Whitepaper

Single Pair Ethernet

Enhanced cloud access to sensors and peripherals

empowering communication

www.hilscher.com

Abstract

The digitization of the manufacturing industry is in progress after several years of governmental activities, demonstrating the benefits in proof-of-concepts and moving standards forward. However, the desire of having a seamless sensor-to-cloud communication as it is required for business models such as predictive maintenance and quality or smart robotics still faces some gaps in the network infrastructure. This whitepaper discusses the status and progress of single-pair Ethernet as a new initiative to enable IP based networks to each sensor.
As the name implies, single-pair Ethernet (SPE) reduces the connection between two communication partners to two wires versus the CAT-5 or CAT-6 based cabling in current Industrial Ethernet standards. Hence, it reduces the required space for plugs from a rather large RJ45 to much smaller plugs. This makes it much more attractive for sensor connections to fit to M8 sized connectors. As the two-wire connection requires a different physical layer specification, the IEEE has released specifications for the physical connection (PHY) from 10Mbit up to 10Gbit. They took the lead in standardizing the industrial version of SPE, coming from former initiatives for SPE in the automotive industry for car communication systems. Especially the 10Mbit version of SPE allows cable lengths of up to 1km, which makes it attractive to process automation and some of the hybrid industries to adopt their current sensor network infrastructure towards Ethernet. Currently, first PHY products are expected to hit the market. Therefore, Hilscher expects an adoption in the process industry somewhere in 2021. Discrete industries are expected to follow later towards 2024, as the Ethernet infrastructure and specifically IO-Link solves already numerous challenges in digitization today.

From Hilscher perspective, there is no doubt, that SPE will be adopted and take market share in the longer run. Our netX family of network processors offer an opportunity to adopt to SPE infrastructure and build gateways from existing network infrastructure to SPE in order to enable a migration path easily.

Table of Contents

List of figures

List of Tables

Introduction

Nothing has pushed the digitization more in to the middle of our daily lives than radical changes to our comfort zones, as it has happened for example in the pandemic of Covid-19. All of a sudden, tools and methods that were partially in use in professional business matters such as video conferencing, online meetings and trainings became a part of our new normal. While this sudden demand increase in the digital eco system and services could be called a revolution, the digitization of the manufacturing industry took a much longer time to ramp-up.

Digitization progress and benefits

Despite the fact that it is called the 4th industrial revolution, the manufacturing industry started their journey into the digitization age around 2011 already. The initiatives behind carried titles like “Plattform Industrie 4.0”, “Industrial Internet Consortium” or “Made in China 2025” and targeted to position and fund programs to use digital methods and techniques to overall improve the performance of production facilities. Various global consulting companies analyzed and called this a “game changer, seizing a trillion dollar opportunity” (Accenture, 2015).

A “new industrial paradigm” became visible with a “need for increased intelligence in embedded systems and value creation though smart services” and key success factors to be advanced analytics for predictive production actions and process transparency” (Capgemini, 2015). A McKinsey analysis also in 2015 based on 100’s of interviews with industrial companies concluded similarly that “disruptive technologies will enable the digitization of manufacturing sector” and lists among others cloud technologies, advanced analytics, touch and next-level GUI, virtual and augmented reality, advanced robotics and additive manufacturing. Based on a number of research institutions, they concluded to value drivers as in the following chart (Figure 1):

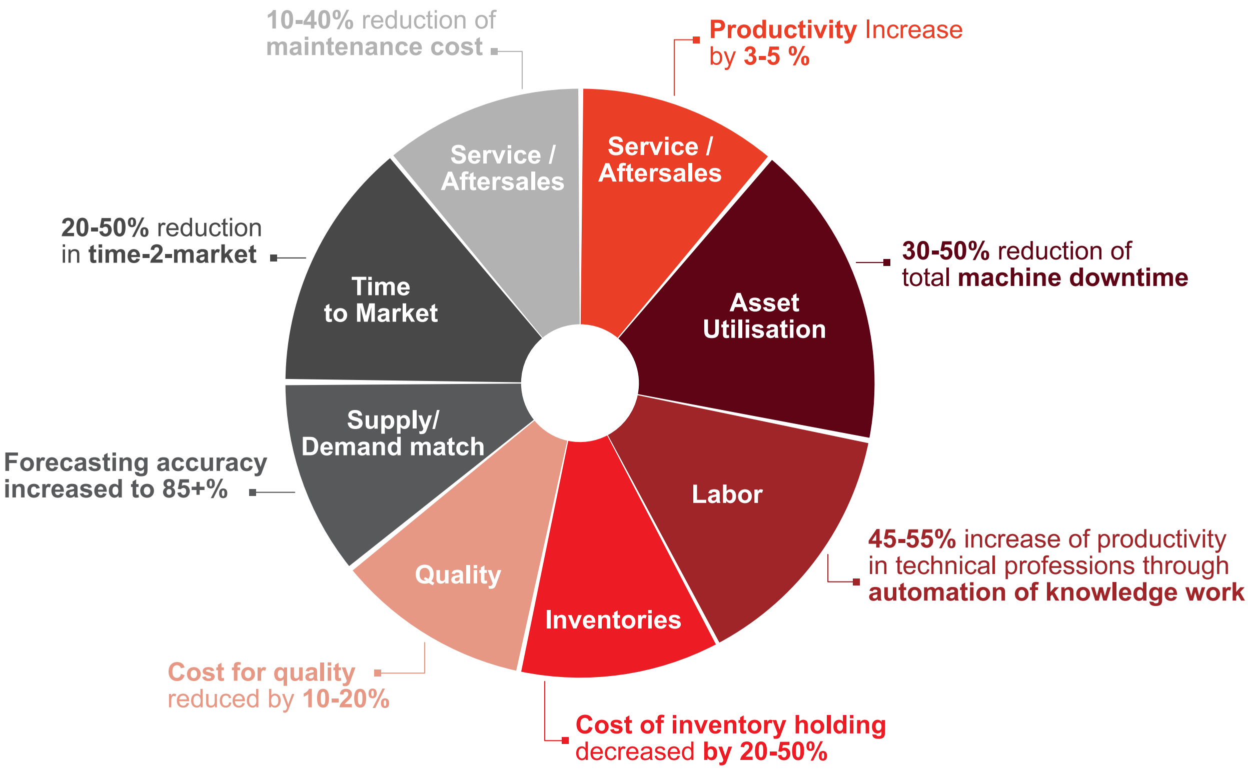


Figure 1: Value drivers and expected benefits of key categories in industrial production (source: McKinsey 2015)

Therefore, the expectations appear to be quite high and the potential indeed tremendous, but despite numerous proof-of-concepts driven for example through the Industrial Internet Consortium, the challenge remained how to enable vertical networking of smart production systems from factory floor into IT systems.

Today, after several years of research and search, we face now a much more focused and commonly shared understanding of the needs and benefits of digitization in the manufacturing sector. Technically, OPC UA has become the most common standard to help solving the vertical semantic challenge between IT and OT world. On the business side, several organizations drive initiatives forward that enable value add for production systems in the various industries similar to those predicted back in 2015.
We at Hilscher engage and drive programs and business models in the Open Industry 4.0 Alliance. We support an open shared eco-system to commonly deliver customer value in collaboration with a large partner network with our netFIELD products and services.
However, connecting cloud services to the sensor level is still a challenge and one opportunity to resolve the access is coming up with single-pair Ethernet.

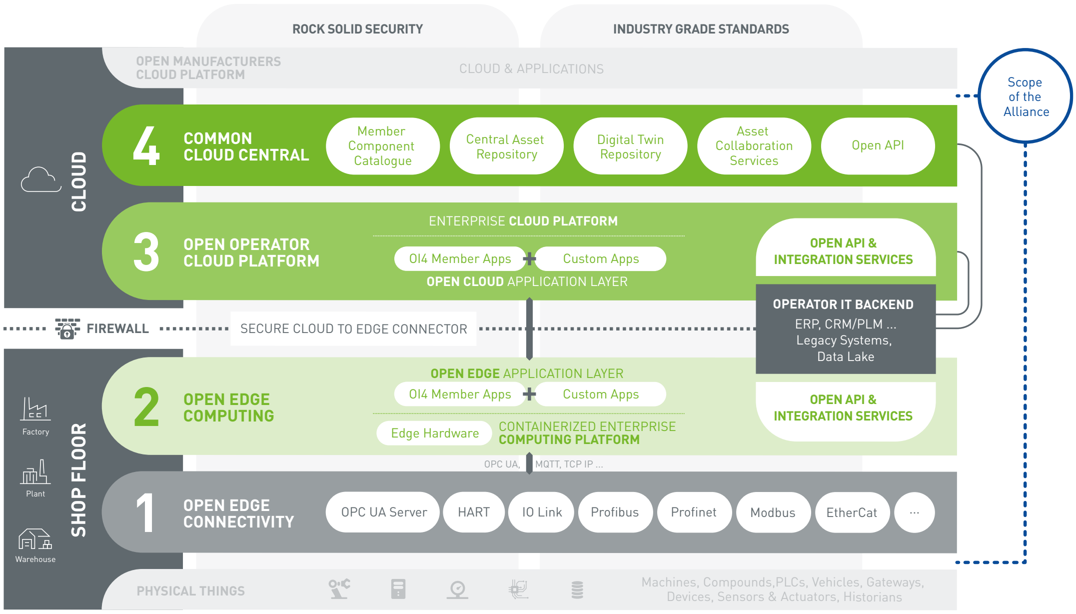


Figure 2: Operating Model of the Open Industry Alliance 4.0 (source: Open Industry 4.0 Alliance 2020)

Industrial networks

Starting in early 2000 and further in parallel to these digitization initiatives, the industry adopted Industrial Ethernet as the dominating communication standard in all industries gradually replacing the former fieldbus systems such as PROFIBUS, InterBus, CC-Link, Sercos or DeviceNet. Several variants of Ethernet were standardized to support the high demand for higher bandwidth and deterministic real-time communication that is specifically required in the factory automation related industries, such as automotive, packaging or food and beverages.

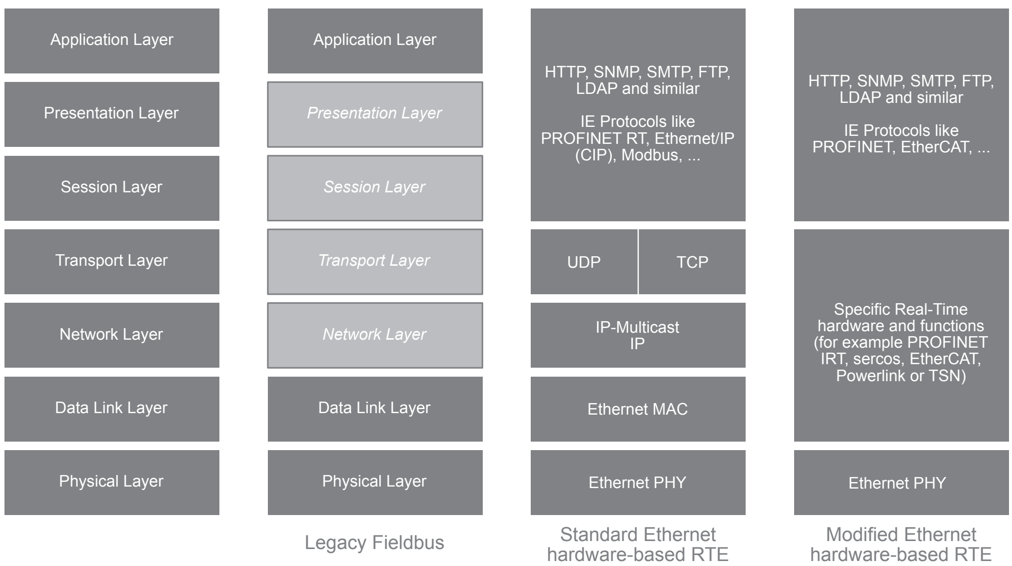


Figure 3: Legacy fieldbus and Ethernet variants in OSI Model

Different standards of Ethernet are driven from different automation companies and have a different level of modification demand of OSI layers on MAC and Link-layer to support real-time demand. Some protocols are based on the classical TCP/IP based Ethernet system, others modify the layers 3 and 4 and some require modified hardware to the Data Link Layer. The latest Real-Time Ethernet system Time-Sensitive Networking (TSN) and is under final release by the IEEE to standardize the real-time functions at layer 1, 2 and 3 for a common hardware base. All Ethernet variants share the ability to network the factory from the office side to the shop floor and enhance overall production performance, diagnosis and availability. However, the complexity of Ethernet and the network topology as daisy chain or switched networks limited its use in peripherals such as sensors and actuators. This gap in a seamless Ethernet-based IP network infrastructure is now addressed by standardization efforts for single-pair Ethernet (SPE).

The start to standardize Ethernet based on a single twisted pair originated from the automotive industry. In their in-car network, the existing standards such as CAN, MOST or FlexRay were too costly in cabling and software. Hence, a common standard to gradually replace these was found with Ethernet. However, the cabling effort for standard Ethernet was comparably high. Broadcom made a first pitch with BroadR Reach to show, that a simple twisted pair cable is sufficient to deliver high-speed data over shorter distances. The IEEE has picked up the standardization initiative under the well-known 802.3 Ethernet Standard and widened the scope to industrial and building area as well in order to address similar challenges there. In fact, the fieldbuses mentioned above in industrial space as well as LON, BACnet or Modbus in Building Automation are in focus, when targeting a seamless IP based network to each sensor.

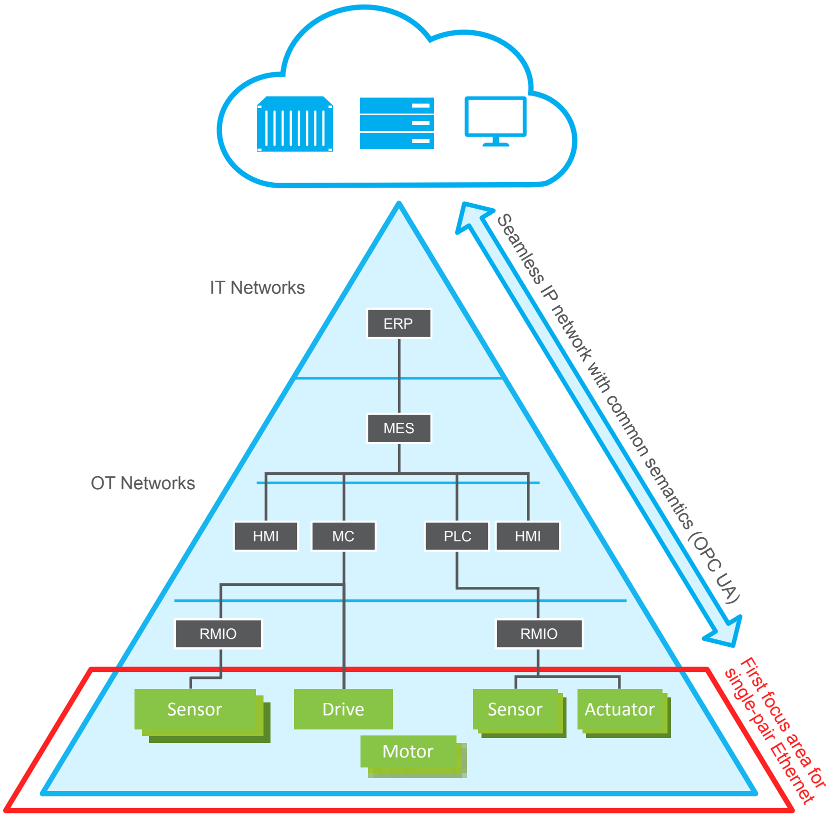


Figure 4: Focus area for single-pair Ethernet deployment in the automation system

As the vertical integration from sensors to cloud is a main basis for digital business models, the benefits to enhance IP networks to the sensor are attractive:

- Enhanced visibility, diagnosis and control
- Access to all automation equipment through one semantic with OPC UA
- One common vendor-independent tooling
- Enhanced robustness and availability
- Enablement of predictive quality and maintenance

Single-pair Ethernet now adds value through the thinner cabling, small footprint plugs and connectors and the less space requirements. For that reason, it is suitable to replace numerous existing fieldbuses in the sensor and peripheral area. However, a key question is how a deployment into the different areas in automation will happen.

Transition paths in different industries

While the idea to enable IP based networks down to the sensor level is obviously beneficial, the question is, how SPE is able to deploy in the focused devices and installations. When looking at the current installed base, there is a large variety of fieldbuses (see Table 1) and sensor networks in the field.

Fieldbus	Transmission speed	Max. distance
Factory Automation		
AS-Interface	125kbit	100m
Interbus	500kBd .. 2Mbit	up to 400m
Profibus DP	9,6kBd .. 12 MBit	100m .. 1200m
CANopen	62,5kBd .. 1 Mbit	30m .. 1000m
Devicenet	125kBd .. 500kBd	100 .. 500m
CompoNet	up to 4Mbit	1500m (@93kBd)
CC-Link	up to 10Mbd	100m
IO-Link	250kBd	20m
Process Automation		
Profibus PA	31.25kBd	1900m
HART	1,2kBd	1500 .. 3000m (dep. on cable)

Table 1: Distance and transmission speeds of current fieldbus technologies in sensors and peripherals

The table shows a mixture of fieldbuses in operation in the process and factory automation. Hence, there are different speed and distance requirements that are deployed today. These requirements define the specification that any following technology needs to support. On top there is the Ex area in process automation with specific requirements for intrinsic safety. The connection to the actual upper layer networks in brownfield installations bares a number of disadvantages as follows:

- demand for gateways between the "old" installation and new Ethernet networks
- lack of diagnosis and parameterization capabilities in some cases
- transmission speed and cycle time of some current networks limits performance
- maintenance and support effort increase for keeping "old" know-how alive
- installation effort to support multi-vendor configuration and tooling
- warehouse cost increase and availability challenged by potential end of life scenarios

In fact not all of the listed fieldbus standards are deeply affected as in the above list and some like for example IO-Link are just in ramp-up stage. But it is clear that the call for action and market pressure is different in the industries depending on the extent of use of old technology in the installations.

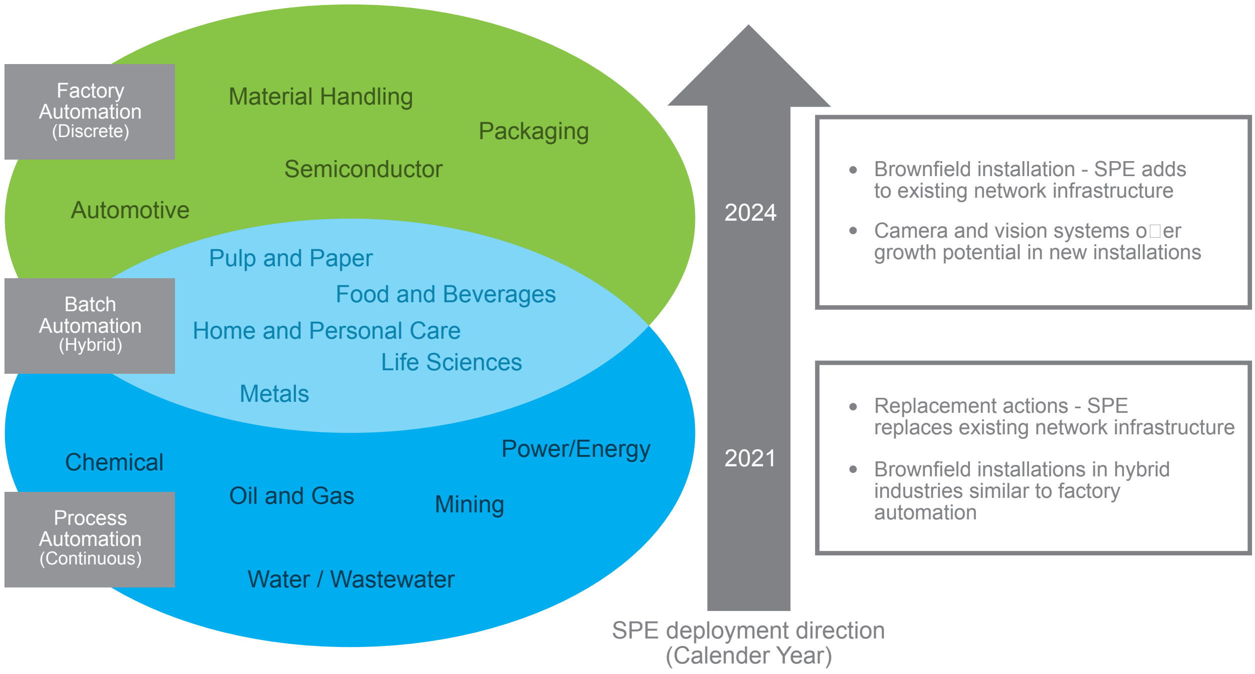


Figure 5: Timeline of system adoptions in different industries

Hilscher expects an early adoption and deployment of SPE in the process automation sector starting around 2021. The reason is that the installations are based to a large extent on HART, PROFIBUS PA and similar fieldbuses that are not in the necessary extend supporting digital business models. The Namur Organisation and specially the FieldComm Group together with the PROFIBUS International (PI) and ODVA strongly drive the move to APL for process automation industries. The applications in these areas have usually lower performance and cycle time requirements and the deployment of diagnosis and parameterization through the net-

work has not yet happened as much as in factory automation applications.
On the other side, the deployment of SPE in factory automation might take a bit longer. Organization such as the ODVA, PI including the IO-Link group have started activities to evaluate the integration of SPE into their respective standards looking at positioning and the benefit in their applications. In parallel, there are two very active groups on their way to propose different plugs, connectors and cabling for the installation. Looking at all these very productive initiatives and the numerous open questions they address, a field deployment in factory automation would rather start around 2024.

As a conclusion we believe that those areas in the manufacturing industry, where equipment is still non-transparent to the upper layers in terms of status, diagnosis and parameterization, the overall system performance lacks and the advantages of digitization such as machine up time increase, availability, predictive maintenance etc. will not materialize. Therefore, the pressure in the process industry is expected to be much higher to act and move forward as quickly as possible.

Single-pair Ethernet at a glance

The question might come up why people have not moved much earlier towards a single twisted pair as the basic idea appears comparably simple and potential benefits appear also quite obvious. However, the change versus an existing Ethernet network is not so quite simple as the exchange of a cable implies. In addition, a number of requirements need to be added to enable the expected benefits for the different industries.

Different physical layer

The current Industrial Ethernet 10Base-T/100Base-TX that is the most deployed and adapted standard in industry, uses two twisted pair cables for unidirectional transmit and receive data. Therefore, in change to this, a single-pair Ethernet transmits and receives via in the same twisted pair and therefore requires a different physical layer as well as different coupling and transducers.

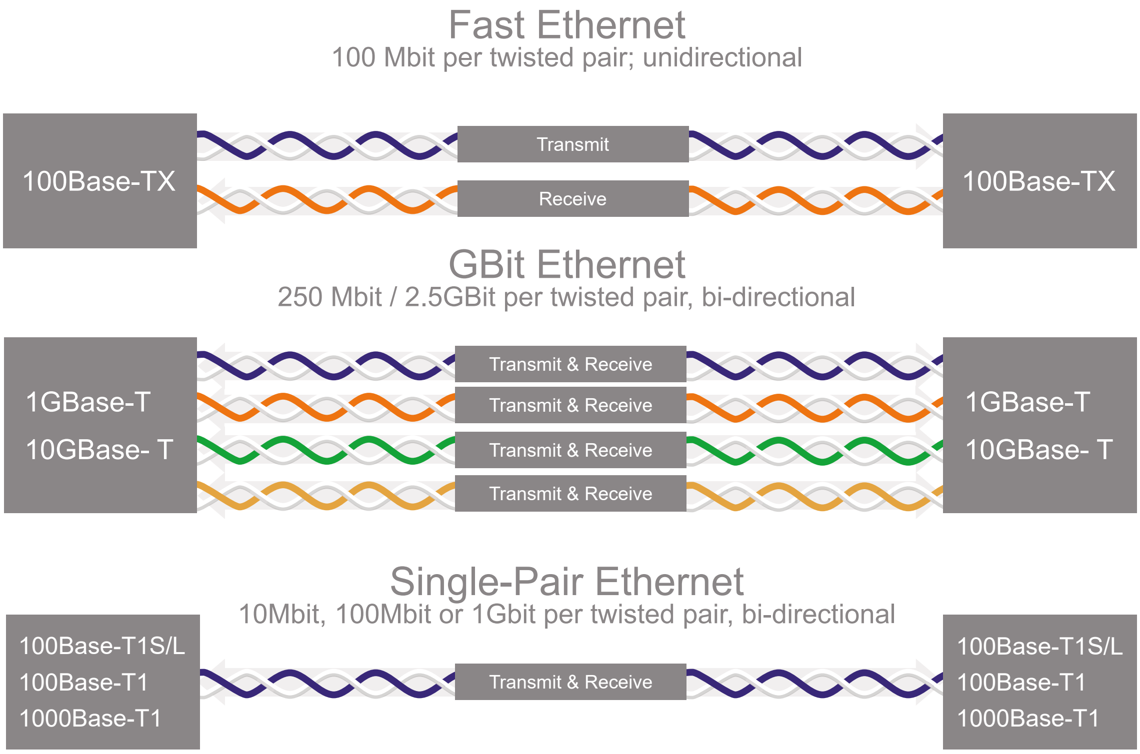


Figure 6: Comparison of Standard Ethernet physics versus SPE (source: HARTING 2019)

Long distance transmission

Especially the targeted sensors, actuators and other peripheral field devices in industrial automation require on top a much larger cable length between them. Hence, a strong demand came to enhance the cable distance between stations up to 1000m, versus the specified 100m that are available in 100Base-TX today.

Intrinsically safe

A third aspect came from the process automation field. Next to the long distance requirement, an intrinsically safe transmission is needed, to support the Ex and hazardous areas.

Power transmission

In many of the actual sensor communication fieldbuses, a power transmission over the communication cable is possible. Hence, the single twisted-pair cable needs to also carry the necessary power to enable the powering of remote sensors and actuators.

Application specific bandwidth demand

Next to field level devices and sensors that are well covered from their bandwidth demand with 10Mbit transmission speed, the idea was to also roll-out SPE into higher bandwidth applications. Therefore, the IEEE also defined standards suitable for vision, motion or HMI including the physical layers.

IEEE Standardization and related applications

All these requirements and inputs led to several SPE IEEE standards in the different transmission speeds as shown in Table 2.

IEEE Standard	PHY standard	Transmission Speed	Cable Bandwidth	Cable length	Applications
IEEE802.3 cg	10Base-T1L	10Mbit	20MHz	1000m (STP)	Sensors, actuators and peripherals, machine controls, train and bus networks, building automation
	10Base-T1S	10Mbit	20MHz	15m (UTP) 25m (STP)	Cabinet installations (no PoDL) half duplex
	APL	10Mbit		1000m (STP)	Intrinsically safe and Ex equipment
IEEE802.3 bw	(BroadR Reach)	100Mbit	166MHz	15m (UTP) 40m (STP)	Automotive
IEEE802.3 bp		1000Mbit	600MHz	15m (UTP) 40m (STP)	HMI, IPC, Camera, Motion & robotics
IEEE802.3 ch		2.5/5/10Gbit	4-5 GHz	15m (STP)	Vision sensing, IPC, HMI, Analytics, medical systems
IEEE802.3 bu					Power over Dataline (PoDL for SPE, max. 60W power transmission

Table 2: Overview of different SPE related Standards

The Table 2 shows a split into three definitions for the 10Mbit single-pair Ethernet Standard IEEE 802.3cg to reflect the different needs and demand from the different sensor, actuator and peripheral applications. The 10Base-T1L is most suitable for the requirements in sensors as it allows up to 1000m cable length in a point-2-point connection and fits very well into actual installations.

In terms of the physical layer definition, the APL is exactly same as T1L, but adds in cases the components for intrinsically safe transmissions in the Ex area. The 10Base-T1S allows in opposite to T1L a multi-drop set-up with much shorter cable length and a different PHY layer called PLCA (physical layer collision avoidance). Multi-drop has a good fit for example in cabinet installations or other short-range applications. Both system require a different physical layer as shown in the picture and following table:

	10Base-T1S	10Base-T1L
Transmission speed	12.5MBit	7.5MBit
	half-duplex multi-drop	full duplex
		echo-cancelled
Line-Coding	DME	PAM-3
Signal-Coding	4B5B	4B3T
Voltage	1Vpp	1Vpp (2.4Vpp)

Figure 7: Table 3: Comparison between the two specified physical layer specifications of SPE

Although the physical layer differs to some details, that connection to the upper layers is the same. The IEEE has taken effort to make sure that any actual system with a MAC and an MII connection can interface to the actual new PHY so that the major change remains in only one OSI layer. The following picture shows the set-up:

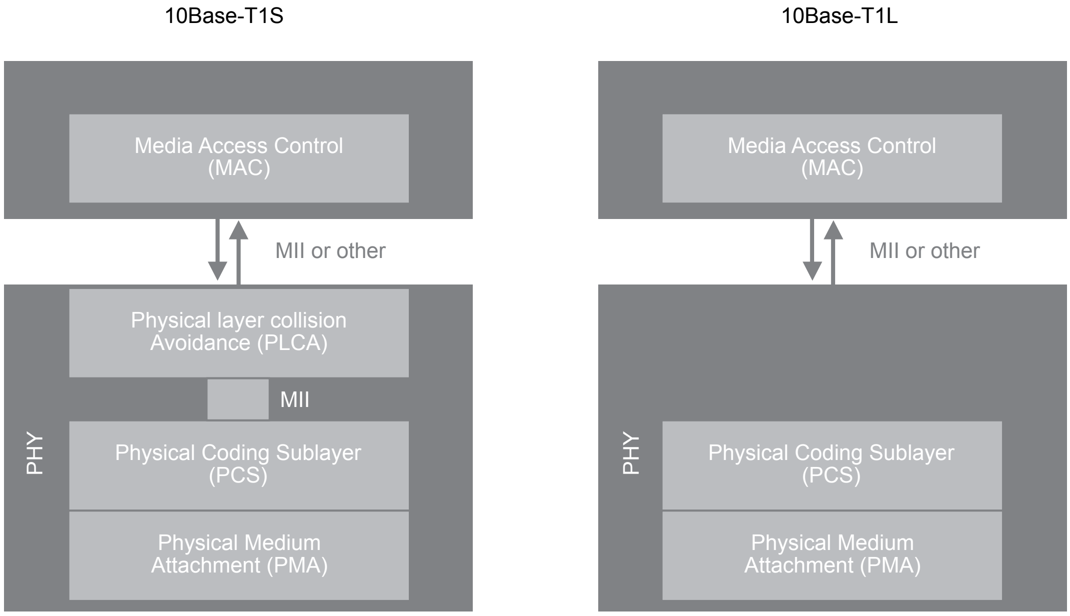


Figure 8: PHY connection to upper layer host system

On top of this, the 802.3bu standard has defined a standardized transmission of power over the data line and it is capable to transmit up to 50W to the single endpoint. This feature allows backward compatibility to several existing sensor network standards that also power the connected sensor from a central power controller. The set-up in SPE is as follows:

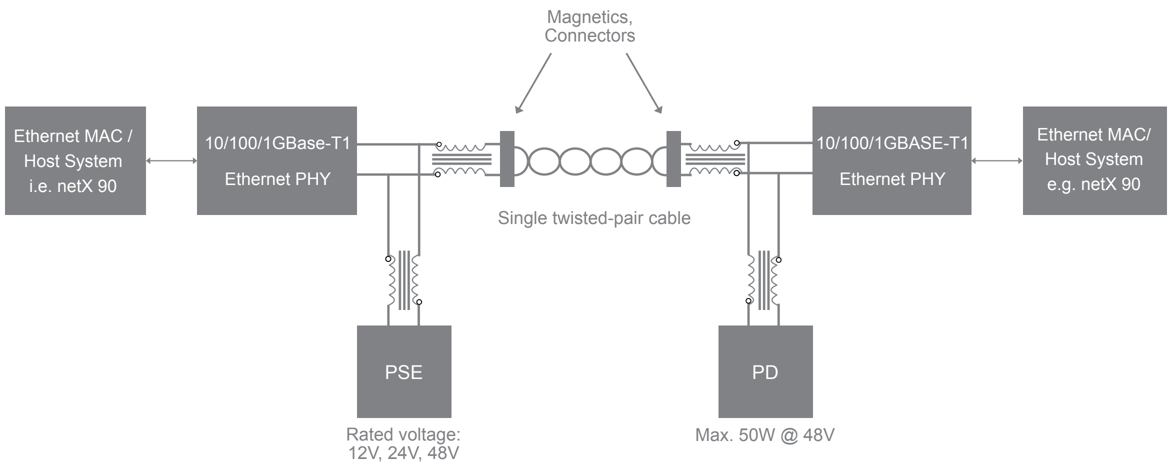


Figure 9: System set-up of a point-to-point connection with power distribution

The system requires a Power Sourcing Equipment (PSE) to deliver energy over the cable. Three different voltages are defined that are connected to specified power. On the receiver side, the Powered Device (PD) in the above case a maximum of 50W at 48V can be delivered in a point to point T1L connection. At 24V it is still a max. of 10W with a regulated PSE. The system is largely compatible to the trunk and spur topology in process automation networks. The standardization of single-pair Ethernet, as it stands, is well suited to support the demand of the industrial automation requirements. As the physical layer technology is already in use in some different flavor in the automotive industry, the industrial users can rely on an already field proven physical technology when they start implementations. However, there is still a distance to go to embed SPE into the actual Ethernet standards specifically in the factory automation environment. From system installation view-point, an IP network into each sensor allows to configure and maintain sensors in the field by a vendor-independent tool environment. From system installation point of view, an IP network into each sensor allows to configure and maintain sensors in the field by a vendor-independent tool environment.

System adoptions in process automation

While the factory automation networks largely base on Ethernet standards today, the adoption in the process automation field is still in progress. To address and enable business models for Industrie 4.0 and Industrial Internet of Things, the Namur released an open architecture (NOA) defining a communication concept across all layers to the cloud. Namur also released a paper to determine future networks in process automation to be IP networks with Ethernet. The FieldComm Group together with PI and ODVA formed a group that has driven the progress in IEEE to a large extend and determined their system requirements for a fast adoption into the field.

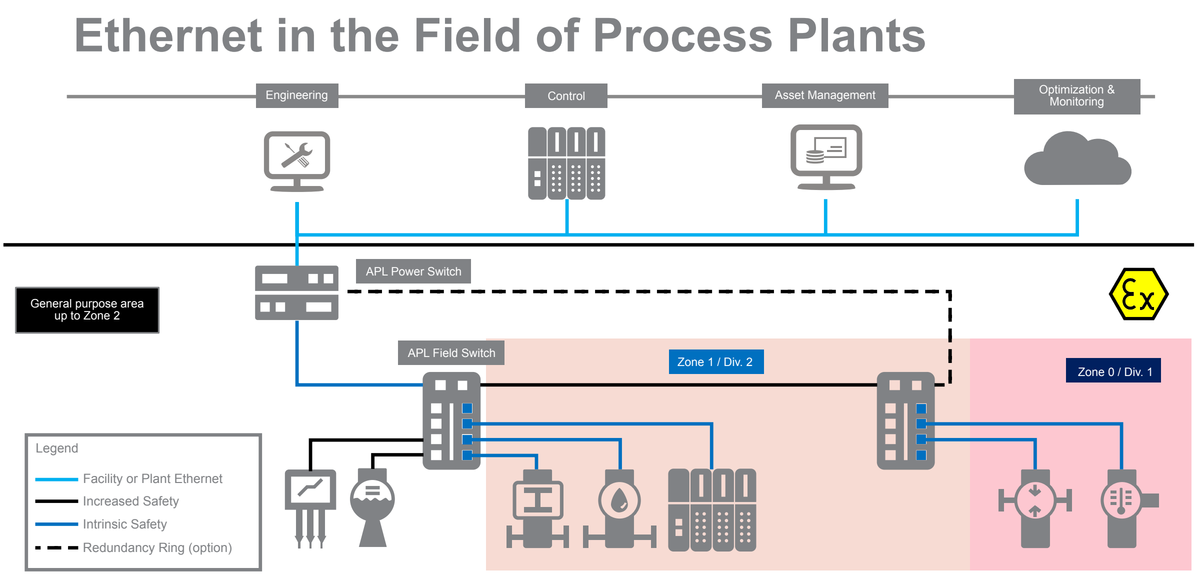


Figure 10: Ethernet-APL implementation scenario in process industry (source: FieldComm Group, 2019)

The picture shows the different zones in a process plant to address different levels of intrinsic safety and loop-powered or separate powered devices in hazardous areas like in Zone 0. The network itself uses the well-known spur and trunk topology that includes the ability to power up to 50 devices with up to 500mA each. Furthermore, existing cables and installations can be reused to reduce the effort of system design and integration time. Hence, the focus of the process industry is to replace the existing fieldbus installations with APL continuously.

System adoptions in factory automation

In opposite to process industries, industrial Ethernet is the dominant network in factory automation industries. However, this also limits the benefit arguments of SPE, which are valid in process automation industries to that of a smaller footprint, less cable weight, enhanced cable length, increased robustness easier installation and maintenance through one tool environment.

The challenge is now to bring these advantages into existing IP based networks that already enable many of the current data-driven business models. The challenges are manifold. Some of the industrial Ethernet standards have no 10Mbit transmission speed in their specs or just started to include. Several sensor manufacturers - being main drivers in APL for process automation - were already actively aligning their needs within the IO-Link standard starting back in 2007. IO-Link supports parameterization, diagnosis and full integration into “Industrie 4.0” eco-systems. However, transporting IO-Link Frames over 1000m of SPE would transfer the former point-2-point sensor network into a kind of fieldbus. A positioning discussion is required to resolve and avoid confusion. Despite these technical matters, a key question for factory automation is the use cases that would benefit from SPE. Various groups in PI, ODVA and IO-Link currently discuss and evaluate these use cases and potential integration scenarios into the field. The IO-Link Consortium has released a whitepaper with several examples of deployment scenarios (IO-Link Consortium, 2020) picking up some sample installations in the brownfield:

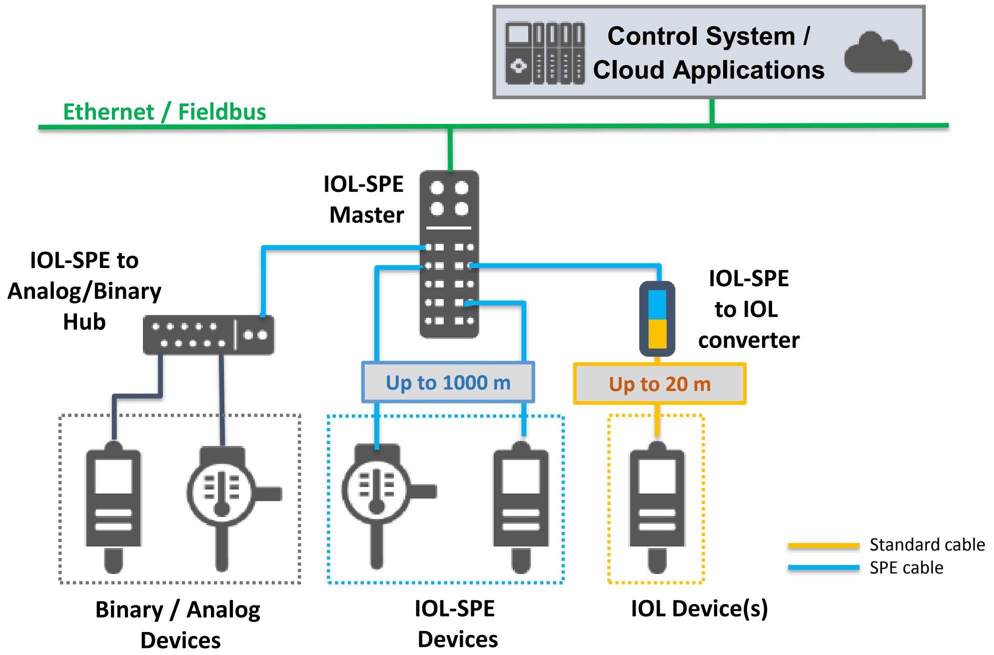


Figure 11: SPE installation in IO-Link eco-system (source: IO-Link Consortium 2020)

The above example allows integrating IP67 SPE master into an existing installation of IO-Link and binary sensors and devices. The proposal in the whitepaper takes SPE mainly as a transport medium for IO-Link Frames.

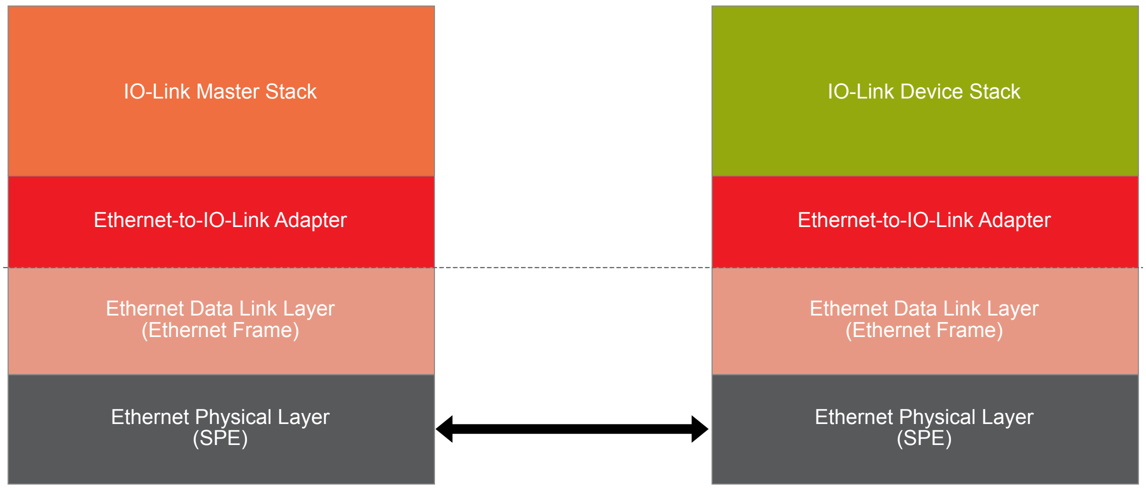


Figure 12: IO-Link data integration into Ethernet hardware and datagrams (source: IO-Link Consortium, 2020)

A software based Ethernet to IO-Link adapter allows to maintain the data format and use the range extension and other SPE benefits by maintaining the opportunity to keep the existing infrastructure and installations alive.

Hilscher participates in several working groups of PI to contribute to the discussions on SPE for PROFINET. We also contribute to the IO-Link working group evaluating the benefits and challenges for a complementary integration of both standards into the field. In IEEE we share the discussions on remaining open topics in the 802.3cg standard and we participate in discussions of the ODVA on SPE topics. Our goal is to help building a migration path to have low-effort integration of SPE into existing systems and to support this with our competence in communication and our products.

Market potential

A lot of work is still ahead of the industry to get open questions resolved in terms of system adoptions, standard integration and leveraging benefits in relevant use cases. At the start of the SPE standardization activities, companies participating showed a quite significant business potential, partially looking similar to the huge expectations raised at the beginning of Industrie 4.0 and IIoT. Today the industry appears to get back to some more realistic view on the potential and the adoption process in the different industries as formerly shown in Figure 5. Hilscher took some analysis from the field, in order to estimate a potential number of installed SPE nodes based on possible adoption rates from legacy fieldbus, TSN and Ethernet networking technologies.

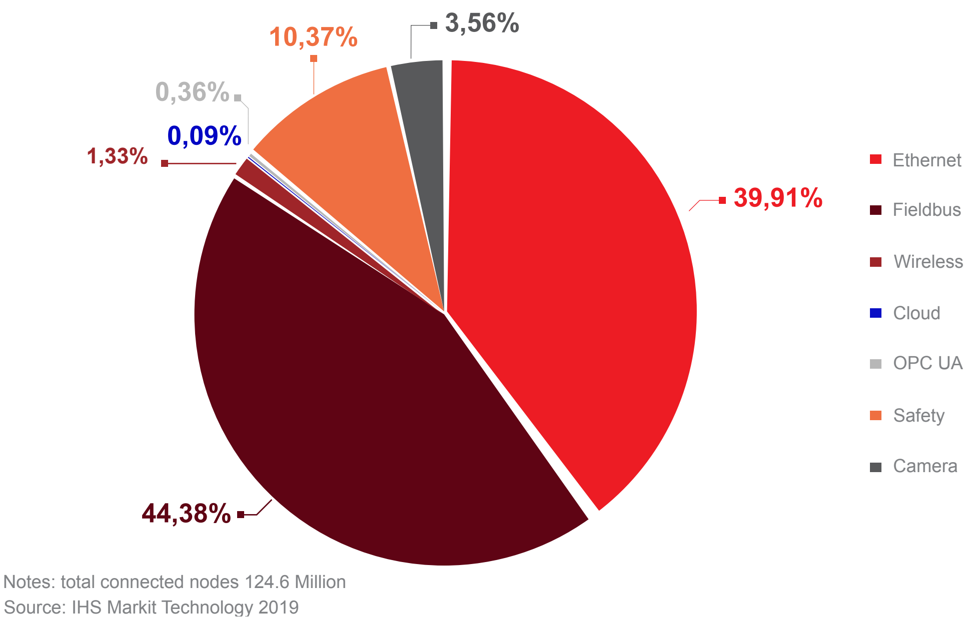


Figure 13: Communication technology share of connected devices in production (Source: IHS Markit Technology 2019)

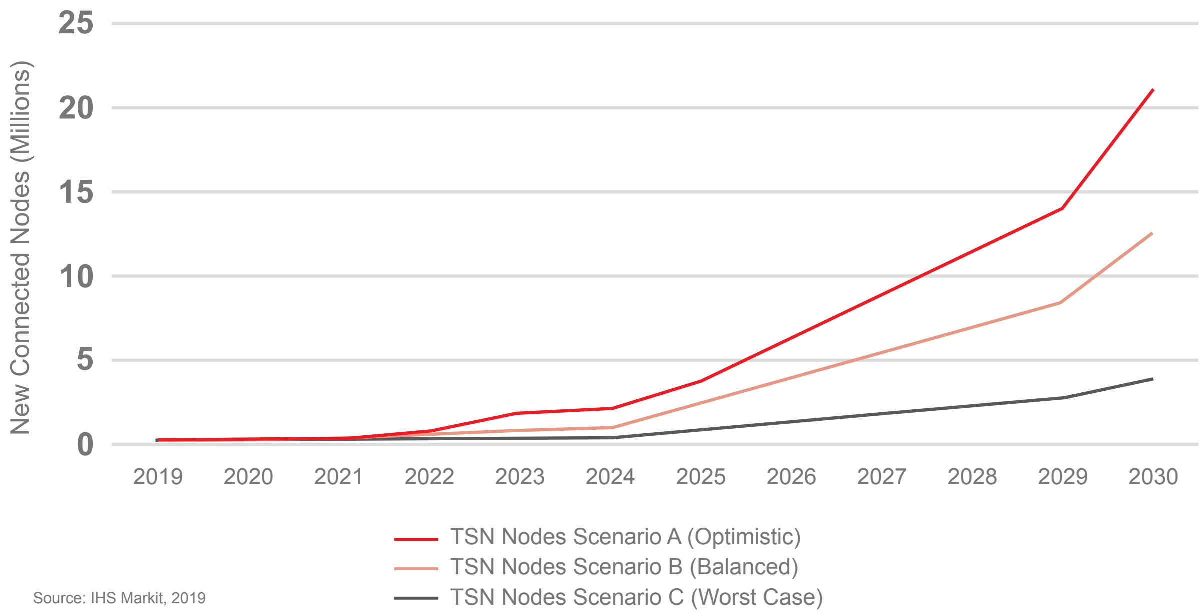


Figure 14: Scenarios of possible deployment of TSN in Factory automation (Source: IHS Markit, 2019)

As we showed, the industries have a different rate of integration and start of adoption of SPE. Therefore, we assumed a migration scenario as in Figure 14:

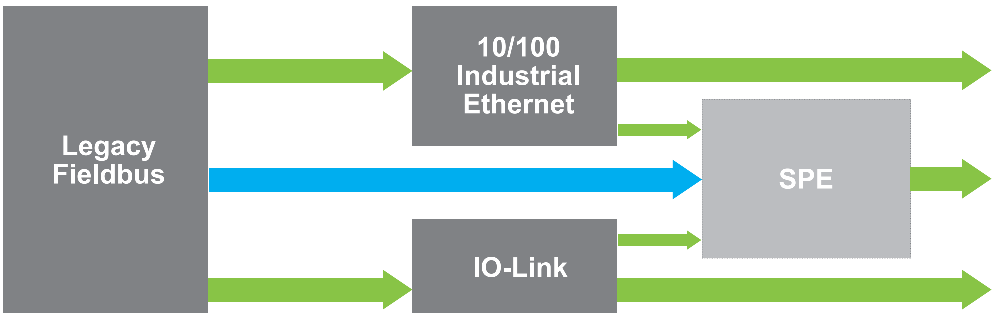


Figure 15: Migration paths for SPE in automation industries

SPE volumes are driven most from transfer from existing fieldbus technologies in process industries to SPE (APL), as the lever to materialize the benefits is highest. We expect initially a small cannibalisation of installed nodes to move from existing Industrial Ethernet 10/100 eco systems into SPE. Also IO-Link is still in the ramp-up stage and investments into IO-Link devices and installations need to amortize first, before a larger installed base is taken over by SPE. Hence, Hilscher´s estimate for annual installed SPE nodes is as follows:

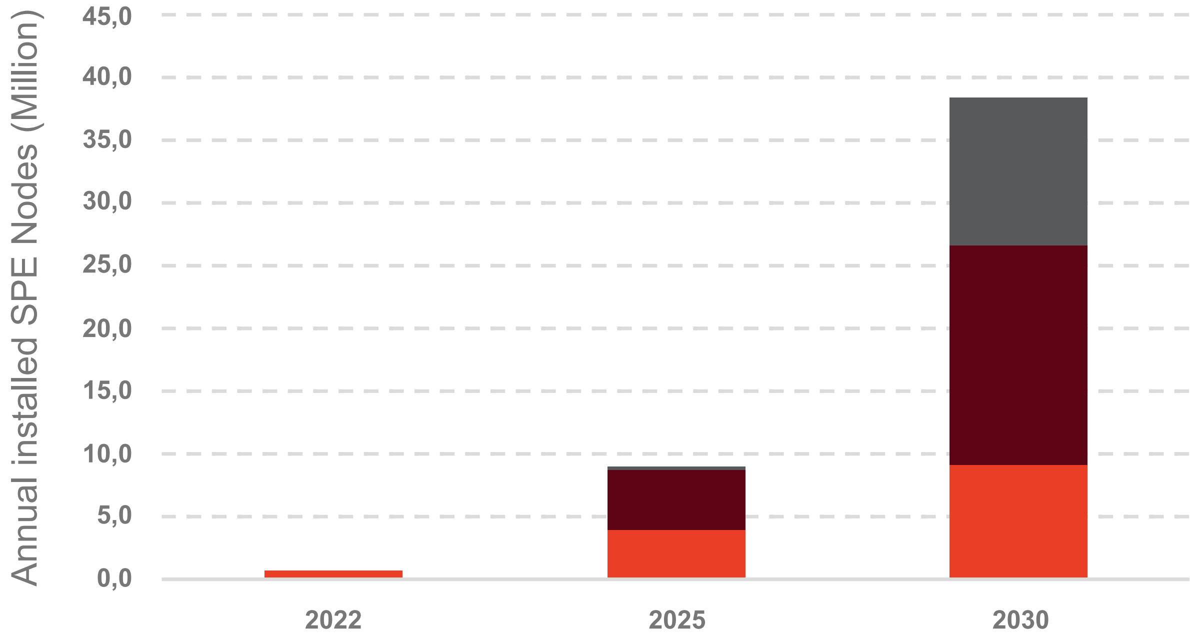


Figure 16: Estimated installed SPE nodes (Source: Hilscher based on IHS, PI, ODVA, FieldComm, ASi, ARC Advisory, HMS 2020)

The first movers will be process automation applications and devices that transfer current fieldbuses to APL. Hence in 2022 we estimate to see first installed nodes in the field. Hilscher expects thereafter a rather fast transition to SPE from legacy fieldbus technologies to SPE and a moderate enhancement of the existing Ethernet Infrastructure in factory automation. Due to the increased digitization of process automation, we expect an increased convergence of the equipment and protocols in use in the industries. Furthermore we expect an overall growth of networked equipment in the field that also contributes to a significant growth rate.

Hilscher solutions in SPE

Hilscher supports the SPE with their netX family of products enhanced by publically available PHY products and upcoming Hilscher product families to enable a fast and easy adoption of SPE in the relevant field of the automation networks.

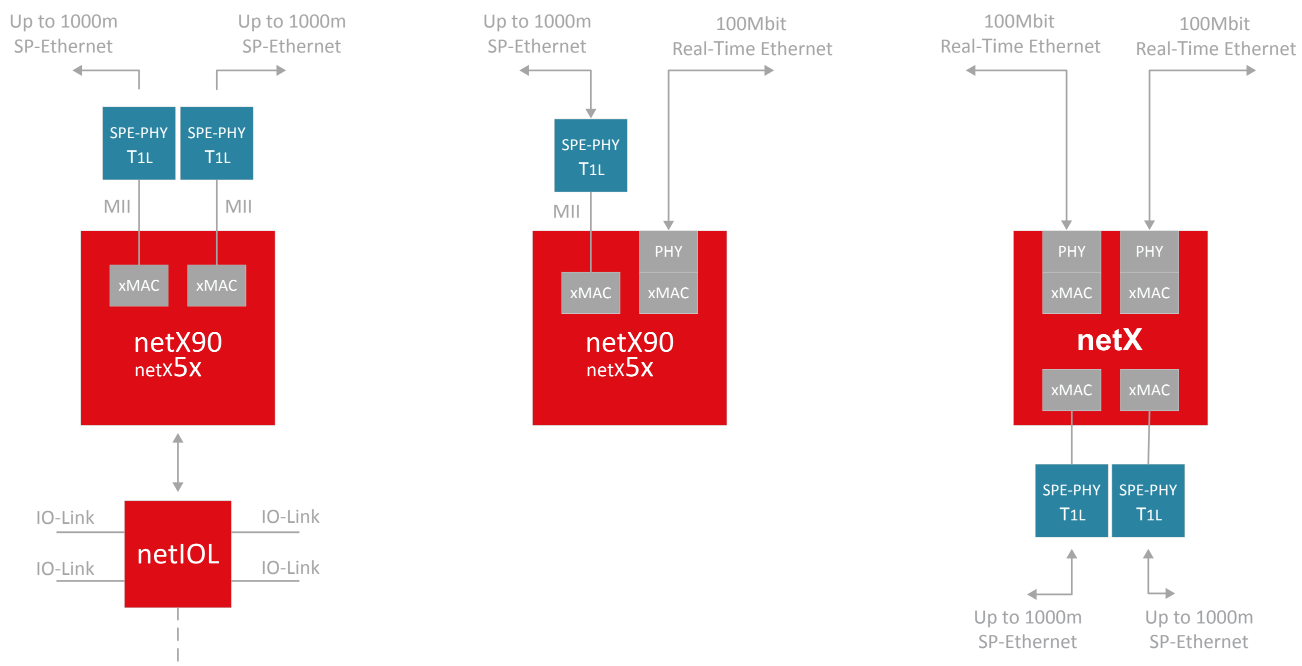


Figure 17: netX based configurations with SPE connection

Our current netX 90 product family allows to connect external PHY products via MII interface. The internal xMAC processors enable the protocol specific switching between the two channels. On the left side of Figure 16 this use-case would enable two 10Mbit channels SPE port up to 1000m line length connected for example to an IO-Link sensor network through our 4-channel netIOL Master chip for legacy implementations.

The constellation in the middle allows to connect an existing Real-Time Ethernet (RTE) system with 100Mbit with a to 10Mbit SPE. In that constellation, one internal PHY and xMAC serves the 100Mbit side, the second xMAC with the external SPE PHY connects to the up to 1000m of SPE network. On the right hand side, the netX serves as a switched device between a 100Mbit based RTE and a 10Mbit SPE network.

Hilscher has developed a first evaluation board with netX90 and SPE 10Mbit T1L PHYs for engineering purposes as visible in figure 17:

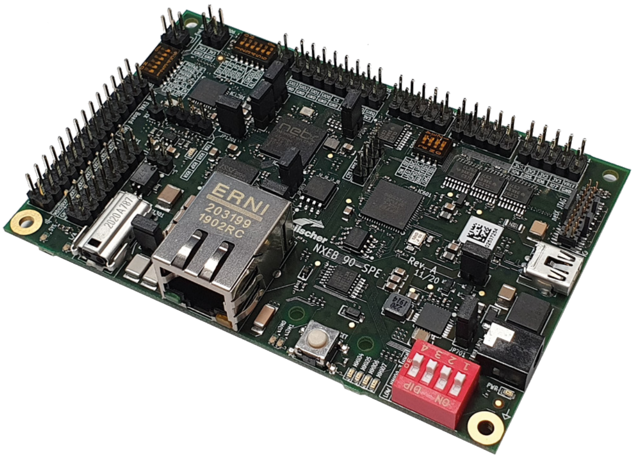


Figure 18: NXEB90 - SPE

The board offers a simple extension of a 100Mbit network towards 2ch SPE to evaluate the SPE network in context of the different Industrial Ethernet Standards. Hilscher expects a starter kit towards Q4/2021.

As the standardization bodies are still in progress to define and determine the SPE in their respective release, the above diagrams show some of the possibilities and options to support brownfield installations based on netX. With the progress in SPE definitions, we will release more options.

Conclusion and Outlook

Single-pair Ethernet has reached a state of definition that allows industries to start adopting in their systems. The focus is to have seamless connection with an Ethernet based IP network from sensors to the cloud. The benefits are different depending on the depth of integration of digitization methods. This leads to a different demand and speed of adopting SPE into the systems. The robust and smaller cables and connectors, the comparably high transmission speed, the distance of up to 1000m, a possible multi-drop set-up and the opportunity for one vendor independent tooling make SPE an excellent for sensor and peripherals. Hilscher is one of the leading companies in the Open Industry 4.0 Alliance that connects industry partners under a common framework to promote Sensor to Cloud eco systems and infrastructure. For SPE, Hilscher enables installations with their portfolio of netX products and in future with standard products from our portfolio of modules, PC Cards and Gateways.

Abbreviations

APL - Advanced Physical Layer

CAN - Controller Area Network

HMI - Human Machine Interface

IEEE - Institute of Electrical and Electronics Engineers

IIoT - Industrial Internet of Things

LON - Local Operating Network

MAC - Media Access Control

MOST - Media Oriented Systems Transport

NOA - Namur Open Architecture

ODVA - Open DeviceNet Vendor Association

OSI - Open Systems Interconnection

PD - Powered Device

PHY - Physical Layer

PI - PROFIBUS International

PLCA - Physical Layer Collision Avoidance

PSE - Power Sourcing Equipment

SPE - Single-pair Ethernet

TCP/IP - Transmission Control Protocol/Internet Protocol

TSN - Time-Sensitive Networking

References

Accenture (2015), Purdy, Davarzani, “The Growth Game-Changer: How the Industrial Internet of Things can drive progress and prosperity”

CapGemini (2015), Bechtold, Kern, Lauenstein, Bernhofer, “Industry 4.0 - The Capgemini Consulting View - Sharpening the Picture beyond the Hype”

Deloitte (2014), Schlaepfer, Koch “Industry 4.0 - Challenges and solutions for the digital transformation and use of exponential technologies”

McKinsey (2015), Industry 4.0 How to navigate digitization of the manufacturing sector

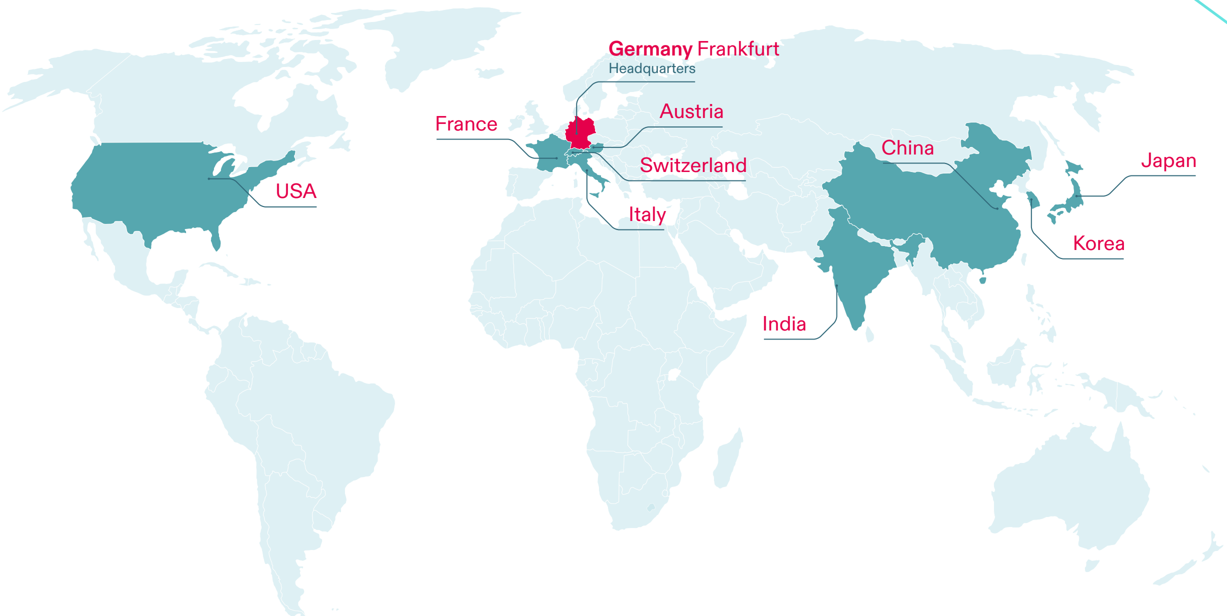
IO-Link Consortium (2020), Gringauz, Moritz, Lindenthal, Witte, „Concept study Extension of IO-Link for Single Pair Ethernet transmission” (Whitepaper), taken from https://io-link.com/de/Download/Download.php?thisID=8

FieldComm Group (2018), Presentation at Singapore meeting, taken from https://field-commgroup.org/sites/default/files/global/Singapore/5%20FCG-181012_APLinAnutshell_lv0.5pptx.pdf

IHS Markit (2020), S.Ali, “Industrial connectivity in the era of TSN, APL and 5G” taken from https://technology.informa.com/620165/industrial-connectivity-in-the-era-of-tsn-apl-and-5g

Notes

Would you like to find out more?
Get in touch with us!



Contact

Headquarter

Subsidiaries

Germany
Hilscher Gesellschaft für Systemautomation mbH
Rheinstraße 15
65795 Hattersheim

Phone: +49 (0) 6190 9907-0
Email: de.info@hilscher.com

Sales
Phone: +49 (6190) 99 07-90
Email: de.sales@hilscher.com

China
Hilscher Systemautomation (Shanghai) Co. Ltd.
Phone: +86 (0) 21 6355 5161
Email: cn.info@hilscher.com

France
Hilscher France S.a.r.l.
Phone: +33 (0) 4 72 37 98 40
Email: fr.info@hilscher.com

India
Hilscher India Pvt. Ltd.
Phone: +91 020 2424 777
Email: in.info@hilscher.com

Italy
Hilscher Italia S.r.l.
Phone: +39 02 250 070 68
Email: it.info@hilscher.com

Japan
Hilscher Japan KK
Phone: +81 (0) 3 5362 0521
Email: jp.info@hilscher.com

Korea
Hilscher Korea Inc.
Phone: +82 (0) 31 739 8361
Email: kr.info@hilscher.com

Northamerica
Hilscher North America, Inc.
Phone: +1 630 505 5301
Email: us.info@hilscher.com

Austria
Hilscher Austria GmbH
Telefon: +43 (0) 732 931 675-0
Email: at.info@hilscher.com

Switzerland
Hilscher Swiss GmbH
Phone: +41 (0) 32 623 6633
Email: ch.info@hilscher.com