control design
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Deterministic variants of Ethernet allows real-time machine control

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Ethernet has taken over industrial automation communications in many areas, but its lack of determinism has limited use in many real-time control applications. Suppliers are addressing this issue by modifying Ethernet to add determinism, and a new Ethernet time-sensitive networking (TSN) standard is also being developed to deal with this problem.

One application using a variant of Ethernet to provide determinism is the deployment of automated guided vehicles (AGVs) by Fori Automation (Figure 1). In one deployment, their AGVs move at speeds up to 2 ft/s across the floor of an aerospace manufacturer's cavernous production facility. One AGV carries a 30-ton, 60-ft-long wing frame for a commercial jet aircraft to its assembly point. With the payload worth several million dollars, the AGV must be controlled precisely to within 5 mm. And with workers walking all around, it must operate safely.

AGV movements are monitored and controlled by a wireless Profinet network, using a modified version of Ethernet to add the required determinism and real-time control. Profinet uses Ethernet's TCP/IP standards for non-time-critical communications such as diagnostics, but adds deterministic channels to achieve real-time communications in as little as 31.25 microseconds. This is critical to the application requirement, which specifies wireless communications, among up to 50 AGVs in any given deployment, be uninterruptible.

A Real Wing Fixture

Figure 1: This AGV relies on wireless Profinet communications to control its movement so it can transport items such as this jig for holding an airplane wing frame.

AGV safety and control devices communicate via Profinet to a managed switch connected to a wireless client onboard each AGV. This onboard client then communicates over the 5 GHz spectrum to fixed-mounted access points, which are IP65-rated for use in industrial environments. These access points are located in regular intervals throughout the plant, usually in a plant's rafters or ceilings, for maximum range with overlapping radio signaling to prevent any coverage gaps.
Historically, AGVs were guided in a fixed circle by a large induction loop, making it difficult to change or add new routes. Lacking real-time communication, functionality and flexibility were limited. With Profinet, continuous communication between the AGV and the plant's master PLC is possible every step of the way, providing much greater flexibility of movement and positioning of travel circuits within a plant.

Many control system engineers aren't necessarily networking experts, but this wasn't a problem for Greg Stegner, the controls project leader at Fori Automation. "You open a browser and follow a series of wizards that walk you through the process," he says. "It gives you all your wireless and security settings. I was able to get the wireless Profinet network up and running in a couple hours on my own."

With the Profinet-based wireless solution, Stegner says Fori Automation can now deploy as many as 50 AGVs across a single customer plant, almost three times as many as previously, providing customers with much greater flexibility. "Typically, in-plant conveyance systems are straight-line designs, but now our AGVs can move in all directions and around corners, so plant operators can make much more efficient and flexible use of their real estate," explains Stegner.

An important corollary benefit of this flexibility is enabling industrial and plant engineers to think differently about plant-floor layouts. "If they have no constraints on how they develop floor plans due to AGV movement restrictions, then they can optimize layouts for maximum output," says Stegner. "They can also modify floor plans much more quickly and easily to accommodate new production requirements." Eliminating tethered HMI controls makes operating the AGVs much easier because plant personnel no longer have to worry about cables breaking or becoming tripping hazards.
The AGV example demonstrates determinism using wireless Ethernet, and this application shows how wired Ethernet can provide determinism.

Deterministic Ethernet communications in this application and many others are provided with EtherCAT, a modified version of Ethernet. "EtherCAT permits communication to as many as 256 digital I/Os in 12 µs, and up to 100 servo axes every 100 µs," claims Matt Prellwitz, the drive technology application specialist at Beckhoff Automation. And for applications requiring real-time control and power over Ethernet, Beckhoff recently introduced EtherCAT P, a solution combining industrial Ethernet communication and a 24 Vdc power supply in a single, standard four-wire Ethernet cable.
A Beckhoff customer implements robotic work cells positioned along a conveyor system in a large manufacturing facility, and it uses EtherCAT to provide the required high-speed communications. "In this application, EtherCAT delivered a wide range of benefits, including increased speed of data transmission and pulse rates," says Prellwitz.
By leveraging real-time EtherCAT in assembly cells, communication speeds increased exponentially. The real-time production data from the robotic systems is fed directly into the enterprise systems, thereby enabling closer integration into the production process with a higher-quality end-product as a result. Weld patterns are also tracked in real-time, providing a means of ensuring high product quality and repeatability of processes.
Processing on the fly is one of the biggest enablers of the real-time performance of EtherCAT. Prellwitz says the general operating principle for Ethernet frames in EtherCAT, along with mapping through a fieldbus memory management unit (FMMU), distinguishes it from other industrial Ethernet protocols.
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One EtherCAT frame holds data for many network devices. The frame is not received and interpreted with the process data copied at each individual device. Instead, each EtherCAT slave device reads the data specifically addressed to it from the frame and inserts data into the frame while that frame passes through the node at full speed. Also, the frame's cyclic redundancy check (CRC) is updated to reflect the new contents of the frame.
"That's just the technical description of how EtherCAT works," explains Prellwitz. "Customers who have heavily implemented this technology focus more on the many benefits and tangible results of real-time functionality in industrial Ethernet systems."
Profinet and EtherCAT work well in these applications to add determinism to Ethernet, but the networks aren't compatible with each other, nor with any of the many other variants of Ethernet designed to provide determinism. This creates a problem as too many Ethernet "standards" can result in no standard at all.