Technical Article

A History of Industrial Ethernet Protocols and Their Benefits

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Every industrial Ethernet protocol has a unique history and differing benefits for industrial applications. In this article, I'll provide a brief overview and key benefits for three key protocols: EtherCAT, Profinet and multiprotocols.

Industrial Ethernet

Industrial Ethernet is used for factory automation, building automation and many other industrial applications. A key benefit of industrial Ethernet over standard Ethernet is the deterministic real-time data exchange and isochronous cycle time – less than 1 ms.

You cannot implement most industrial Ethernet standards with standard Ethernet media access control (MAC); instead, you'll need a dedicated application-specific integrated circuit (ASIC) or field-programmable gate array (FPGA). That is because the Ethernet frame is received as "cut-through," which means that while the first Ethernet port is receiving the frame, a dedicated industrial Ethernet MAC hardware block is already processing and transmitting that frame onto the second Ethernet port. The cut-through method can achieve a port-to-port delay of less than 1 µs for an Ethernet frame.

EtherCAT

An invention of Beckhoff Automation, Ethernet for control automation technology (EtherCAT) has lived under the EtherCAT Technology Group umbrella since 2003. On the technical side, EtherCAT is a controller-and-device network architecture, as shown in Figure 1. The EtherCAT device has two Ethernet connectors in order to support a simple line topology. An EtherCAT network can support as many as 65,535 EtherCAT devices.

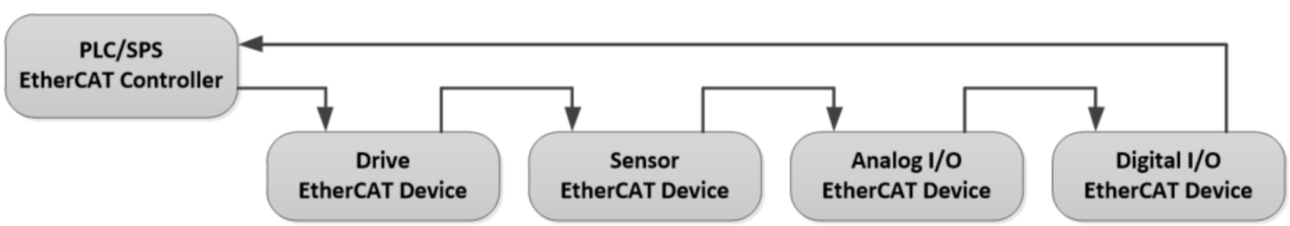

Figure 1. Controller-and-device example network with EtherCAT frame flow

Only the EtherCAT controller generates an EtherCAT frame; all devices receive and process this frame. The last device loops back the EtherCAT frame, and the EtherCAT frame travels back through all devices (without further processing) to the controller. The EtherCAT frame has reserved space to process data for each device, and none of the devices change the frame length itself.

An EtherCAT device requires specific Ethernet hardware (EtherCAT MAC) support, as it needs to process incoming EtherCAT frames as they arrive. Typical implementations use ASICs or FPGAs, as shown in Figure 2. This means that the EtherCAT MAC processes the EtherCAT frame while frame reception is ongoing. Typical EtherCAT devices have a 1-µs port-to-port delay between received and transmitted frames.

Figure 2. EtherCAT device with an ASIC/FPGA and external processor

Key features and functions of EtherCAT devices include:

- Distributed clocks – a precise time-synchronization method across the devices and the controller.
- Fast link-drop detection with loopback (requiring Ethernet physical layer [PHY] transceiver support) – when an Ethernet PHY such as the DP83822 or DP83826E detect a link down, the Ethernet PHY notifies the EtherCAT MAC. Within less than 10 µs, the EtherCAT MAC will loop back the EtherCAT frames.

Using an ASIC or FPGA adds cost and board space when supporting EtherCAT along with additional protocols. An alternative solution is.to use the programmable real-time unit industrial communications subsystem (PRU-ICSS) peripheral found in Sitara™ processors, which allows engineers to support multiple industrial Ethernet protocols with the same IC.

How to select the right industrial Ethernet standard: EtherCAT

More information on EtherCAT

Profinet

Process field network (Profinet) is one of the leading industrial Ethernet standards for factory automation. There are different versions of Profinet, but in this article, I'll focus on Profinet input/output (I/O).

Profinet operates on full-duplex 100-Mbps Ethernet and has a device-and-controller network architecture, as shown in Figure 3. It consists of a Profinet controller that takes over the controller role in the network; I/O devices take over the device roles. Profinet is very flexible in terms of network topology and includes line topology, ring topology, star topology or combinations of these topologies using hub and switch devices.

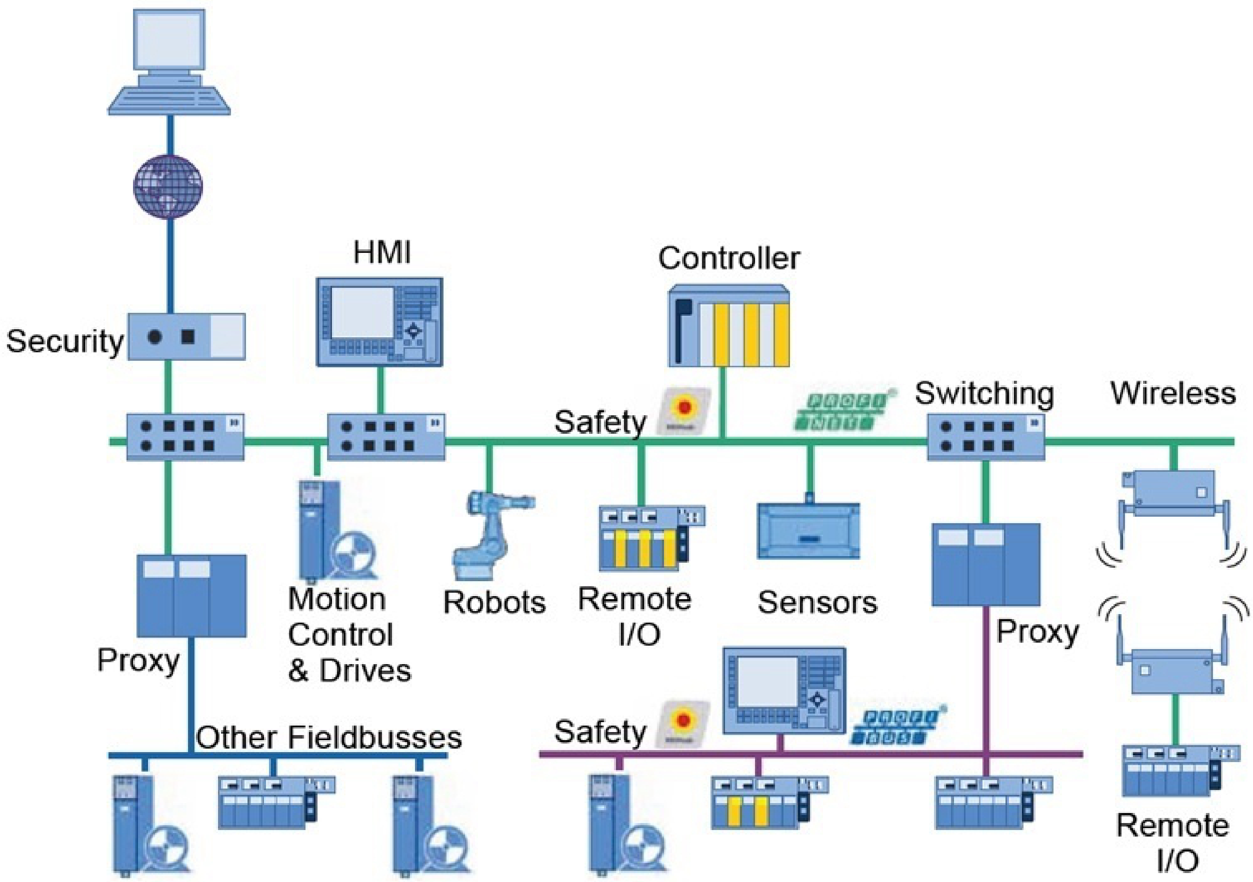

Figure 3. A Profinet network in an automation system (Source: Profibus International)

Over the years, the Profinet standard has evolved based on market requirements. Various kinds of performance classes are simply named A, B and C. Each performance class adds more functions than the class below, an approach that enables Profinet to be backward-compatible with previous Profinet device generations.

Let's review the important functions of each performance class.

- Conformance class (CC) A (CC-A):
- Real-time Ethernet communication.
- Cyclic I/O.
- Parameter configuration.
- Alarms.

In most cases, this performance class is implemented on a standard Ethernet MAC. The device does not even need to have two Ethernet ports; a single MAC is sufficient.

- CC-B. The same functions as CC-A, plus:
- Network diagnostics.
- Topology detection.
- System redundancy.

This version of Profinet I/O also performs with a cycle time in the 1-ms range.

- CC-C. The same functions as CC-B and CC-A, plus:
- Reserved bandwidth for specific Profinet frames, also known as isochronous real time (IRT).
- Time synchronization for the controller and devices.

This version of Profinet I/O supports a cycle time down to 31.25 µs, although most applications operate with a cycle time of 250 µs or slower. The IRT version of Profinet I/O requires a dedicated two-port industrial Ethernet MAC.

For a more detailed look at Profinet IRT, read this technical article.

How to select the right industrial Ethernet standard: Profinet

More information on Profinet

Multiprotocol

Because of the number of industrial protocols offered, product manufacturers have not defined a common industrial Ethernet standard; instead, the field is fragmented. Many leading manufacturers have defined a specific industrial Ethernet standard to fit their needs, often derived from one of their existing serial-based field buses.

Adding an industrial Ethernet standard to a product and then certifying the communication interface with certification bodies has its challenges. Most manufacturers need to support multiple industrial Ethernet protocols in order to sell their equipment to customers using different standards. One way to add multiple Ethernet standards to a product is to create separate printed circuit board (PCB) modules for each industrial Ethernet standard. You plug one of the modules into the main board at a time. Exchanging the protocol always requires a hardware change, however, which makes the product more complex in terms of the bill of materials (BOM) and the need to produce multiple PCB modules and source multichip solutions.

To solve this challenge, designers can use products such as the Sitara™ Arm® processor. These application processors have an integrated PRU-ICSS, which is able to operate multiprotocol industrial Ethernet. Let's review the key differences and advantages of this solution. Learn more about multiprotocol support in our demo video and get the software.

The PRU loads industrial Ethernet protocol firmware at device run time. There are PRU-ICSS protocol firmware releases available for EtherCAT, Profinet, , Ethernet/IP, High-Availability Seamless Redundancy-Parallel Redundancy Protocol (HSR-PRP) or Sitara processors also support Control and Communication Link Using Industrial Ethernet (CC-Link IE) Field basic in the Processor SDK, and does not require any FPGA or ASIC.

The protocol firmware performs real-time critical tasks such as cut-through frame processing.

The PRU-ICSS, together with the scalable and powerful Arm core (Cortex®-A8, A9, A15 or A53, depending on the Sitara processor) enables you to build a single-chip solution for products in factory automation, which can then operate in multiple industrial Ethernet standards through the flexible exchange of PRU-ICSS firmware. In addition to these advantages and the ability to handle real-time critical industrial Ethernet processing tasks, the PRU-ICSS also:

- Eliminates the need for external ASICs and FPGAs.
- Reduces BOM and PCB space, and therefore cost.
- Enables fast I/O data exchange between the Arm processor through an internal high-speed memory bus interface.

Read this article for more information about multiprotocols.

How to select the right industrial Ethernet standard: Multiprotocols

More information on Multiprotocols

An EtherCAT dedicated option with real-time control

When facing the design challenge of a dedicated, optimized integrated EtherCAT system-on-chip, the C2000™ F28388D real-time MCU is a good option. Designed with ultra-low real-time latency in mind with 925MIPs of real-time signal processing power, these MCUs feature an ultra-fast ADC sensing unit, a DSP-core for real-time computation and flexible high switching frequencies, high resolution Pulse Width Modulator (PWM) for actuation abd up to 1.5 MB of on-chip flash. The F28388D also integrates EtherCAT, for applications such as AC servo drives and robotics.

Whether using EtherCAT, Profinet or multiprotocols, each one has its own unique benefits for industrial applications as we have outlined above. You can find more information on selecting the right industrial communications standards in the white paper, selecting the right industrial communications standard for sensors.

Additional resources

- Read these technical articles:
  - "How to select the right industrial Ethernet standard: Ethernet Powerlink."
  - "How to select the right industrial Ethernet standard: Sercos III."
- Check out the application report, "Industrial Communication Protocols Supported on Sitara Processors."

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