The Brave New World of Industrial Automation

Real-Time Ethernet-Based Fieldbus Technology Revolutionizing Industries

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One of the best things about being a journalist — whether for example it be reporting on manufacturing, politics, show business, or anything else — is being paid to "go to school" and learning about any number of things that you were perhaps ignorant of at the outset.

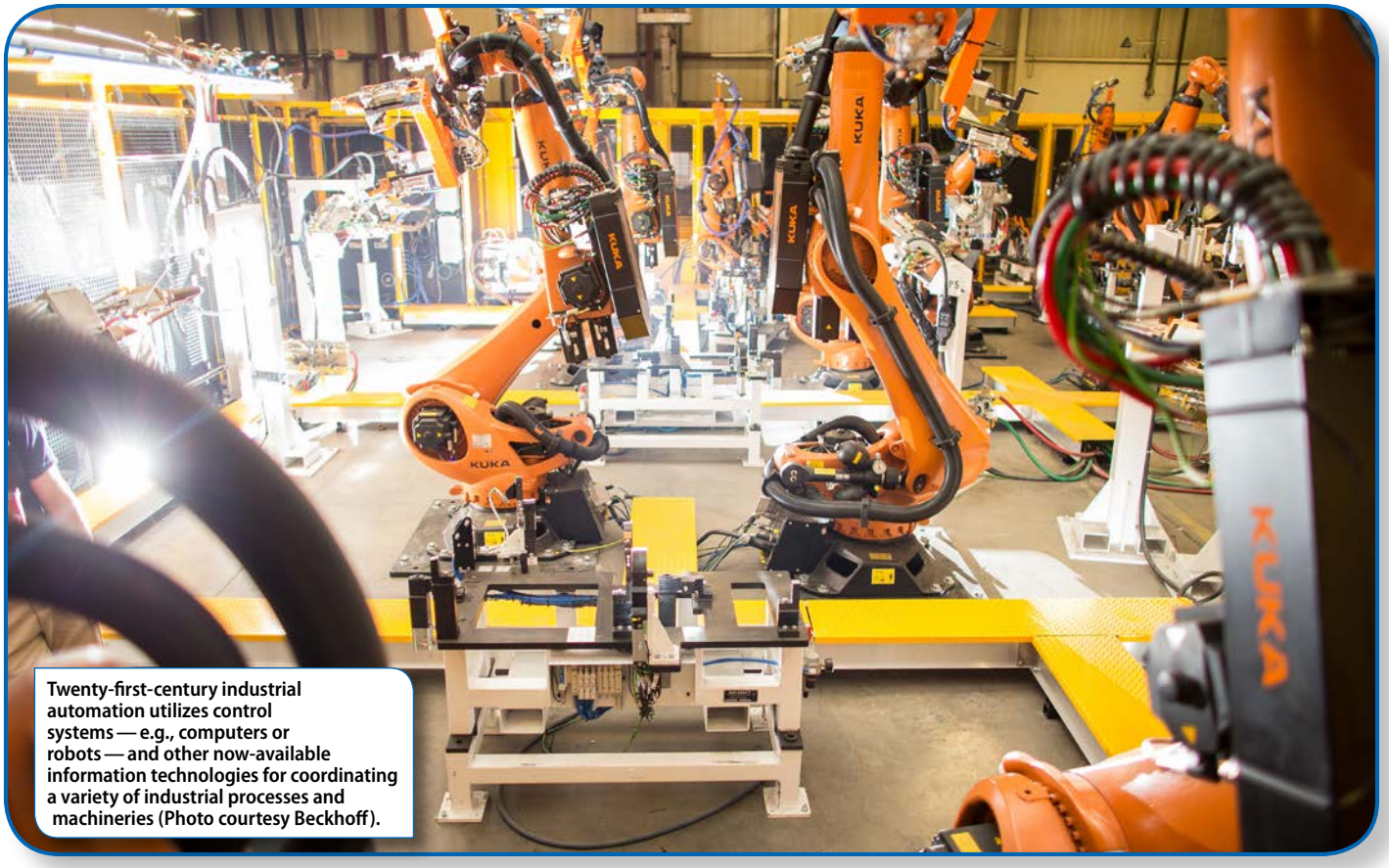
Sometimes, however, you catch an assignment to write about a subject that, at least at first blush, seems frighteningly intimidating due to its scope and complexity.

For this reporter, at least, real-time Ethernet fieldbus industrial automation is one of those subjects. Graze the Internet for information on this burgeoning smart manufacturing development and you'll quickly see that there is certainly no shortage of technical papers, supplier information, governmental input, etc. The only problem is trying to make a layman's sense out of it. There are seemingly countless, devilish details concerning hardware, software and standards (protocols) — not to mention a phalanx of competing views as to which iteration is best for this or that application. We're talking about discerning the differences between the five most applied (since 2001) protocols/standards — in use on factory floors, i.e. — EtherCat (*www.ethercat.org*); EtherNet/IP (*www.odva.org*); Powerlink (*www.ethernet-powerlink.org*); Profinet IRT (*www.profibus.com*); and Sercos III (*www.sercos.de/en*). And while there are other technologies that leverage Ethernet as well, "their components are not sufficiently published, downloadable or promulgated in the open source community to be considered standard and open." (*Source*: *kingstar.com*)

But then I received some brief but exceedingly sensible advice, to wit:

Focus on the big picture: what does it do, how does it do it — and worry less about the details.

In case you were wondering, fieldbus is a family of industrial computer network protocols used for real-time distributed control, standardized as IEC (International Electrotechnical Com-



Twenty-first-century industrial automation utilizes control systems — e.g., computers or robots — and other now-available information technologies for coordinating a variety of industrial processes and machineries (Photo courtesy Beckhoff).

mission) 61158. It is an industrial network system for real-time distributed control that connects instruments in a manufacturing plant. Fieldbus works on a network structure that typically allows daisy-chain, star, ring, branch, and tree network topologies.

And "industrial automation," in Ethernet fieldbus form, is use of control technology such as computers or robots, and information technology for handling different processes and machineries in an industry to replace a human being. It is the second step beyond mechanization in the scope of industrialization (*SureControls Inc.; surecontrols.com*).

Note the absence of any concern over eliminating "the human being" in the equation. But face it — that sort of sentiment is *so* last-century.

Anyone questioning the rapid spread of highest-tech industrial automation and motion control need only look at the lineup of high-tech automation-related exhibitors for this year's IMTS (*www.imts.com*). Beginning with the 2014 IMTS co-location of the IANA and MDA shows, and continuing with this year's event, industrial automation is becoming one of the show's lead players. According to Larry Turner, president & CEO of IMTS partner Hannover Fairs USA, Inc., "The single most important development in manufacturing in the past two years has been the overwhelming discussion around and movement towards investing in Industrial Internet of Things (IIoT) programs and initiatives to help accelerate the era of IT-optimized smart manufacturing. As IIoT solutions providers better frame, define and create IIoT strategies, many organizations have started to look at what is possible in the age of Industry 4.0. Manufacturers around the world are now embracing the Internet of Things and smart manufacturing. Digital factory solutions will be showcased across all of the 2016 shows."

Industrial automation in today's high-tech, world economy-competitive context is much more than simply making more things and making them faster. Today it is also all about making those same things more cheaply, yet with higher quality.

The Ethernet and TCP/IP protocols have in the past been used in manufacturing to network control systems, management systems, and manufacturing cells on the shop floor, but *not* for the controlling communications *inside* the actual machines and equipment. (*Transmission Control Protocol is a core protocol of the Internet protocol suite. It originated in the initial network implementation in which it complemented the Internet Protocol (IP). Therefore, the entire suite is commonly referred to as TCP/IP.*) The machine controller itself and the communications to the actuators invariably demand use of deterministic fieldbus, so TCP/IP is not suitable. Essentially, the use of the "traditional" TCP/IP protocol — from machine control to the sensors and actuators — has failed, as it is incapable of satisfying deterministic, real-time demands.

But machine-builders — including CNC machine tool builders — recognized an inherent, value-added opportunity to *retain* those hardware com-

ponents typically used in the accepted TCP/IP network setting. That, coupled with explosive growth of the Internet, led to a universal standard for communication cards and cabling. For example, a network interface card (NIC) and a TCP are a mere fraction of the cost of an industrial fieldbus cable and DAQ card. Indeed, the ability to "recycle" this existing hardware can provide savings of at least 50% above a traditional, proprietary fieldbus configuration.

Example—the economics of adopting Ethernet as a fieldbus are compelling because Ethernet components offer dramatically lower costs and are universally available. But in order to implement a *proprietary* fieldbus motion assembly, an IO card at up to $400, proprietary cables at up to $30/linear foot, and servo drives and premium motors must be purchased.

However, if an Ethernet-based standard protocol is used, the IO card can be replaced by the onboard NIC card ($0 additional cost) that comes installed on the PC; the proprietary cables can be replaced by inexpensive CAT5 cables; and the servo drives will be dramatically lower if the standard is strong enough to support multiple vendors. Equipment assembly for Ethernet components is much simpler too. Rather than having cable harnesses that are 4 inches in diameter at the PC interface, a simple CAT5 cable similar to the one that connects to your home PC is far more manageable; other economic benefits for Ethernet as well.

This NASA application required EtherCAT-protocol robotic transporters for moving rockets from place to place at NASA assembly facilities (Photo courtesy Beckhoff).

Beyond that, it was then decided that a new, real-time protocol could deterministically connect and communicate the machine controller to all the sensors and actuators in a machine, i.e.—*real-time industrial automation and motion control.*

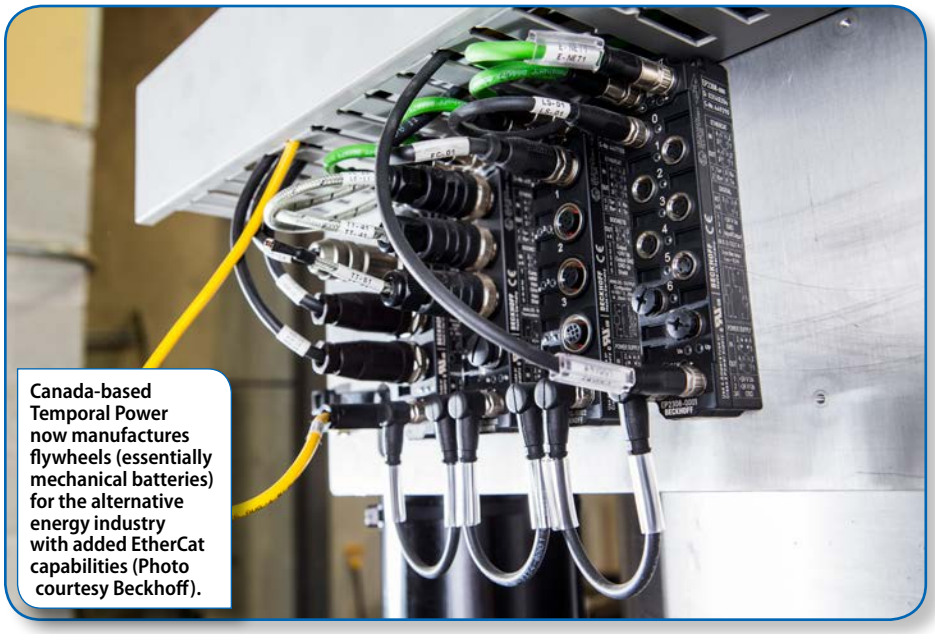
While not as yet necessarily accepted as the gold standard, of the five real-time Ethernet fieldbus standards (protocols) EtherCAT appears capable of superior performance and winning market acceptance. Its performance, for example, is rated an order-of-magnitude better than Ethernet IP and Powerlink.

As for PROFINET IRT and SERCOS III, while they apparently offer near-equivalent performance characteristics, EtherCAT offers a more "open" solution. EtherCAT has been adopted by 10 times more servo drive and IO suppliers than any other standard. As a result, many machine builders adopting real-time fieldbus technology are opting for EtherCAT.

The EtherCAT protocol, developed by Beckhoff Automation LLC (*www.beckhoff.com*), prompted the formation of the EtherCAT Technology Group (ETG) (*www.ethercat.org*); machine builders will note that it is capable of processing 1,000 I/Os in 32.5 µs, or 100 axes in 125 µs.

What is driving this need for speed? Time-to-market and energy savings, for starters. Also, maintenance costs associated with machinery used for industrial automation are less because, reportedly, it does not often fail. But *should* it fail, only computer and maintenance engineers are required to repair it.

Today's increasingly complex, automated industrial systems, such as a manufacturing assembly line, typically require a "distributed control system" i.e.—an organized hierarchy of controller systems—to operate. In this hierarchy, there is usually a human machine interface (HMI) at the top where an operator can monitor or operate the system. This is typically linked to a middle layer of programmable logic controllers (PLCs) via a non-time-critical communications system (e.g. Ethernet). At the bottom of the control chain is the fieldbus that links the PLCs to the components that actually do the work, such as sensors, actuators, electric motors, console lights, switches, valves and contactors.


Canada-based Temporal Power now manufactures flywheels (essentially mechanical batteries) for the alternative energy industry with added EtherCat capabilities (Photo courtesy Beckhoff).

Q&A

Beyond the preceding, what follows is input from several company spokespersons invested heavily in fieldbus Ethernet industrial automation motion and control. They include: **Jeffrey D. Estes**, Certified Engineering Technologist (CET), Okuma America Corporation (*www.okuma.com*); **Joey Stubbs**, North American representative, EtherCat Technology Group (*www.ethercat.org*); and **Gale Lu**, Sr. Business Development Manager, Nexcom U.S. (*galelu@nexcom.com*).

PTE: What would be your layman's definition of industrial automation and real-time communication?

Jeffrey D. Estes (JDE). Simply put, being able to transfer, bi-directionally, information and data points over our IT technology. The IT technology continues to evolve and become faster and more capable. Okuma's position is to connect through the most universally accepted manner, allowing data to flow to all areas of the organization, Big Data.

Joey Stubbs (JS). Industrial automation takes the inconsistencies, quality issues and labor costs out of the production of goods by utilizing manufacturing equipment specifically designed to produce those goods. Also, in many cases, industrial automation enables the manufacturing of products that *could not* be made by people.

Real-time communication can be defined as digital communication that is fast and offers predictable timing.

PTE: Would you say the following is accurate?

One of the five real-time Ethernet fieldbus standards has achieved a tipping point of acceptance. It appears that EtherCAT offers both superior performance and market acceptance. Its performance is an order-of-magnitude better than Ethernet IP and Powerlink. And while PROFINET IRT and SERCOS III offer nearly equivalent performance characteristics, EtherCAT offers a more "open" solution at far lower cost than both PROFINET IRT and SERCOS III. From a technology and price/performance standpoint, EtherCAT is far superior. And the market agrees. EtherCAT has been adopted by 10 times more servo drive and IO suppliers than any of other standard.

Joey Stubbs (JS). I wouldn't say that PROFINET IRT and SERCOS III offer nearly equivalent performance to EtherCAT, but they are definitely "higher performance" than Ethernet/IP and Powerlink. The remaining bulk of the above statement is very correct. There are currently 193 different EtherCAT master vendors, 155 different companies with at least one model of EtherCAT drive, 105 different vendors of EtherCAT I/O and 45 vendors providing Functional Safety over EtherCAT (FSoE) devices. These vendors contribute to the thousands of different EtherCAT components and controllers available today. Worldwide vendor acceptance is phenomenal, to say the least.

PTE: Does this industry also have trouble finding young replacement talent as an older workforce retires?

JDE: Finding talent that understands Big Data and willing to treat a $100,000+ computer in the machine tool control the same as the $1000 PC on most desks is challenging. Okuma is constantly learning and training on how to connect/communicate as the various manufacturing systems evolve. Much like smart phones, the technology is growing at a rapid pace and the knowledge of our workforce, of all ages, must learn and adapt in this environment. Very exciting time to be working in manufacturing!

PTE: What accounts for the high start-up cost of implementing fieldbus technology/automation? Are, for example, custom motors and other custom hardware a big-ticket item? Cabling?

JS: The term "high start-up costs" can be an oxymoron when examining the overall costs of a fieldbus technology implementation. It depends on the type of system specified by the user. EtherCAT does not require special fieldbus cards in the controller, and has no need for special cables, connectors or any Ethernet infrastructure devices such as switches, hubs, or routers.

Additionally, EtherCAT reduces overall costs due to the inherent noise immunity offered by CAT5e cables, and the protocol's incredible suite of pinpoint diagnostics tools, which help minimize downtime, while maximizing uptime and production.

PTE: Does preventive maintenance assume an entirely new dynamic regarding the hi-tech hardware/software? Who is qualified to do it?

JDE: Electronic hardware is extremely reliable. The amount of data coming from, and flowing through, the electronics is astounding. That same data is also providing the health of the electronic devices processing it. The hardware is able to self-diagnose its own health and efficiency. Example: much like our cars, a technician can obtain data from new electronics through connecting to the machine.

JS: Because of the high throughput and high levels of determinism, EtherCAT is well suited to data acquisition tasks, including very specialized services, such as local machine condition monitoring on the same communication network controlling the machine(s). This condition monitoring enables functionality such as vibration monitoring, which can indicate bearing wear on rotating motors and internal problems with pumps, as well as harmonics on gears and other rotating machinery. This makes it possible to perform corrective measures during regular maintenance downtime, as opposed to permitting equipment to fail and having to do corrective measures when the machine should be running. This amounts to a huge increase in overall throughput that cannot be ignored, especially in the long run.

PTE: Please speak to the energy savings tied to fieldbus automation, perhaps for machine tool builders as an example.

JDE: Okuma has a technology called Eco Suite that constantly reviews key energy usage of key components of the machine and reduces their energy consumption when not demanded by the machining process. Check it out at *www.Okuma.com*.

JS: Using a high-speed, highly efficient, highly responsive fieldbus and control system can certainly bring energy saving benefits, depending on the industry. Plastic injection molding equipment, for instance, can save energy and raw materials by achieving tighter control of the plastic melting process, thin down the walls of plastic products and create less waste. This all adds up to a considerable reduction in energy use and waste. EtherCAT power monitoring terminals can enable the machine to monitor its own power usage and, if set up to do so, modify power settings and turn off unused equipment or devices, again saving power and operating costs.

PTE: Of the fieldbus protocols available—EtherCAT, EtherNet/IP, PROFINET IO, Ethernet Powerlink, SERCOS III, etc., is one best suited for machine tool automation?

JDE: EtherCAT has positioned itself as the clear winner. The protocol is not intended for any particular industry or application, but has found its niche in a variety of different industries with many different types of users. EtherCAT offers a low-cost fieldbus option for embedded control systems

Unified EtherCat controllers enable PLC-CNC robotics collaboration for automated production lines (Photo courtesy Nexcom).

for embedded control systems and low cost PLCs. It is also a high-speed, highly deterministic bus for data acquisition systems that supports even the most demanding applications, such as to form the "nervous system" for advanced robotic controls. The protocol has even been applied in R&D for space applications, as EtherCAT is used by NASA in several vehicle applications. It also performs well in generic applications, such as machine tool automation, because of the high speed, low cost, flexibility and device variety.

PTE: What determines whether a machine tool builder's existing infrastructure is suitable for converting to fieldbus/industrial? Ethernet-driven control and automation? Put another way, is it usually a blank-sheet scenario or are a good portion of existing components retained?

JDS: One of the great things about EtherCAT, and one of the properties that has allowed it to achieve its current high level of acceptance, is that a user doesn't have to "start over" and use only EtherCAT devices in a network. There are gateways from EtherCAT to over 30 different fieldbuses, both in Master and Slave configurations, which facilitate communication to individual legacy devices, or complete non-EtherCAT networks, such as PROFIBUS, PROFINET and DeviceNet, among others.

PTE: How robust are the existing IEC standards? Has time spent developing these standards (some taking decades apparently to be written) over the years slowed the progress of industrial automation?

JDE: In my opinion, it is probably good that there are some lags due to standardization processes. Otherwise, the industry would be flooded with spur-of-the-moment technologies that are half-baked and not very well thought out. That alternative scenario would seriously confuse and degrade the industry.

PTE: What might be the next "automated" miracle? Glass half-full?

JDE: Simply connect your machine tool and start collecting data. This data can be used by planner/schedulers, maintenance, manufacturing engineers, finance, quality assurance and compliance, simulations, or six sigma project determinations, just to name a few. Big Data provides information that pieces can be extracted and used by everyone in the organization. What's so exciting is the data is *milliseconds* old. It's real time! Amazing!

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