Whitepaper

Single Pair Ethernet for Field Devices

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This whitepaper aims at Panel Builders, Machine Manufacturers and Product Managers who want to understand what Single Pair Ethernet is and how it can help to solve the challenges they are facing.
It focuses on the benefits of Single Pair Ethernet for industrial applications and gives an outlook into the future of connecting field devices like sensors, switchgear, etc.

Keywords: Ethernet, Single Pair Ethernet, Automation, Networking, Communication, Field Device

1 Introduction

Across all industries, Ethernet has long served as a backbone for networking. In the field of machinery and equipment specifically, a strong, general trend towards Ethernet-based communication can be observed over the last decade.

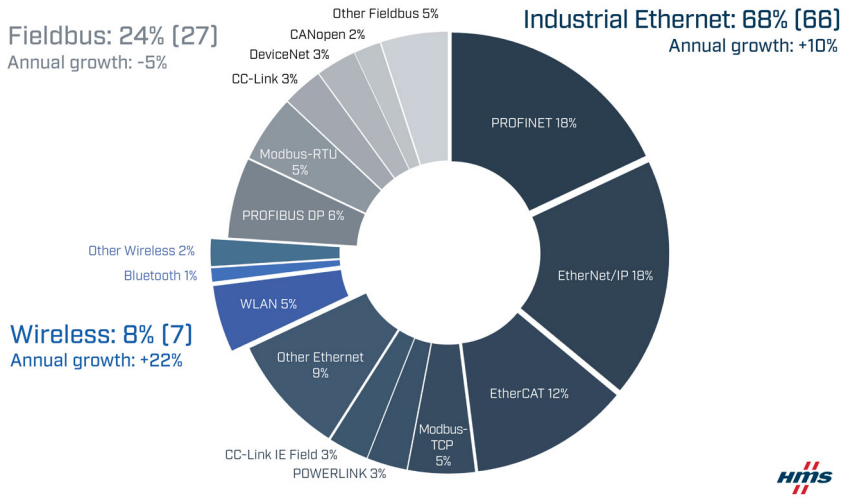

Figure 1.1: Industrial Ethernet market shares 2023 (Source: HMS)

The advent of digitalization and the Industrial Internet of Things (IIoT) yields an increase in the density of data delivering devices and a corresponding demand for seamless communication. This marks a shift in the role of Ethernet – it no longer just complements serial fieldbus and legacy communication systems but replaces them.
A good example for this is the industrial plant. This area historically featured an Ethernet networking backbone and a collection of fieldbus systems at the field device level. With the need to replace fieldbuses with a more efficient and flexible communication sub-system, the emergence of the Industrial Internet of Things (IIoT) overthrew this established order.
More devices need to exchange data, not only with the controller just above but also with other services and systems. This leads to several challenges which go beyond just the resulting need for complex system architectures, the use of Gateways and immense efforts in configuration, commissioning and troubleshooting.
A similar shift can be observed in any market or application area featuring communication both at sensor and network levels, e.g. smart cities, building automation or in-vehicle communications.

2 Technology

For all these purposes, seamless communication is crucial. More complex devices often offer Fast Ethernet or Gigabit Ethernet. Fast Ethernet needs two pairs of wires, Gigabit Ethernet and above even requires four pairs.
Meanwhile, Single Pair Ethernet (SPE) works with only one pair of wires, being able to provide power as well as data on this single pair. Its transmission rates – 10 Mbit/s with a maximum transmission length of 1,000 m (10BASE-T1L) up to 1 Gbit/s with a maximum transmission length of 40 m – are completely sufficient even for the most sophisticated sensor technology. Even scanners and cameras can be integrated with this technology.
These SPE standards are ideal for field devices outside of the cabinet like sensors, remote enclosures with pushbuttons or even edge devices as the installation becomes a plug and play solution with reduced cost for wires, especially on long distances. In addition, the IEEE adopted the 10BASE-T1S standard in November 2019. The suffix "S" stands for "short range". This standard works in half-duplex mode and can be operated in both point-to-point and Multi-Drop applications. It defines a cable length of up to at least 25 m with 10 cm stubs.
Multi-Drop is the main advantage of this network topology as the network nodes do not require an active Ethernet switch in this mode. Instead, nodes can be connected to a single cable in a daisy chain as it is known from classical fieldbuses. The PLCA (Physical Layer Collision Avoidance) arbitration scheme ensures that no data collisions occur, simplifying the infrastructure and wiring immensely.

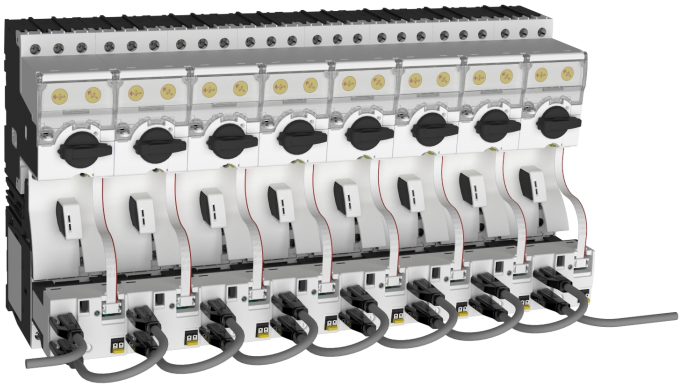

Figure 2.1: Multidrop application for motor starters

Therefore, this technology is well suited for the use within the cabinet, where motor

starters, circuit breakers and other switchgear can be easily connected and send their data up the automation pyramid without the need for complex wiring or expensive network infrastructure.
Single Pair Ethernet fundamentally is no competition for the well-known Ethernet standards but complements these by allowing Ethernet to penetrate further down in the automation pyramid, bringing standardized and transparent communication into all the field devices which are currently either not connected at all or rely on legacy or even proprietary communication systems.

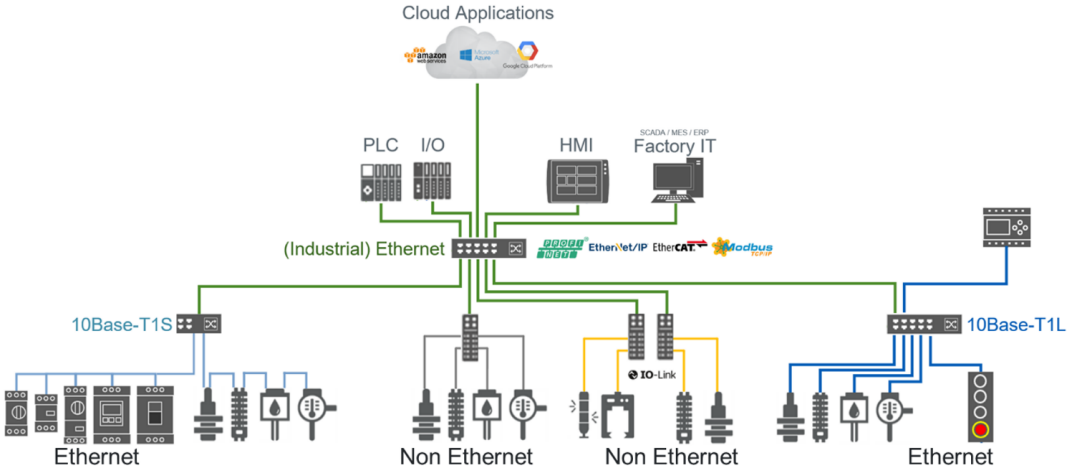

Figure 2.2: Example of system architecture with SPE

This way, the overall architecture can be simplified and new features and ideas can be implemented. Single Pair Ethernet is ideal for application fields where maximum bandwidth is less important than space efficiency, ease-of-use and quick and easy installation. With a connection technology suitable for industrial use, it is possible to create a continuous, transparent connection from the field device all the way up to the cloud without communication breaks.
Of course, an integration of SPE into an application can happen step by step, without the need to completely redesign systems. For some devices, existing non-Ethernet communication systems will still co-exist, as we have seen in the past.

3 Challenges for Panel Builders and Machine Manufacturers

Increasing globalization puts a growing cost pressure on panel builders and machine manufacturers alike. This is not only limited to component cost but also on installation and commissioning expenses. Furthermore, errors are not only expensive but cause project delays which can be critical. This situation is exacerbated by an increasing lack in qualified workforce in most countries.
Machine manufacturers are faced with increased demands to reduce the carbon footprint of their products, leading to a need for insights into their processes and ways to optimize for energy efficiency.
In a similar fashion, data from machines and – subsequently – the components used within those machines can be used not only to add new and exciting features to machines and systems but also to explore new, service-based business models. Both of which can be a strong differentiator for machine manufacturers.
Trends towards the widespread use of digital twins and product data management with concepts like the Asset Administration Shell (AAS) accelerate this even more.
Alongside this increased need for data, there are more and more cybersecurity threats which cannot be parried effectively with legacy communication systems. Manufacturers and users alike therefore need communication systems which can utilize well established security mechanisms to protect their data.
These challenges can only be met by a standardized, transparent and open communication system which is easy to install, commission and use. Future trends and developments also call for a system which can support a multitude of protocols and use cases. We have already seen that Ethernet brings all these benefits. SPE now promises to extend the reach of Ethernet down into in-cabinet devices, adding the benefits required for this environment.

4 Benefits of Single Pair Ethernet for the Industry

How does SPE benefit panel builders? SPE allows to remove the classical, parallel control wiring – where the number of wires scales with the complexity and functions of a device - and replace it by a pluggable 2-wire connection. This simplifies connecting devices and reduces the likelihood of wiring mistakes, not only enhancing efficiency but also aiding in producing panels faster, thus boosting productivity. The SPE connectors are designed to meet IEC Industry standards. Both plugs and sockets are built with metal snap-in hooks which provide a simple assembly due to a two-part connector design.

Figure 4.1: SPE infrastructure components

Furthermore, the industry faces challenges like labor shortages, making it difficult to find individuals for the tasks at hand. Even more pressing is the expertise shortage, where there's a scarcity of skilled professionals who can read and interpret wiring diagrams, essential for tracing and troubleshooting. SPE addresses these pain points, making the process smoother for panel builders. The same benefits also extend to maintenance (replacement of devices) and later extension of systems as well.
For machine builders and integrators alike, the added connectivity is a strong benefit. Not only does the integrated communication allow for better and more granular process control but it also greatly simplifies the integration into higher level systems like MES, ERP or cloud infrastructures due to the transparent and protocol agnostic communication via Ethernet.
This removes the need for the mapping of data inside a gateway, the time-consuming configuring and programming of data handling and communication with higher level services on the controller level and the issues related to these topics. In addition, in-

frastructure cost is reduced as SPE just requires transparent infrastructure components like network switches instead of more complex translation devices like Gateways while at the same time allowing easy remote access to every device in the system.
The increased need for connectivity as well as the advent of stronger governmental regulation towards Cybersecurity also poses a challenge for which most fieldbuses and legacy communication systems do not have an answer. SPE, being "just Ethernet", on the other hand, allows the utilization of well-known and proven Cybersecurity measures and network management features. This allows for a holistic approach to Cybersecurity across the whole system, reducing the need for highly specific skillsets and the development of overly complex security concepts.

5 Communication Protocols

As already mentioned, SPE is a variant of Ethernet and therefore defines the lower two layers of the OSI model.

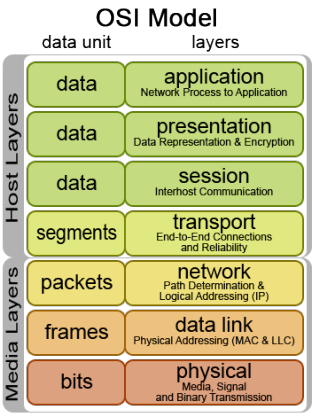

Figure 5.1: OSI layer model

Above those layers, a multitude of protocols does exist which are used in the industry for specific purposes or in specific applications and many of those are using Ethernet for transport. Among those are of course Industrial Ethernet protocols like Modbus TCP and others.
Notable is also OPC-UA which aims to unify the communication with industrial equipment and for which also a variant for the use within field devices (OPC-UA FX) is in definition. This promises to become a completely vendor-agnostic way of integrating field devices into systems.
Several other, more IT-centric protocols like MQTT or even HTTP (used also for REST-Services) are also usually using an Ethernet transport and can be implemented directly within field devices. Therefore, SPE constitutes a highly transparent method of getting such protocols also to field devices directly, allowing to offer new applications and workflows not currently possible with legacy communication systems.
An example would be a circuit breaker with integrated energy measurement which can communicate with the PLC using e.g. Modbus TCP while at the same time publishing energy measurement data via MQTT so that the data can easily be integrated into an existing service infrastructure. Furthermore, the circuit breaker could offer a web interface for configuration that can either be accessed from a browser or via an API. All over two wires thanks to a compact and simple Ethernet implementation using SPE and well-established industry standards.

With most legacy communication systems, this would only be partly possible and only by implementing these features e.g. inside the PLC or some kind of Gateway, which obviously requires a significant amount of work and is highly application specific.
The benefits of standards also extend to security, as well-known and proven security technologies like TLS, HTTPS, etc. can be implemented and security updates can be rolled out automatically if required, ensuring that machines are always secure and safe and machine builders and end users can ensure that their processes and data is secure.
To conclude, Ethernet allows a flexible integration of current or future protocols without the need to change the product or the infrastructure, offering a future-proof solution and enabling long-term support of components.

6 Conclusion

The advent of Single Pair Ethernet marks a significant point in the history of industrial automation as this technology allows to bridge the still existing gap in the automation pyramid and natively integrate field devices into the overall communication without barriers.
Therefore, SPE will lead to a new generation of products which include standardized, transparent communication – for some products even for the first time ever – to allow machine builders and system integrators to tackle the challenges of the digitalized world.
While the number of available products is still small right now, a strong growth can be expected here as the benefits specifically target shortcomings of existing solutions. The success of SPE within the automotive industry – where it replaces several legacy communication systems in modern vehicles – shows that these benefits can be realized in practice. And with increased availability of devices, also completely new ideas and concepts for future machines will emerge.
In the beginning, Ethernet too had been perceived as not required for industrial automation – a perception which has since been proven wrong by Ethernet becoming the standard which fundamentally changed the communication landscape in the industry. SPE marks a comparable turning point, with the chance and promise to transform industrial communications in a similar way once again.