WHITE PAPER

Forging Open and Unified Industrial Network Architecture With TSN and Single-pair Ethernet

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Overview

Ethernet technology, which marked its 50th anniversary in 2023, remains an ever-evolving transformative innovation that sets the foundation for future connectivity. To ensure Ethernet technology remains relevant for industrial applications, continuous advancements are necessary. These advancements may include improving data transmission speeds, providing real-time and reliable communication, and supporting a greater variety of connections. Hence, it is vital to explore new possibilities and push the boundaries of this established technology.

This paper will explore how the combination of time-sensitive networking (TSN) and Single-pair Ethernet (SPE) solutions propel standard Ethernet to new heights across industries. First, we will delve into how TSN, an extension of standard Ethernet that enables real-time and deterministic communication, meets the evolving requirements of industrial network architecture. Then, we will examine how SPE, a standard Ethernet transmission technology that employs just one pair of copper wires for both data and power transmissions, increases the potential of diverse applications.

Standard Ethernet Is the Key to Realizing a Unified Network

With Industry 4.0, the focus has shifted from simply establishing connections between devices to effectively accessing and using data. To achieve real-time data management and transmission, the key is the construction of a flat and unified network architecture that enables seamless communication between IT and OT systems throughout the entire network.

"By adopting one standardized technology to achieve integration among various systems, we establish a unified network architecture, which elevates production efficiency to the next level, offering enhanced flexibility and real-time capability. Time-sensitive networking (TSN) together with SPE and OPC UA FX reshapes the landscape of industrial manufacturing." said Stefan Schönegger, Vice President Controls at B&R Industrial Automation, a global leader in factory and machinery automation.

"By seamlessly connecting field instruments to the plant's network, we can gain simple access to data to improve maintenance processes and increase production efficiency. Extending Ethernet to field instruments boosts the competitiveness of end users who are seeking future-proof networks. To achieve a reliable futureproof network, Ethernet technology is the key." said Michael Bückel, Head of Product Management Platforms at Endress+Hauser, a global leader in measurement instrumentation, services, and solutions for industrial process engineering.

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Moxa is a leading provider of edge connectivity, industrial computing, and network infrastructure solutions for enabling connectivity for the Industrial Internet of Things. With 35 years of industry experience, Moxa has connected more than 82 million devices worldwide and has a distribution and service network that reaches customers in more than 80 countries. Moxa delivers lasting business value by empowering industry with reliable networks and sincere service for industrial communications infrastructures. Information about Moxa's solutions is available at www.moxa.com.

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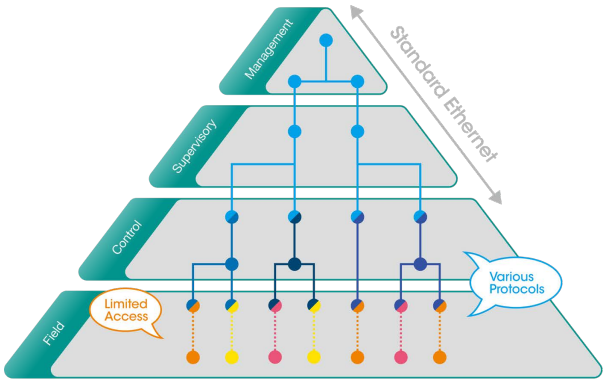
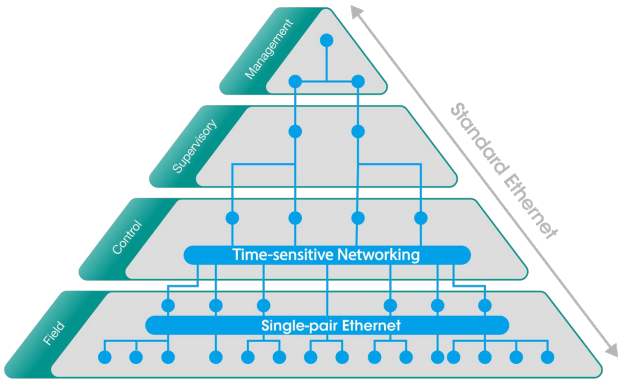
Because of its reliability, security, and simplicity, standard Ethernet has been a proven communication technology in IT applications for decades. Now, it will also play a crucial role in vertical integration and cross-system collaboration in the OT domain. Here, standard Ethernet enables effective communication among different devices and systems, achieving reliable and secure data transfers.

TSN and SPE have emerged as the two important Ethernet technologies that enable the development of a unified industrial network and push Ethernet's capabilities to new heights. Leveraging standard Ethernet, TSN facilitates real-time and deterministic communication and establishes a unified industrial network backbone for a variety of systems. With the use of just two wires, SPE enables the transmission of data and power over long distances, extending Ethernet to the industrial field, connecting the last frontier for a truly unified industrial network.



Existing Industrial Network Architecture



Future Industrial Network Architecture

The Foundation of Unified and Open Infrastructure—TSN

The future of industrial networks is largely centered on TSN, according to industry forums. Using TSN, deterministic services can send time-sensitive data over standard Ethernet networks. TSN incorporates network traffic management to maintain strict time frames for end-to-end transmission latencies. All TSN devices must synchronize their clocks with each other and use a common time reference. Additional traffic control can be included to establish a fully deterministic network. Thus, leveraging TSN's deterministic capabilities enables real-time communication for industrial control applications using standard Ethernet. Furthermore, TSN can transmit a variety of communication protocols and coordinate different systems without interference, facilitating a unified and open network architecture.

TSN's successes in various sectors show its effectiveness as a unifying platform for integrating different systems. Implementing TSN in manufacturing, for example, has reduced production cycle times and total cost of ownership, while achieving mass customization to meet market demands. In a home appliance manufacturing scenario, for instance, TSN realized a real-time, deterministic network infrastructure and enabled precise control and synchronization of production line devices and processes.

As TSN expands its capabilities, we recognize common network requirements across different applications. To meet evolving needs, TSN must continue to adapt.

Evolving Requirements

As unified industrial networks expand and integrate diverse applications and devices, they demand new requirements from TSN technology.

- **Higher Port Counts**
  With the need for more and more device connections, TSN network devices must have larger port counts to accommodate the growing demand for future networking.
- **More Bandwidth**
  The rise in ports, devices, and TSN-enabled applications leads to increased data traffic. Bandwidths of Gigabit, 10G, or higher are necessary for processing and transmitting such large volumes of data.
- **Different Form Factors**
  With the increasing adoption of TSN in various applications, the demand for TSN network devices of different form factors is also rising.
- **Easier Management**
  As the number of devices and applications in a TSN network grows, the need for management and configuration tools becomes more apparent. Tools such as central network controllers (CNCs) are essential for simplifying network management and configuration.

Navigating the Last Frontier to Achieve a Unified Network—SPE

SPE refers to four IEEE Ethernet standards: IEEE 802.3ch, IEEE 802.3bp, IEEE 802.3bw, and IEEE 802.3cg. Each specifies a transmission distance and speed, varying from 10Mbit/s to Gigabit and from 50 meters to 1 kilometer—all based on two wires. With a single pair of copper wires for both data and power transmissions, SPE offers several advantages over traditional Ethernet wiring, such as being lighter, more space-saving, less expensive, easier to install and wire, and faster to implement.

Before, standard Ethernet provided a copper connection with four or eight wires and a defined transmission distance restriction up to 100 meters. This was not suitable to be adopted in industrial field applications. Nevertheless, SPE has changed things for the better, expanding Ethernet networking possibilities in various field applications.

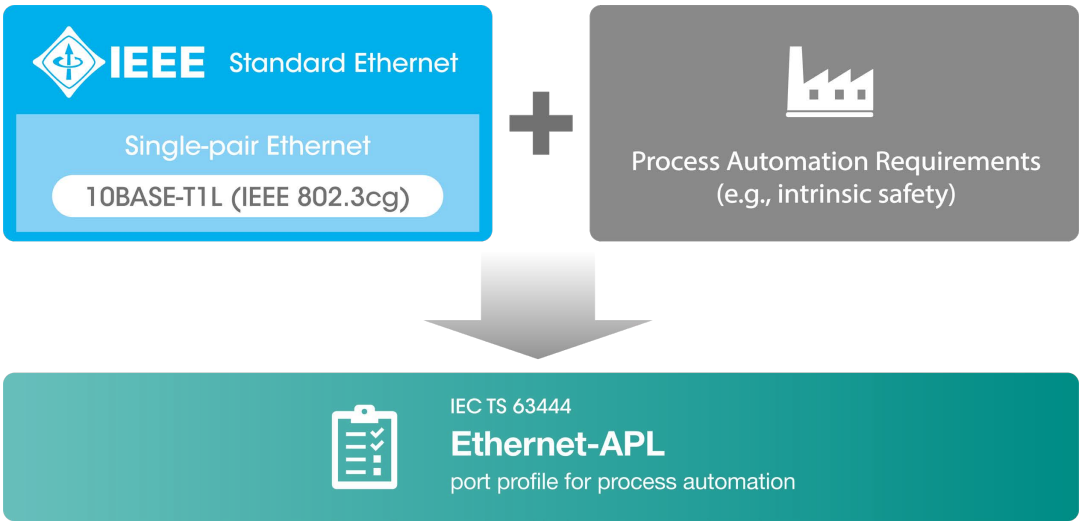
As SPE connects devices and equipment at the field level with the upper network, it enables the entire system to achieve a unified network architecture. This integration allows seamless data transmission to improve production efficiency and reduce production costs by using technologies like predictive maintenance and other data-driven applications.

However, various applications have different requirements. Let’s examine how SPE is revolutionizing the process automation industry.

Unveiling the Power of SPE in Process Automation—Introducing Ethernet-APL

In process automation, especially within the chemical and oil-and-gas sectors, common requirements include transmitting data and power simultaneously on the same cable over distances exceeding 100 meters and operating in hazardous environments with intrinsic safety requirements.

IEC TS 63444:2023 outlines Ethernet Advanced Physical Layer (also known as Ethernet-APL or APL), which is designed for hazardous areas in process automation plants. It incorporates SPE technology—IEEE 802.3cg 10BASE-T1L—and explosion protection through intrinsic safety (IS).



In the past, process automation relied on multiple technologies like 4-20 mA and various fieldbuses. However, as market demands for more data access and optimization increase, the limitations of legacy technologies are becoming clear. These legacy technologies pose obstacles between upper network layers and the field level, as well as security risks and limitations because of slow transmission speeds and complex system integrations. Furthermore, managing multiple communication protocols in the field is both complex and costly, as it involves implementing intricate protocol conversions, maintaining different systems, and allocating multiple groups of professionals.

Despite the significance of standard Ethernet solutions in enabling an open and unified architecture for industrial automation, field-level applications have not always reaped the benefits. Introducing Ethernet-APL—a fully compatible two-wire, intrinsically safe, long-distance solution that also offers power supply on a two-wire capacity—empowers process automation applications to establish a unified network from the management system to the field, using standard Ethernet.

With Ethernet-APL, you can expect much higher speed and improved data access, surpassing existing 4-20 mA and fieldbus solutions. For example, Ethernet-APL provides speeds of 10Mbit/s, 300 times faster than fieldbus. Beyond speed, Ethernet-APL, as a standardized technology, offers the advantage of protocol independence, allowing for the use of multiple protocols with no need for a gateway. With Ethernet-APL, complex device setup and system calculation are no longer necessary compared to fieldbus or analog systems, resulting in significant cost and effort savings across engineering, installation, commissioning, and operations. More importantly, with improved data availability and a unified architecture, efficient monitoring and optimization of field processes become workable.

	4-20 mA with HART	Fieldbus	Ethernet-APL
Cable	2-wire	2-wire	2-wire
Communication	1.2 kbit/s half duplex	31.25 kbit/s half duplex	10 Mbit/s full duplex
Signal	Analog and digital	Digital	Digital
Trunk	N/A	1,900 m	1,000 m
Spur	N/A	120 m	200 m
Unified Network	Gateway required	Gateway required	Seamless connectivity
Total Cost of Ownership	High	Medium	Low

Summary

In the age of Industry 4.0, network transformation plays a crucial role in driving digitalization and intelligence in the industrial sector. The adoption of standard Ethernet technologies to achieve a unified network has elevated production efficiency and propelled the evolution of intelligent manufacturing. The shift in networking has great importance for the industry, empowering businesses to navigate dynamic market conditions with agility, optimizing their production processes for increased effectiveness, and establishing a sound basis for ongoing innovation in future industrial practices. At its core, TSN serves as the cornerstone of this unified infrastructure and the emergence of SPE brings us closer to a unified network by extending Ethernet to industrial fields.

For more insights into TSN and its applications, visit Time-sensitive Networking | Moxa