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# CONTROL ENGINEERING

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## Industrial Internet of Things and Industry 4.0

Connected automation,  
analysis enable smart  
factories

Featuring IIoT benefits  
and comments  
by Emerson Process  
Management's Bob  
Karschnia, vice president  
of wireless, on page 6.



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# Industrial Internet of Things, Industry 4.0

Connected automation and analysis enable smart factories. How can Industrial Internet of Things and Industry 4.0 concepts help with your next automation, controls, and instrumentation implementations? Advice from industry experts follows.

## Go Online

Each of the six articles summarized here has more information and images in the online portions of this June *Control Engineering* print/digital edition cover story.

Search the headline of each at [www.controleng.com](http://www.controleng.com) for more information.

See the RCEP/PDH webcast: "Industrial Internet of Things (IIoT) and Industry 4.0: Overview and practical advice for today." Organizations with more information include:

[www.plattform-i40.de](http://www.plattform-i40.de) (use a translating browser)

[www.iiconsortium.org](http://www.iiconsortium.org)

[www.smartfactory.eu](http://www.smartfactory.eu)



Advocates say Industrial Internet of Things and Industry 4.0 concepts can create smarter factories. Learn how experts suggest your next automation, controls, and instrumentation implementations can change as a result of these frameworks. Dr. Richard Soley, executive director of the Industrial Internet Consortium (IIC), said, "As with any new technology or management approach, choose an important but smaller problem to attack and bring in the right expertise to get the problem solved. Don't ignore organizations that bring together end users, vendors, and researchers as places to get solid experience and good advice!"

- Edited by Mark T. Hoske, content manager, Control Engineering, [mhoske@cfemedia.com](mailto:mhoske@cfemedia.com).

*Automation components with decentralized intelligence equip machines to use data to improve the process (adjust throughput, use energy more efficiently...) rather than depend on the "cloud."*

Cover image courtesy: Bosch Rexroth

## Connect Industry 4.0 with real manufacturing

### Key concepts



- Industry 4.0 technologies are in use today, increasing productivity and decreasing inventory.
- These tools can improve a manufacturer's flexibility and speed, enabling more individualized products, efficient and scalable production, and a high variance in production control.

A new manufacturing line can produce one product and up to 25 variants, with a 10% increase in productivity and a 30% decrease in inventory by using Industry 4.0 technologies. See the five qualities Industrial Internet of Things (IIoT) devices need to create the Industry 4.0 manufacturing environment, said Allen Tubbs product manager, electric drives and controls, Bosch Rexroth Corp. His advice follows.

Industry 4.0 manufacturers focus on production that generates strong returns on investment (ROI).

Industry 4.0 is the rapid transformation of industry, where the virtual world of information technology (IT), the physical world of machines, and the Internet have become one. It centers on the integration of all areas of industry enabled by IT. Technologies improve flexibility and speed,

enabling more individualized products, efficient and scalable production, and a high variance in production control. Machine-to-machine communications and the improved machine intelligence lead to more automated processes, self-monitoring, and results in real time. Open web-based platforms will add competitiveness and opportunities.

### Five IIoT considerations

IIoT devices should work to bring about Industry 4.0 manufacturing in five ways.

#### 1. Decentralized intelligence

Decentralized (or distributed) intelligence is where intelligent drive and control technologies network with other devices with decentralized autonomy—putting as much intelligence and

*In Industry 4.0, the operation of a machine tool or a packaging machine should allow for easy connections with smart devices such as smartphones or tablets. Courtesy: Bosch Rexroth*

control capability as possible in the machine, or the individual drive axis, rather than handling all activity from one central processing unit (CPU).

Holding process data at the machine level, and deciding what to do with it, reflects the belief that a machine can be equipped to do something with the process data and improve the process on its own—adjust throughput, use energy more efficiently, and so forth—rather than depending on the “cloud” to handle all these tasks.

Connected machines communicate to higher line-level, plant-level, and enterprise-level networks, with the capacity and systems to make event-specific or product-specific adjustments in real time. Drive-integrated servo motors and cabinet-free drive systems put drive components and motion logic sequencing at individual axis.

## 2. Rapid connectivity

Systems that facilitate instant vertical or horizontal connectivity to allow data to flow freely across the enterprise structure need continual investment and improvement. Leveraging the intelligence and information available on an Industry 4.0 factory floor could overwhelm networks. How can we improve the physical and software capabilities of automation systems to make this design process simpler, less time consuming and more open? Communication paths are more streamlined as they are created and implemented. When determining what fieldbus capabilities should be used, look at whether the production platform support standards such as OPC UA (from the OPC Foundation). Eliminating barriers among supplier systems and taking a more open approach to communications and controls platforms are important.

## 3. Open standards and systems

Focus on expanding how “open” systems are, in terms of support for emerging communications and software standards and in how open individual components are to make Industry 4.0 a reality.

Open standards allow the more flexible integration of software-based solutions—with the possibility to migrate new technologies into existing automation structures. Open control and engineering software move in that direction to bridge the gap between automation and IT software programming. An open controller kernel enables the creation of automation applications using common high-level IT languages, such as Java and C++.

Operation of a machine should allow for easy connections with smartphones or tablets. Software can help speed the design and commissioning of automation systems with the connection of the controller to 3D modeling software. A motion controller can send commands and receive feed-



back from the model, allowing machine functionality to be optimized with motion control in the mechanical design phase. This allows machine testing and programming before commissioning. Virtual machines can be tested and refined before parts are ordered to build the machine.

## 4. Real-time context integration

In Industry 4.0 factories, it will be possible to draw on real-time machine and plant performance data to change how automation systems and production processes are managed. Instead of capturing and analyzing several months’ worth of data on throughput rates, machine downtime, or energy consumption, Industry 4.0-enabled platforms integrate data into routine plant management reporting. This will equip manufacturers and machines with details to execute the rapid process and production changes to fulfill the vision of profitably making products for specific customer needs.

## 5. Autonomous behavior

Real-world initiatives can make production more connected and demand-driven. Technology helps the production line to become autonomous. The goal is to have workstations and modules that can adapt to individual customer or product needs.

At a manufacturing facility for hydraulic valves, a new adaptive assembly line uses a radio frequency identification chip on each work piece. Nine intelligent stations on the line recognize how the finished product has to be assembled and which tool settings and operational steps are necessary. Each associate carries a Bluetooth tag that automatically transmits information to the assembly station. Assembly step information is displayed with a matching level of detail depending on the product and the skill level of the associate. The line can produce hydraulic valves with a lot size of one and can manufacture 25 product variants without human intervention. Set-up times or excessive stocking are not necessary. Productivity increased 10%; inventory decreased 30%.

“Decentralized autonomy puts as much intelligence and control capability as possible in the machine or even in individual drive axis, rather than handling all activity and control from one central processing unit (CPU).”

### Consider this...

What impact on the bottom line would a 10% productivity increase mean for you or your customers?

# Putting Industry 4.0 and IoT to work in smart factories

**Key concepts** 

- IIoT and Industry 4.0 include greater connectivity of devices and systems.
- Industry 4.0 concepts are in practice today.
- PC-based control hardware and software are useful Smart Factory tools.

Industry 4.0 and Industrial Internet of Things (IIoT) are enabled with connectivity to and from devices (from a sensor to a large-scale control system), data, and analytics, said Daymon Thompson, TwinCAT product specialist, Beckhoff Automation. Sensors and systems need network connectivity to share data; analysis enables informed decisions. Industry 4.0 works for German kitchen manufacturer, Nobilia. Thompson explains more, including three smart factory questions.

IIoT consists of four basic elements: the actual device, connectivity to and from that device, data, and analytics. The device can be anything from one sensor to a large-scale control system. Sensors and systems need connectivity with a greater network to share the third element—the data generated by the sensor or system. The analysis of this data generates actionable information, allowing people to make informed decisions as a result.

Putting this into practice for industry, IIoT, devices or assets connect to the cloud or local information technology (IT) infrastructure to collect and/or transmit data. This data can be analyzed, providing insight about the device or asset.

Sensors monitoring the operating temperature in mechanical components can track any abnormalities or deviations from an established baseline. This allows the company to proactively address undesired behavior as predictive maintenance before crippling system failures can develop, which would otherwise lead to plant downtime and lost production revenue. Information of this magnitude offers value to the enterprise, helping to influence new product designs, streamline system performance, and maximize profitability.

## Flexible manufacturing, Industry 4.0

Use of connectivity to drive new insights and optimizations can be applied to a manufacturing process and overall supply chain. This is one of the core concepts of Industry 4.0, a technological movement called the fourth industrial revolution.

Industry 4.0 working group Acatech defines the first industrial revolution as the invention and widespread use of the steam engine in the 18th century. The second was conveyor-belt use for assembly lines in the early 1900s. The third was development of microelectronics, the PC and programmable logic controller (PLC) in the mid-1900s. The fourth connects PCs and machines to the Internet, enabling cyber-physical systems.

Industry 4.0 requires computerization of traditional industries in manufacturing. Using IIoT and the concept of cyber-physical systems will result in the “Smart Factory,” enabling unparalleled manufacturing flexibility and exceptionally lean operational efficiency. In manufacturing, an area of significant focus extends beyond the product to the process of making that product.

Manufacturers need flexible manufacturing lines that can quickly adapt to rapidly changing customer demands. Flexible machines run many product types, with the goal of profitable production at reduced lot sizes, enabling a complex mixture of products to be run and filled on demand.

## From big idea to implementation

Software in today’s converging AT and IT permits machine control programming in multiple languages, facilitating a wider range of engineering tools to complete necessary tasks. Protocol selection should be considered in controls platforms primed for Industry 4.0 connectivity. Many traditional PLCs offer fieldbuses, but machines need a faster, more flexible communications protocol, such as EtherCAT, for deterministic communication to sensors, servos, and other motion hardware. [EtherCAT is an industrial Ethernet protocol managed by the EtherCAT Technology Group.]

A critical component of implementing this level of connectivity is a secure and easy-to-configure protocol that can transmit data safely to the enterprise or cloud or even horizontally to other machines. Vendor-independent OPC Unified Architecture (UA) protocol, from the OPC Foundation for industrial environments, offers integrated security functionality, data encryption, and advanced information modeling.

Industry 4.0 is happening today. Successful integration of PC-based controls that support a highly connected Smart Factory can be found at German kitchen manufacturer, Nobilia. The company produces more than 2,500 complete kitchens daily and manufactures each set of kitchen cabinetry to specifications outlined by each customer. “Lot size 1” automated manufacturing requires a high-flexibility system—achieved through Industry 4.0 concept implementation.

When an order reaches the plant, the system determines the necessary materials, the required machines to finish components, calculates how to best move the customized order through the fac-



*German kitchen manufacturer Nobilia uses PC-based controls to support automation of “lot size 1” as it manufactures more than 2,500 unique kitchens daily using Industry 4.0 concepts in its Smart Factory. Courtesy: Beckhoff Automation*

tory, and efficiently constructs the custom kitchen cabinets. This exemplifies the entire point of a Smart Factory—efficient production and superior flexibility, with little plant personnel intervention.

### **Smart factory: three questions**

Three smart factory questions to ask are:

**1.** Do you want to further automate rapid product changeovers and better respond to market demands?

**2.** Do you want to drive up your overall equipment effectiveness (OEE) and production throughput by identifying areas for continuous improvement?

**3.** Do you want to root out waste (such as energy, raw materials, and idle time)?

After determining and refining real-world Smart Factory goals, tools to succeed are available with PC-based control hardware and software.

### **Consider this...**

What tools can you use to improve information integration as part of Industry 4.0 concepts?

# IIoT benefits, examples, rapid returns on investments

**Key concepts** 

- Many sensors already in place make the IIoT more advanced than the IoT.
- Interconnectedness and analysis augments value.
- IIoT examples now in place show very fast ROI, less than half a year.

Industrial Internet of Things (IIoT) technologies, applied for monitoring valves in a refinery, used wireless acoustic transmitters to improve regulatory compliance and reduce hydrocarbon losses by \$3 million per year from timely detection and repair of faulty valves. The project paid for itself in five months, said Bob Karschnia, vice president of wireless, Emerson Process Management. His comments and four IIoT benefits follow.

Industrial IoT (IIoT) is more advanced than commercial IoT with the prevalence of connected sensors in the industrial world, which are the “things” in the IoT. Hundreds of millions of connected wired and wireless pressure, level, flow, temperature, vibration, acoustic, position, analytical, and other sensors operate in industry, and millions more are added annually, for more monitoring, analysis, and optimization value.

Sensors connect to higher level software platforms, on- and offsite. On-site connections are often via a local intranet, creating an IIoT. Internet usually makes offsite connections, often with cloud-based storage. Higher-level software does control and monitoring, asset management, and specialized data-analysis. At remote data-analysis centers, experts perform big data analytics showing patterns, problems, and solutions.

## Four IIoT benefits

The IIoT connects sensors to analytic and other systems to automatically improve performance, safety, reliability, and energy efficiency by:

1. Collecting data from sensors (things) much more cost effectively than ever because sensors are often battery-powered and wireless
2. Interpreting this data strategically using big

data analytics and other techniques to turn the data into actionable information

3. Presenting this actionable information to the right person, either plant personnel or remote experts, and at the right time
4. Delivering performance improvements when personnel take corrective action.

IIoT technology was implemented at Ergon Refining’s Vicksburg, Miss., facility by connecting vibration, acoustic, level, position, and other sensors to an asset management system via a wired fieldbus network (Foundation Fieldbus) and a wireless network (WirelessHART). [FieldComm Group governs these protocols.] The wireless network connects instruments to plant control and monitoring systems via a wireless mesh network with wireless instruments and access points.

Sensor data is sent to asset management software with specialized data-analysis applications for valves and smart meters. Software analyzes sensor data and transforms it into actionable information. Control room operators view information on human machine interfaces (HMIs), and mobile workers view it on handheld industrial PCs connected to a plantwide Wi-Fi network. Capital expenditures were reduced. Wireless cut sensor installation costs, and operational benefits increased capacity and avoided capital investments through wireless tank monitoring.

Asset management software allowed consistent setup and cut commissioning costs, with alarm management software. Safety improved by automating vibration monitoring in hard-to-reach locations (previously by manual rounds), and energy was saved with wireless steam trap monitoring. Ergon wireless infrastructure (for data collection, analysis, and distribution) makes it easy and inexpensive to add wireless sensors and improvements.

An IIoT example uses wireless acoustic transmitters at a refinery to improve regulatory compliance and cut hydrocarbon losses by \$3 million annually with timely detection and repair of faulty valves. The project paid for itself in five months; estimated annualized return on investment (ROI) was 271% annualized over 20 years.

IIoT is here today. Low-cost wireless sensors and accompanying analytics can dramatically improve plant performance, increase safety, and pay for themselves within months.

**Remote wireless access to DeltaV software is possible via a Panasonic Toughbook. In an IIoT implementation at Ergon Refining, mobile workers view sensor and other data on handheld industrial PCs connected to a plantwide Wi-Fi network. The AMS software analyzes sensor data and transforms it into actionable information. AMS allowed consistent setup and reduced commissioning costs, along with reduced call-outs through the use of an AMS Alert Monitor. Courtesy: Emerson Wireless**



## Consider this...

Are you taking advantage of sensors now in place, making real-time corrections to the process, and taking advantage of IIoT benefits?

# Platform-based tools overcome IIoT complexity

## Key concepts

- An IIoT platform-based approach allows one flexible hardware architecture deployed across many applications and removes hardware complexity.
- IIoT systems represent a massive investment for decades to come.
- Faster wireless networking, 5G, will help IIoT performance.

Smarter, platform-based approaches can address the complexity challenges the Industrial Internet of Things (IIoT) brings to enable IIoT systems that are adaptive, scalable, secure and continually modified and maintained, explained Ray Almgren, vice president of marketing, National Instruments. His observations follow.

The world has long been composed of devices that are connected or intelligent, but not both. Connected systems like telephone lines and light switches can transmit information, but offer little to no intelligence. Intelligent systems such as engine control units and thermostats have onboard processing intelligence, but can't communicate outside of the closed circuit. People use systems and devices that marry the two concepts to become intelligent and connected in the Internet of Things (IoT): a collision of systems that have traditionally been disparate.

### Platform IIoT approach

This connectedness, particularly in the industrial and consumer spaces, increases the demands on traditional design and manufacturing test systems. Once popular options like fixed-function, black-box instrumentation, and turn-key data-logging software can't keep up with the number of standards, protocols, and functionalities that modern business demands. These systems of systems require software that meets key requirements like prototype to deploy, flexibility, and decision making at the node. When building a system today, use a platform-based approach foundation that adapts to and even anticipates changing system requirements. A platform-based approach will enable

companies and makers to accelerate productivity, innovation, and discovery in the IoT era.

Connected IIoT systems need the flexibility to evolve and adapt. Developing and deploying IIoT systems represent a massive investment for decades. The only way to meet future needs is to deploy a network of systems flexible enough to evolve and adapt.

A platform-based approach offers one flexible hardware architecture, deployed across many applications to remove hardware complexity and makes each new problem primarily a software challenge. Platforms that system designers choose should be based on an information technology (IT) friendly operating system (OS) so they can be securely provisioned and configured to properly authenticate and authorize users to maintain system integrity and maximize system availability.

A platform-based approach reduces time and cost to market in the consumer IoT. New networks, referred to as fifth generation or 5G, may transform lives and unleash enormous economic potential; 5G researchers need to take a platform-based approach to design and rapidly prototype concepts more quickly to expedite time to market and deployment, unlocking IoT potential.

### System integration

Integrated hardware and software will allow makers to advance the IoT. Makers around the world are inspiring each other to create smart gadgets, robotics, autonomous drones, and wearable devices. Innovations are no longer monopolized by multimillion dollar companies. Instead, makers work in home garages and collaborative workspaces with peers. They share inventions online to inspire new innovations from other makers.

The proliferation of wireless connectivity and cloud computing helps makers contribute to the IoT. An interconnected world adds functionality and greater insight into existing and new devices. Integrated hardware and software platform will enable the maker movement to advance the IoT much like the open platform for mobile app creation has developed a new smartphone economy.

More companies and makers are adopting a smarter, platform-based approach to address the complex challenges the IoT brings. Ultimately, this will enable IoT systems that are adaptive, scalable, secure, and continually modified and maintained.



PLATFORM-BASED DESIGN | OPEN ARCHITECTURE | REALTIME ETHERNET

*To adapt to changing requirements, devices that power the IIoT will need to be built on an open, integrated hardware and software platform and a real-time network that can scale with new technologies. Smarter automated test equipment enables test engineers to anticipate and economically incorporate technology advances into test systems through an open platform of modular hardware and scalable software. Courtesy: National Instruments*

## Consider this...

Will you be keeping up with smaller, nimble competitors as IIoT accelerates the pace of innovation?

# Optimize cable's role in IIoT

Internet of Things (IoT) is influencing the future of industrial automation with continuing convergence of information, automation, and operations systems in the Industrial Internet of Things (IIoT), according to Mark Knebusch, vice president of marketing for Softing Inc. With faster Ethernet speeds, cabling system integrity is more important, and cabling certification can help, he said; additional comments follow.

Industrial automation will soon make up the majority of the installation base for devices connected to the IoT. With forecasts of more than 60 billion Internet-connected devices within the next 10 years, the importance of industrial Ethernet is becoming more apparent.

For factory, industrial, and plant professionals, the on-going convergence of information and automation and operations technologies ultimately leads to more efficient communications, which can decrease labor costs and improve supply chain management. As the industrial channel continues to adopt the IoT concept, faster machines requiring more bandwidth are necessary.

Ethernet media with a variety of industrial protocols is the primary method for networking future IIoT initiatives. More facility managers are

**Key concepts** 

- Greater emphasis on IIoT increases the need for reliable networks.
- Standards and cable testing can help increase reliability.

replacing fieldbuses with Ethernet entirely in an effort to accommodate the IIoT. With more connected devices and more information being transmitted, more is demanded of network cabling resulting in a greater impact if commissioning is delayed, or transmission is unreliable.

## Cabling standards

Key organizations that govern standards for cabling include the Telecommunications Industry Association (TIA), International Organization for Standardization (ISO), and the International Electrotechnical Commission (IEC), and each is gearing up for faster speeds.

Increasing network frequencies mean impedance, crosstalk, and other parameters are more critical. More care will be required when choosing media vendors and cable installers.

The evolution of the TIA 568 cabling standards illustrates the rise in speeds as a result of increased demands on networks. While Category-5e cable (100 MHz) is common, increasingly Cat-6 (250 MHz) and -6A (500 MHz) are being installed in industrial applications. Category-8 cable (2,000 MHz), which will be widely used by data center applications, is currently in draft

mode and is expected to be finalized as a new standard.

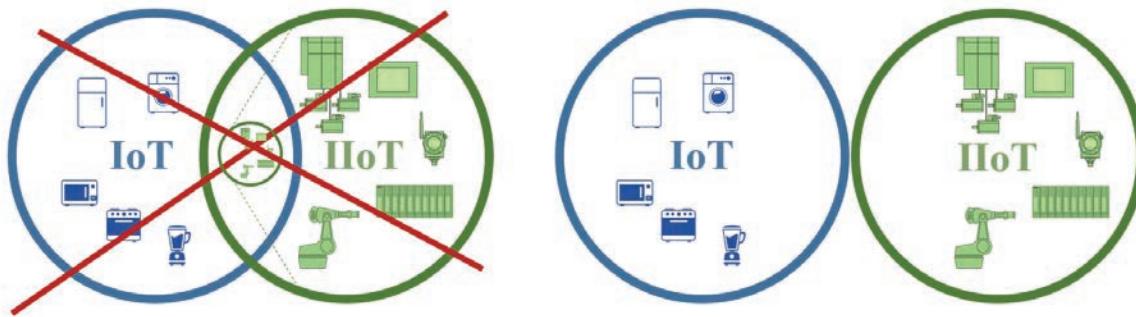
## IIoT increases network needs

Ensuring cabling systems are up to the task of managing all devices and control systems integrated within a factory automation infrastructure is paramount for optimal performance. By adopting efforts made by commercial cable installers, the industrial channel can reduce issues when connecting more devices. In anticipation of a heavier load and stress as a result of the IIoT, certification of all cabling is encouraged. Certifying a cable requires advanced testers that can adapt to rapidly changing standards. Each test can collect nearly 200,000 data measurements including resistance, crosstalk, return loss, and propagation delay.

IoT is affecting the future of industrial automation. With increased Ethernet speed, cabling systems become more important. By first ensuring the cabling is certified, the IIoT can be more effectively optimized.

**Consider this...**

Can your networks handle anticipated increases in information flow related to IIoT optimization?



*IIoT does not overlap with, nor is it a subset of IoT. Things in IIoT make the things in IoT. Courtesy: PI North America*

## Industrial Internet of Things (IIoT): data, clouds, analytics

**W**ithout data there is no big data, clouds, or analytics, and the Industrial Internet of Things (IIoT) differs from the Internet of Things (IoT); IIoT's things make IoT's things, said Carl Henning, deputy director, PI North America. Open standards are required for IIoT, and Ethernet and software standards can deliver data for control and information for decision making, Henning said. His advice follows.

Everyone seems to be excited about the IIoT's clouds and analytics, but without data there can be no big data, clouds, or analytics. Who put the "Industrial" in the "Industrial Internet of Things"? IIoT is not a subset of IoT—the "things" are too different, as are many aspects of the two approaches. The things in IoT are toasters, coffee makers, and refrigerators; the things in IIoT are programmable logic controllers (PLCs), input/output (I/O) blocks, drives, and vision systems.

### Industrial data for IIoT

Maybe IIoT should be called the Industrial Internet of Data. Without the

data there is no control, no operator interface, no historian, and no analytics to improve industrial processes. IIoT data comes from: switches and buttons, sensors and actuators, and drives and vision systems. IIoT extends into controllers, such as PLCs, distributed control systems (DCS), or programmable automation controllers (PACs). Combining data from different devices creates actions. From this point the data turns into information to be communicated to human-machine interfaces (HMIs), historians, and analytics packages using OPC Unified Architecture (UA) [a connected framework defined by OPC Foundation].

According to recent *Control Engineering* research, most users felt interoperability and open standards were the most important benefits of IIoT (more so than analytics). When asked about Industry 4.0 (of which IIoT is one component) the majority thought the most useful feature was real-time capabilities.

Open standards exist. The Industrie 4.0 group has looked with favor on Profinet and OPC UA as suitable open stan-

dards, calling OPC UA a "recommended standard for Industrie 4.0."

Profinet is an open-standard, real-time, deterministic Ethernet with cycle time down to 31.25 microseconds. And in Profinet's case the open standard extends below Ethernet to existing fieldbuses like Profibus (governed by PI North America, along with Profinet) and DeviceNet (governed by ODVA). Not all devices will have an RJ45 connector. Ethernet will be too expensive to include in simple switches and actuators, and there are hundreds of millions of those devices already installed. Rip and replace is not an option for most switches and actuators. The Profinet standard includes proxies to integrate nonEthernet devices. **ce**

### Consider this...

As part of IIoT and Industry 4.0, do you have a plan for improving information flow?

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