can cause both bandwidth reduction and data loss. This is manageable in the enterprise (office) environment, but not so much in the industrial plant environment.

What happens is that data can take variable paths and therefore variable times to travel from the sending node to the receiving node. If this is an email, nobody cares—in fact nobody notices. If this is a control variable for a high-speed CNC mill, packet loss and speed loss can be disastrous.

The industrial environment requires “real-time” information transfer. Because the time it takes for any given packet to arrive at its destination on an Ethernet LAN is not determined, it is difficult to guarantee real-time control functions over Ethernet. The time it takes for each packet to arrive at its destination should be determined...that is, the process must be deterministic.

Determinism does not define speed. These are quite different concepts. Here's an example to help us understand the difference between determinism and speed. If you live a mile from work, and at 4 pm you tell your wife that you will be home in an hour, you've *determined* the time frame in which to conduct your trip home. Note that your speed will be about 1 mile per hour. It doesn't take much speed to accomplish this timing goal. But things hold you up at work and you don't get home until 6 pm. What happened? Well, you told your wife, when you realized what time it was, you drove 100 miles an hour all the way home (one mile). It wasn't an issue of speed; it was an issue of determinism. The desired effect was not accomplished in the specified time frame.

Generally, in the control world on the industrial plant floor, speed and determinism are both needed. Speed is necessary for the greatest possible throughput. Determinism is necessary to define a level of quality for the throughput; that is, the highest speed throughput that is usable.

MODBUS AND MODBUS TCP

Originally, data transmission on the plant floor was done by proprietary twisted pair serial communications protocols (like RS-232 and RS-485) which were deterministic by nature, since they were half-duplex. There was a defined amount of time to wait for any response after sending any message from the master. The timing was very predictable (hence deterministic) but it was very slow.



One of the first, if not the first, industrial data network was Modbus, a half-duplex serial protocol devised by Hung Yu in 1979 for Modicon PLCs, hence the name MODiconBUS. Modbus, being half-duplex, is highly deterministic, but being serial, is quite slow, with data transmission rates as slow as 300 baud (typically 2.4Kbaud).

Figure 3 - Modbus is still used, now with TCP/IP connectivity

The COTS Revolution

With Ethernet, the rate of communication (the speed) is much faster, but the time span (the determinism) in which a response is expected is unpredictable.

Using Ethernet is also a gateway to the extremely large and relatively inexpensive pool of COTS (commercial off the shelf) products that have been created for Ethernet and the enterprise environment. With many IT departments in control of both plant and enterprise networking, there is significant pressure to use COTS network nodes and switches, even in the environment of the factory floor. Ethernet is everywhere already, the argument goes, so let's use it everywhere, even where it isn't the optimum solution.

There have been many attempts to adapt Ethernet technology to better serve the plant floor. There are, at last count, over 30 protocols specifically designed for the industrial environment. Many of these are open, and standards-based, such as Foundation fieldbus, Modbus, DeviceNet and ControlNet (the Common Industrial Protocols) and others.

Three of these protocols have significant followings in both discrete and process automation: EtherNet IP, Modbus, and Profibus and PROFINET.

ETHERNET IP AND THE COMMON INDUSTRIAL PROTOCOLS

EtherNet IP can easily be confused with Ethernet and IP, the Internet Protocol. EtherNet's "IP" actually stands for "Industrial Protocol." EtherNet IP is an industrial protocol that operates over Ethernet, using the Common Industrial Protocols (ControlNet, DeviceNet). EtherNet IP is an application-layer protocol, and it considers all of the devices on a network to be objects. Here is where the confusion begins. EtherNet IP is built on the standard TCP/IP stack, making it easy to interface plant floor data from devices such as PLCs and PACs with enterprise servers running Ethernet TCP/IP. This also makes transmitting data over the Internet practical and even makes storage in "cloud computing" servers possible.

Although EtherNet IP was developed by Rockwell Automation for its Allen-Bradley line of controls, it is now considered an open standard, and is managed by ODVA (www.odva.org). Formerly known as the Open DeviceNet Vendors Association, ODVA now calls itself "the organization that supports network technologies built on the Common Industrial Protocol (CIP) — DeviceNet, EtherNet/IP, CompoNet, and ControlNet." EtherNet IP is designed for those control applications that can accommodate a measure of non-deterministic data transfer, but it is significantly more robust and deterministic than standard Ethernet and TCP/IP are.



Figure 4 - More robust than standard Ethernet

Profibus and ProfiNet Technology

Profibus and PROFINET are also managed as open standards by Profibus and Profinet International (PI) even though they were originally created by Siemens.

Profibus is significantly more deterministic than EtherNet IP, just as the other CIP protocols (DeviceNet and ControlNet) are. PROFINET is designed to be an industrial protocol running on Ethernet, similar to EtherNet IP. Profibus and PROFINET are designed to work together, just as

ODVA has revised the CIP protocols to work together. There are millions of Profibus nodes installed in both discrete and process automation.



Figure 5 - Real Time Ethernet

According to Profibus/PROFINET International, PROFINET is an open Ethernet standard, designed to be “real-time Ethernet.” PROFINET has two models: the component model or PROFINET CBA and the peripherals model, or PROFIBUS IO. The transmission times, however are different.

Speed is everything. There are three different protocol levels in PROFINET, and they are differentiated by speed.

PROFINET CBA for a plant with reaction times in the range of 100ms uses TCP/IP.

PROFINET CBA and IO applications up to 10ms cycle times use the RT (Real-Time) protocol.


PROFINET IO applications in drive systems for motion control use the IRT (Isochronous Real-Time) protocol for cycle times of *less than 1 ms*.

What EtherNet IP and PROFINET have shown is that determinism isn't all or nothing. If you can legitimately expect to operate at speeds of less than 1 ms, the potential for deterministic failure is extremely low. Especially if you're really working at 10 ms or 100 ms.

WHAT THE FUTURE HOLDS

While EtherNet IP, ODVA and the Common Industrial Protocols along with Profibus/PROFINET International are useful and widely used relatively stable non-deterministic protocols, each of the standards organizations' objective is to prove themselves to be the highest speed solution. This, while they remain highly deterministic under the most rigorous use of the speed available.

Each of the 30+ fieldbus protocols has advantages and disadvantages. In many cases, the choice of fieldbus protocol depends on the user's choice of products and components from a vendor or vendors. Compatibility of the control device must also be considered. End users, machine builders and integrators often select protocols based on the purchaser's comfort level with the vendor, or a favored protocol type. Sometimes, users will select protocols and bus types based on performance. If you need 1 ms speed, you will not choose a 250 ms response bus, regardless of how much you like the slower vendor.



The battles over fieldbus protocols continue. There are no clear winners out of the 30-odd. The first protocol that can produce robust, fast and deterministic control, all three, will win. Determinism is the limiting factor to overcome.

Unfortunately, the limiting component is, and will remain, Ethernet. As long as it is the protocol of choice in IT, and the cost of even industrially hardened Ethernet switches and I/O are low, Ethernet will remain the communication protocol of choice.