Automation World®

TACTICAL BRIEF

FIELDBUS I/O

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NETWORKED I/O RIDES THE ETHERNET WAVE

Users are taking advantage of the different ways suppliers are exploiting Ethernet and the various communications protocols available to distribute I/O devices.

By James R. Koelsch, Contributing Editor

There may be more than one way to skin a cat, but there is just one way of processing turkeys at the Cargill plant in Waco, Texas. And that way now relies on networked input-output (I/O) devices to oversee the ammonia-based refrigeration system at the heart of production. Like many users seeking to keep their processes as simple as possible, Minneapolis-based Cargill is linking the devices over an Ethernet-based network.

Keeping tabs on the refrigeration is crucial. "If the system were to go down, they would have to shut the plant down," explains Barrett Davis, owner of Automate Co. LLC (www.automateco.com), a systems integrator based in Pacific, Mo. For this reason, Cargill asked Davis to upgrade the system with controls and I/O from Opto 22 (www.opto22.com), an automation supplier based in Temecula, Calif.

The upgrade at Cargill is indicative of a trend toward greater proliferation of Ethernet in industrial automation. "The use of Ethernet as a physical layer has been the biggest advancement in fieldbus I/O over the past decade," observes Joey Stubbs, P.E., North American Representative for the Nuremberg-based EtherCAT Technology Group (www.ethercat.org). He attributes the trend to the ability of the automation industry to industrialize consumer-driven commodity products for fieldbus implementation, thereby driving development costs down.

"In the past, the world's fieldbus organizations had to create their own standards for everything from the connector to the protocol to the stack," Stubbs says. "Now, the physical layer can be handled by broader-based international standards organizations that drive these technologies for all areas of use–industrial, office, and consumer."

Consequently, networked I/O has continued to advance, resulting in better performance, flexible topology, and simpler configuration. "With today's networked I/O, system updates can be processed real-time in the sub-millisecond to microsecond range," reports Kurt Wadowick, I/O product specialist at Beckhoff Automation LLC (www.beckhoff.com/usa) in Burnsville, Minn. These higher processing speeds continue to generate efficiencies in data collection and analysis.

Just as important has been the simultaneous evolution of open communications protocols. "Ethernet's physical wiring combined with protocols such as EtherCAT, Profinet, EtherNet/IP, Powerlink and others were each originally developed individually by controls manufacturers," explains Wadowick. "They, however, have re-emerged as open standards that can easily interface into other companies' devices, such as drives, encoders and various kinds of industrial controls on the I/O network."

As fieldbuses have become more open and dependent upon known physical technologies like Ethernet, I/O network update rates have increased to the point where they can keep pace with real-time events in the control system. Another important advantage has been less copper. "In the good old days, a great deal of wiring was required for industrial devices, says Wadowick. Today, he says, connecting these devices to the controller requires only the I/O network connection, control power and, in the case of high-energy devices, three-phase power.

Simplicity with TCP/IP

At Automate Co., Davis specializes in the Opto 22 products because they use standard transmission control protocol and Internet protocol (TCP/IP) on Ethernet-based networks. He likes the protocol's simplicity. "It's been well-thought-out from the get-go," he says. "Serial has always been kind of a hassle to work with because you can have mismatches between two systems from different manufacturers." Although he acknowledges that you can always get serial networks to work, he notes that it usually requires a lot of effort.

So, Davis usually argues for TCP/IP over some of the newer deterministic fieldbus networks wherever data collisions do not affect the reliability of TCP/IP communications in control applications. "These fieldbus solutions add complexity to Ethernet and TCP/IP," he says. "They try to turn something nondeterministic by nature into a deterministic network. These attempts often over complicate the entire process and make interoperability between different systems difficult." It also drives up costs, because installing such things as IGMP (Internet group management protocol) snooping switches is necessary.

Davis has found that the added complexity is unnecessary for most applications that he typically sees. "UDP [user datagram protocol] packets go across the network in a matter of a few microseconds," he says. "Even if you get a collision, it has a whole scheme for handling that, and it retries very quickly." Based on his analysis of Opto22's hardware to respond, he is confident that he can configure most proportional-integral-derivative (PID) loops to scan rates of less than five milliseconds.

Although Davis believes that TCP/IP communications are fast enough for many I/O networks, an important exception is machinery requiring sub-millisecond timing. For now, most of these applications will rely on specialty bus networks, he says.

Delivers flexibility

Builders of industrial automation for heavy manufacturing industries like automotive are also seeing the benefits of networked I/O. Not only must the automated machinery there coordinate the motion of its own components, but it often must also synchronize its tasks with other equipment and people. And these lines must have the flexibility to accommodate a mix of products and design changes.

An example is vehicle production. "With high production rates and a wide variety of model mixes within today's automotive factories, manufacturing systems are becoming much more complex," says Andy Jones, global segment director for commercial vehicles for Comau–Adaptive Solutions of Southfield, Mich. "Even within commercial-vehicle manufacturing facilities, where the production rates can be more than 10 times lower than the typical passenger vehicle factory, networked I/O is still extremely important."

Simplicity is also important to this business unit of Comau S.p.A., the Turin-based builder of assembly lines for a variety of industries. One reason is that the business unit serves industries, such as commercial vehicle manufacturing, that are relatively new to complex automation. Another reason is time to market. The time for bringing a vehicle from concept to market is as crucial to market share in commercial vehicles as it is for passenger vehicles.

A flexible and robust communications architecture, therefore, is very important for eliminating costly delays in designing, integrating and delivering the automation built by Comau's Adaptive Solutions business. "Our customers expect reliable, cost-effective systems with the flexibility of changing to alternate component suppliers when necessary," says Jones.

Although the existing infrastructure—as well as the needs and abilities of the user—will dictate the networking scheme

continued

Networked I/O Rides the Ethernet Wave

chosen in the end, Camau engineers often specify EtherNet/IP, a standard protocol promulgated by ODVA (www.odva.org), with products from Milwaukee-based Rockwell Automation (www.rockwellautomation.com) and others.

The EtherNet/IP protocol "enables all network devices to speak the same language, making network communications much more robust," says Jones. This ability allows putting a variety of floor-level components, as well as integrated technology, including motion control, on the same network.

Right now, Comau is looking into using EtherNet/IP for changing the tools used by its robotic technology. "Automatic tool-changing is very common in our assembly systems, in order to make best use of the robots, precious floor space, and available cycle time by performing multiple operations within the same workspace," explains Jones. Because quick-connect technology has not always been available for making these changes, the automation builder's engineers would often have to design solutions that required communicating over DeviceNet, which added an extra protocol. Putting the robots on the EtherNet/IP network should eliminate this complication.

Another important feature of EtherNet/IP is that it supports the development of modular solutions that can be used again and adapted for future projects. Not only does reusing previously proven modules save time in design and commissioning, but it also streamlines equipment validation.

On the Safety Side

Networked I/O can be an improvement over safety relays as well, as the Lawrence Berkeley National Laboratory (LBNL) learned in Berkeley, Calif. The lesson came when it built Bella, the world's most powerful laser, a petawatt laser that generates pulses that last for 40 fetoseconds. To protect workers and visitors from harmful radiation and exposure to laser light, LBNL installed safety system with a distributed I/O and human-machine-interface (HMI) architecture.

Bella occupies four moderate-sized rooms. The safety system monitors the 14 access doors and the shutters covering the large picture windows that observers use to view the laser. Some of the doors prohibit access to hazardous areas while the laser is on. If, however, other doors or the shutters are open, the programmable logic controller (PLC) will safely shut the laser down by taking control of the 18 shutters, three laser beam dumps, and 17 power-supply circuits.

"It wasn't possible to do this project with safety relays. There is just way too much I/O for a programmable safety relay," notes David Di Giorgio, lead engineer for the project to design and install the laser's safety system. Di Giorgio is director of computer engineering at Deterministic Systems Inc. (DSi) (www.dsicontrols.net), a controls engineering company in Walnut Creek, Calif.

The heart of the system is an S7-319F safety PLC, the fastest model made by Siemens Industry Inc. (www.usa.siemens.com/industry) of Alpharetta, Ga. Using ProfiSafe open communications, an Ethernet-based ProfitNet network links the PLC to four remote safety I/O racks and four HMIs, one each for each room. Distributing the racks to the rooms simplified installation. "The cabinet would have been quite long if we would have wired them all to one rack," observes Di Giorgio. "Then, we would have had to figure out how to route all these cables and pay for all the copper."

The ability to send safety information and control "from one room to another using only Ethernet and a set of power wires made the design clean and easily modifiable during the design phase," Di Giorgio adds. "In the future, this will also allow LBNL to modify the system as the needs of the experiments change."

DSi engineers got an idea of just how flexible the system is near the end of the project, during the final checking phase. The inspection uncovered that a group of four alarms failed to turn off a device as they should have. Rectifying this oversight was a matter of changing one instruction because the alarms were already grouped. Di Giogrio reports that actually reconfiguring the instructions and compiling and downloading the change took roughly 15 minutes, but that the whole event took about an hour when you include the discussions surrounding it.

Besides this ability to make changes on the fly, another benefit of the distributed I/O architecture is that it assists troubleshooting. "When you're troubleshooting a problem, it is more convenient to have the rack in the same room," notes Di Giorgio. More importantly, the network offers more diagnostics than relays do. Although relay-based systems can offer redundancy, they cannot detect a short circuit to a sensor coming from another system. Failsafe inputs and outputs on the safety PLCs, on the other hand, can detect short circuits.

ETHERNET ENTERS NEW FIELD

The ubiquitous office networking standard rapidly displacing proprietary fieldbus for input/output communications.

By Terry Costlow, Contributing Writer

An aging fieldbus system was causing too much aggravation for engineers and technicians at Radiator Specialty Co.'s Charlotte, N.C., factory. A palletizing system for containers of Gunk, Liquid Wrench and other products was often stopped when a fault on one node brought the whole system down.

Networking glitches became so common that technicians created a workaround so that many of the workers on the plant floor could restart the network."We put a power switch on the system so equipment operators could reboot when we weren't around," says Shawn LaHart, control technician at Radiator Specialty. That reduced the pain and saved time, but production still remained at a halt for a couple of minutes while the system rebooted.

Late last year, the company installed an Ethernet-compatible field bus, bringing the office networking standard used in the factory down to the input/output (I/O) level. Now that Radiator Speciality has deployed Beckhoff Automation's EtherCat protocol, the emergency power switch is getting dusty."Our EtherCat system's been running for months without any errors," says Project Engineer Murray Williamson.

Radiator Specialty is one of many manufacturing companies taking Ethernet down to the fieldbus level, making the ubiquitous network look like the winner of the fieldbus wars of the mid-1990s. It's even being used to tackle real-time problems, as many vendors provide variations that provide determinism.

Analysts note that adoption is still low compared to the fieldbuses that have been used for years."There are still more nodes of all other fieldbuses than of Ethernet, but it's definitely growing pretty rapidly," says Harry Forbes, senior analyst at ARC Advisory Group Inc., in Dedham, Mass. He notes that in 2004, there were fewer than 1 million Ethernet nodes at the fieldbus level.

However, there are a number of reasons that Ethernet's growth in this role is expanding. Among them is that once standard Ethernet cabling—called "Cat 5" in the industry—is installed, companies are no longer tied to a fieldbus. Ethernet gives manufacturers an open environment, letting them use hardware and software from various vendors. For many engineers, that's cause for celebration.

"Ethernet as a fieldbus has a ton of advantages," says Ryan Becker, senior programmer analyst at Brown Printing Co., which prints many national magazines at its Waseca, Minn., headquarters. Brown is now using modules from Opto 22, of Temecula, Calif., to connect to I/O points.

Becker notes that with older fieldbuses, it is difficult to extract data for production reporting, and it's expensive to use their specific middleware to tie into I/O points. Now, he uses Java, C or Visual Basic programming languages to access nodes. "With Ethernet I/O, I can communicate directly to I/O points at no added cost, and I can use any language I choose to tie into I/O points and extract data," he adds.

Vendors note that the broad support for Ethernet makes it much simpler to do many common jobs. Ethernet connections and compatible software are on personal computers (PCs), and there are a number of off-the-shelf programs for many common tasks."Now it's relatively easy to develop and monitor software.

Every laptop has Ethernet, so you can use a Web browser as a debugging tool. There's nothing else to buy," says Helge Hornis, intelligent systems manager at Pepperl+Fuchs, a network component supplier based in Twinsburg, Ohio.

Another benefit is that regardless of which communication protocols are deployed, data can be transferred freely throughout the network. That means maintaining these systems can be handled efficiently even from remote locations. "Now I can monitor the whole system from my desk, I don't have to go onto the floor and plug into a system," says Williamson, of Radiator Speciality. He adds that he can also log in from home or from an off-site meeting.

Finding people who can do this debugging and other work is also much simpler."The knowledge base for Ethernet is far higher than for any fieldbus," says Benson Hougland, marketing vice president at Opto 22. This experience makes it possible to set up a fieldbus in fairly short time.The PC world's push towards plug-and-play has made a networking technician's job relatively simple.

"Reconfiguring the system was mostly copying and pasting. I had the whole thing done in a day," says Radiator Speciality's LaHart.That installation has eliminated delays from oft-occurring shutdowns, which provides a payoff that Radiator Specialty management understands and appreciates. "An hour to us is a few thousand dollars, so we're probably looking at a few tens of thousands of dollars in extra throughput," Williamson says.

REAL TIME

Many users have been gaining the benefits of Ethernet field buses since roughly the start of this decade. But in applications that needed determinism, conventional fieldbuses have been the only option. However, that's changing quickly. "There are already a number of protocols for I/O tasks that aren't time critical. Now there are companies coming out with the speed that's needed for determinism," says Todd Walter, a group manager at National Instruments Corp. (NI), an Austin, Texas, automation products vendor.

A handful of networking companies are now providing variations of industrial-grade Ethernet technologies that provide realtime capabilities, going into the low milliseconds and even low microsecond times needed to assure timely delivery of message packets. This determinism now comes in many flavors. Among the available technologies are EtherCat, EtherNet/IP, Ethernet- Powerlink, the Fieldbus Foundation's High Speed Ethernet, Modbus TCP/IP, Profinet, and SERCOS III.

Vendors note that the speed of these networks makes it possible to continue the broad thrust to integrate more functions into a single controller. Even in complex and demanding applications such as motion control, it is now possible to handle many modules from a central control panel.

"Synchronizing 100 servo axes in a microsecond is something that's never been done before," says Skip Hansen, I/O systems product manager at Beckhoff Automation LLC, of Burnsville, Minn. Beckhoff developed EtherCat, which is now an International Electrotechnical Commission (IEC) specification.

Hansen notes that the bandwidth of real-time Ethernet gives system integrators the ability to consolidate many jobs, or to alter the way they link equipment together. "Engineers have to think differently to gain the full benefit of the technology," he continues.

The capabilities of the network also make it possible to link modules located at fairly long distances. Beckhoff is touting an approach that eliminates the delays of very long cable runs. It's no longer necessary to be close to get real-time performance. "We can synchronize I/O down to the nanosecond level, providing deterministic I/O regardless of wire length," Hansen says.

If membership in technical groups is any measure, interest in real-time Ethernet is high throughout the industry. Fieldbus Foundation has more than 300 members and the EtherCat Technology Group has more than 200.

All this attention to high-speed Ethernet moves the fieldbus wars to another level, looking at applications and protocols rather than all-encompassing proprietary architectures. But the competitive markets of this era make it likely that this fieldbus war won't last nearly as long as the battles that began in the '90s. Most vendors don't have the wherewithal to provide equal levels of technical aid for multiple solutions to one problem."We can't provide the same level of support for each bus, so we're spending a lot of time evaluating which one will be our select bus," says Brian MacCleery, group manager for NI's Industrial Control and Measurement Group.

ARC's Forbes notes that these varied solutions are "a point of confusion," but that the diversity isn't likely to have a major impact on market growth. The various guises of real-time Ethernet are linked to vendors, so many users will likely follow the lead of their key vendors.

However, the incompatibilities will show up when different vendors' equipment must communicate. While this will be an annoying issue for many plant managers, it will be even more vexing for the system integrators who help them get plants functioning efficiently. For these companies, and forequipment suppliers who must work in heterogeneous applications, it often won't be possible to pick only one.

The vendors promoting these disparate architectures want to provide differentiation, so they have little incentive to work toward finding a single solution. But most observers feel the field will narrow over time. "Eventually, this will resolve down continued

Ethernet Enters New Field

to one or two leading architectures. The networks won't all grow at the same rate, so the market will decide how many and which ones survive," Forbes predicts.

Though there is significant momentum behind the expansion of Ethernet usage, observers note that the Institute of Electrical and Electronics Engineers (IEEE) standard isn't the ultimate solution for current problems. In many applications, there's still some need for a hierarchy of networks.

"There's still cost associated with Ethernet switches for each device that needs a switch," says Jim Remski, automotive powertrain business manager for Siemens Energy & Automation's Automotive Business Unit, in Alpharetta, Ga. He points out that existing fieldbus switches are often embedded into equipment.

Remski also notes that lower-level buses that handle small amounts of data from sensors and other devices with minimal intelligence are sometimes the best solution. That sentiment is echoed by others.

"We don't condone using Ethernet for everything. CAN (Controller Area Network) is good for products with small pieces of data like sensors," says Hougland, of Opto 22. ARC's Forbes notes that simple products such as proximity switches that don't have diagnostics are another application where Ethernet may be too costly.

Another potential reason for avoiding Ethernet is its openness to viruses and hacker attacks. But for the most part, that's a higher-level issue that doesn't go down to the fieldbus level. That's because it is not generally desirable to have equipment on a fieldbus communicating freely with any other device on the network. "You can configure the I/O so it only listens to communications from defined addresses," Hougland says.

Though there are solid reasons for not using Ethernet everywhere today, that may not remain the case. Some observers feel that the semiconductor industry's continuing drive to integrate more peripherals onto chips that cost less may eventually make Ethernet suitable in those low-performance applications. "When you can buy a microcontroller that has everything for under $5, Ethernet becomes basically free," says NI's Walters.

The low cost of microcontrollers is already making it easy for design engineers to include Ethernet on a growing number of products that tie into fieldbuses. As with many electronic technologies, once a couple of high end products incorporate a feature or function, it rapidly becomes a common attribute on many of the emerging new products.

"Many motor controllers have Ethernet now; they didn't a couple years ago," Hougland says.

READER FEEDBACK: ALL-DIGITAL DIAGNOSTICS SOLVES TODAY'S PROBLEMS

Letter to the Editor Re: Field Device Diagnostics: Desire and Reality, AW September 2012

By Larry O'Brien, global marketing manager with Fieldbus Foundation

I read with interest the article by Peter Ebert on field diagnostics. To me and to many of us that deal with fieldbus technology on a regular basis, the diagnostics issue is really an information management problem that can be solved with the technology we have today, and there are key differences in how Foundation fieldbus handles diagnostics versus HART and other protocols.

Let's start with NAMUR NE 107, which the Fieldbus Foundation has incorporated into our specification. NE 107 diagnostics have been part of our specification since 2010. Our Field Diagnostics specification was developed in close collaboration with NAMUR [a German process industry user organization]. Many of the requirements outlined in the NAMUR recommendations, such as support of alarms, were already included in the specification.

In fact, all new devices that will be registered from this point on with Version 6 of our Interoperability Test Kit (ITK) must support NAMUR NE 107 graphics and diagnostic management capabilities. All of our host systems tested through our Host Profile Testing and Registration program must also conform—that's especially applicable to our integrated DCS hosts. We are currently the only organization with this mandatory requirement for NAMUR NE 107 support for testing and registration of devices and hosts.

NAMUR NE 107 is extremely valuable because it not only creates standard symbols and terms for reporting diagnostic conditions, it makes it a lot easier to classify diagnostics in terms of severity and root cause (i.e. is it a process problem? A sensor problem? An electronics problem?)

Yes, both HART and Foundation fieldbus and lots of other protocols offer diagnostic information. However, when you go completely digital as you do with Foundation fieldbus, the volume and type of diagnostics that are available to you increase exponentially, as does the bandwidth to report these diagnostic conditions (all-digital, so you can transmit multiple process variables and diagnostic conditions across the network).

The Foundation publish/subscribe architecture also means that diagnostic information is continuously pushed to the people that need it, when they need it, with no delay and no requirement for polling devices. All of a sudden you find yourself able to access thousands of diagnostic parameters at a time from many different devices across your fieldbus network. It's like seeing television in high definition for the first time, and it goes way beyond the ability to detect a plugged impulse line.

You need a common sense way to manage the information you are getting so that it is actionable, and people only get the right information to the right people at the right time. That's the real beauty of NAMUR NE 107 and why our end user clients decided it was time to make these recommendations part of the Foundation fieldbus specification. Because we are an open standard guided by our end user council, we can make additions and improvements to the specification as they are required.

The all-digital nature of our diagnostic capabilities also allow users take the whole diagnostics platform up a level, by looking at interrelationships between diagnostic conditions on different devices across the unit or the plant to create diagnostic profiles of the process itself and even plant equipment. This takes diagnostics into a whole new dimension, where it becomes part of your overall plant optimization strategy.

AUTOMATION WORLD SURVEY: ETHERNET AND WIRELESS IN PRODUCTION FACILITIES

An exclusive Automation World survey looks at current engineering and management opinions surrounding the use of Ethernet and wireless networks across industry.

By David Greenfield, Media & Events Director, Automation World

Ten years ago it was difficult to find large numbers of engineers open to the idea of using Ethernet for plant floor operations. As for their opinion on wireless… forget about it. If Ethernet was a stretch for most engineers due to its perception as an IT network for front office operations, the use of wireless (outside of remote, long distance process operations) was just crazy talk.

But in the last few years, a noticeable shift has taken place in operations engineers' attitudes about Ethernet and wireless network technologies. We first started seeing demonstrable proof of this in the Automation World Innovation survey conducted in late 2011. In that survey, nearly half of respondents said the incorporation of Ethernet into plant floor systems was the most innovative advance to occur in automation over the past decade. With so many readers citing this development as being more innovative than any other, Ethernet's advance onto the plant floor was recognized as the clear innovation winner in readers' opinions.

With this new Automation World survey, sponsored by Moxa (www.moxa.com), we wanted to dig deeper and learn not just what engineers think about Ethernet and wireless in the plant, but how they are using it there and what their plans are for it. Nearly one thousand readers from a variety of industries– ranging from automotive, chemicals, and electronics to food & beverage, oil & gas, and machinery/equipment OEMs – responded to the survey. Here's what we learned.

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Automation World Survey: Ethernet And Wireless In Production Facilities

Are Plant Managers and Engineers Open to Using Ethernet?

With only 7 percent of plant managers and engineers now opposed to the idea of Ethernet in the plant, the number of naysayers that could block adoption of this technology has shrunk considerably over the years. Ethernet is a rugged and versatile technology, and multiple robust and high-speed protocols are available. Research shows users in all industries are investing in Ethernet technologies.

Where Respondents Use Ethernet

One result that speaks to the overwhelming acceptance of Ethernet in the plant is the fact that Ethernet is used at the machine level to connect devices and instrumentation (74 percent) nearly as often as it is used to connect front office device communications (77 percent). Given that an initial use of Ethernet in the plant was to connect production systems to the enterprise, a surprisingly lower number of respondents (56 percent) currently use Ethernet to connect shop floor systems to the enterprise than use the technology to connect devices at the machine level.

Current Status of Ethernet Adoption

Though a number of respondents are just now beginning to use Ethernet on the plant floor, a significant number (41 percent) has been doing it for years and is thinking about additional applications for it. The fact that nearly as many respondents (22 percent) have connected everything possible on the plant floor with Ethernet as are just beginning the process (26 percent) really speaks to how widely Ethernet is accepted as a factory floor network compared to prevalent opinions just a decade ago. The number of respondents beginning to explore wireless (12 percent) may seem low, but in many factory installations high levels of electromagnetic interference can cause problems for wireless networks. New products (such as wireless/cellular hybrid technologies) are now coming to market to address these issues and will likely cause this percentage to surge in the years ahead.

Installation and Maintenance of the Current Ethernet Network

Despite the fact that tensions between IT and production engineers still persist in many companies, Ethernet may well prove to be the technology that helps lead these two groups to develop a better perspective of one another. When it comes to Ethernet installation and maintenance responsibility, the approaches are evenly split: Roughly one-third say the IT department handles it, and another one-third give the responsibility to staff engineers. The remainder outsource responsibility to systems integrators or equipment suppliers via service contracts.

How Ethernet Use on the Plant Floor is Expected to Change in the Next 5 Years

Beyond the top responses about expected changes for Ethernet on the plant floor, a separate open-ended question revealed other specific ways users want to use Ethernet. These include: remote switching of power distribution networks; more use of Power over Ethernet; real-time instrument data feeds over Ethernet; converting process control operator stations to Ethernet; connecting dedicated safety controllers with Ethernet; connecting servo drives with Ethernet; implementing IEEE 1588 precision time control; connecting work cells and machines to form a SCADA/MES system; and connecting to factory floor machines with a smart phone.

REAL-TIME ETHERNET/IP—PROFINET TECHNOLOGY

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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.

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.

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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

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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 rates as slow as 300 baud (typically 2.4Kbaud).

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

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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.

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.

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.

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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 EtherNe/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.