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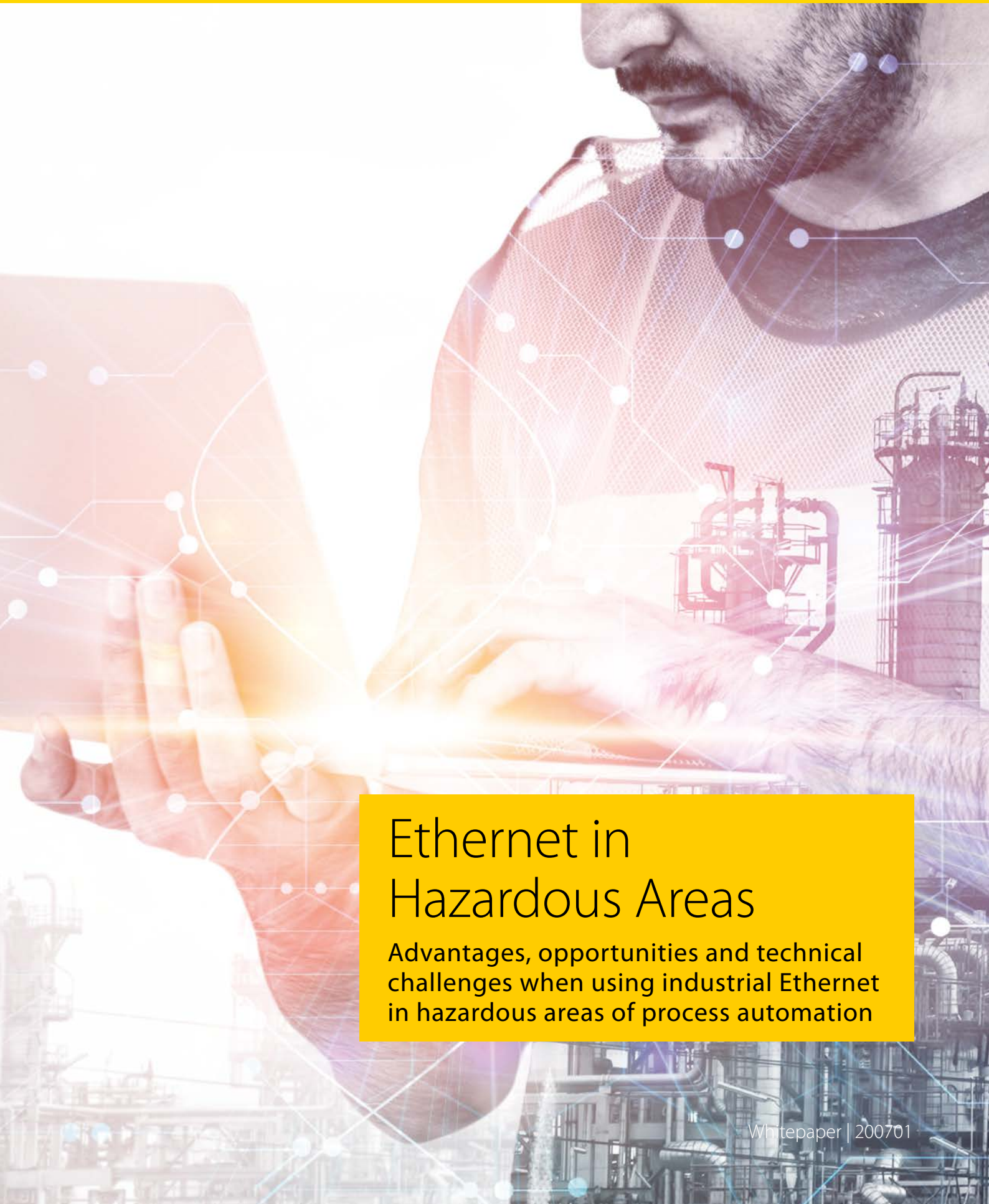


Ethernet in Hazardous Areas

Advantages, opportunities and technical challenges when using industrial Ethernet in hazardous areas of process automation

Whitepaper | 200701

Content

This whitepaper describes the evolution of Ethernet technology in process automation and explains the reasons for its delayed adoption. The paper also presents the latest initiatives to develop an intrinsically safe Ethernet standard and shows the benefits of the technology that will make a breakthrough in process automation. Process plants will be part of the IIoT (Industrial Internet of Things). The thesis is that secure and highly available Ethernet technology is the key to this development.

Ethernet: Origin and Early Development

The foundation stone for the development of today's Ethernet was laid in the 1970s. At that time, Robert Metcalfe, who is considered to be the inventor of the Ethernet, worked at the Xerox Palo Alto Research Center in California. One of his tasks was to network the company's computers. His idea later became the Ethernet standard.

As far back as the early 1980s, the American Institute of Electrical and Electronic Engineers (IEEE) adopted the idea of the Ethernet and established the IEEE 802.3 working group, which defined an official standard from the foundations. At that time, transmission was still carried out via a coaxial line. Several further developments followed until the 10BaseT standard was adopted in the early 1990s. 10 stands for the maximum transmission rate of ten megabits per second, base for the basic band (Ethernet) transmission technology and T for twisted-pair cables. Only five years later, the IEEE released the 100BaseX Fast Ethernet standard. At the physical level, this Ethernet standard supports both glass fiber (100BaseFx) and twisted pair (100BaseTx). For the first time, the Fast Ethernet standard defined the full-duplex transmission mode.

Ethernet in industrial automation
Ethernet has been a success in office IT for many years and has become indispensable since the global spread of the World Wide Web. The question arises as to why the technology has not been introduced to industry at the same time. The reason lies in the special demands of the industry. While it is accepted in office use that a website can take a while to load, such small shifts in production processes can have serious consequences. In industry, communication between the field and the control levels must be error-free and deterministic (can be determined beforehand) without people having to constantly initiate new processes. With regard to the protocol, it must also be ensured that data packets are sent and received at the exact time required, because data loss can cause delayed communication between devices and controls and hence cause disasters.

Industrial Ethernet was developed to meet these needs. In addition to the requirements regarding the protocol, the components must also meet a variety of industry-typical physical challenges, such as resistance to chemicals, oils, dust, shocks, vibrations, temperature fluctuations, etc.

Fast Ethernet in full-duplex mode
The demand for a deterministic transmission was met with the establishment of Fast Ethernet in full-duplex mode. This standard does not use the asynchronous media access method CSMA/CD (Carrier Sense Multiple Access with Collision Detection) and thus avoids telegram collisions. Due to the consistent use of switches and message prioritization, the Fast Ethernet standard in full-duplex mode meets all the essential requirements for fast real-time transmission in automation technology. The industrial Ethernet protocols such as Profinet, Ethernet/IP or Modbus TCP implement Fast Ethernet in full-duplex mode and ensure that data is available at the right location at the right time.

Other features of Fast Ethernet devices include auto-sensing and auto-negotiation. The functions allow mixed operation of different Ethernet stations and detect devices at 10 Mbps or 100 Mbps in semi- or full-duplex mode. The maximum possible transmission speed and the usable duplex method are negotiated jointly and set automatically.

Ethernet technology in the IT environment is constantly advancing. Currently, efforts are being made to establish a specification for Terabit Ethernet (TbE) with transmission speeds of up to 1000 Gbps.

Ethernet in Process Automation

Alongside the question of why Ethernet arrived so late in industry, the question arises as to why the technology has so far hardly been used in the process industry. This is again due to the special requirements of the process industry and especially of processes in hazardous areas, which have not yet allowed the use of Ethernet.
These requirements include:
A: Long cable lengths over copper cables
B: Intrinsic safety
C: Redundancy

For industrial fieldbuses, such as Profibus-DP, Profibus-PA or Foundation fieldbus, these requirements are already included in the specifications and have been implemented in almost all devices, including process control systems and controllers. This implementation has not yet been carried out for industrial Ethernet.

A: Long cable lengths over copper cables
Process plants usually extend over large areas. Copper is the standard conductor in these plants, because the energy for the individual field devices can be transmitted via copper and, at the same time, communication can be transmitted via the same line. Copper connections and conductors are also more robust and easier to connect than alternatives such as fiber optic cables. As a rule, fiber optic cables are only assembled by specialist companies and require a quality check. In addition, they are more susceptible to installation errors, such as incorrect bending radii or pinched lines and require monitoring for aging.

B: Intrinsic safety
Intrinsic safety is often required in the process industry in order to communicate safely via Ethernet, even in hazardous areas. Automation companies and various user organizations are currently working on the definition of an intrinsically safe Ethernet standard (as of 05/2020). While one working group is developing an intrinsically safe two-wire Ethernet with initially 10 Mbps (APL), another group is working in parallel on a standard called 100BASE-TX-is, which is designed to enable intrinsically safe four-wire Ethernet with a data rate of 100 Mbps.

C: Redundancy
In the process industry, many production processes are continuous or designed as batch processes. This means that systems cannot usually be stopped or shut down. Therefore, around-the-clock plant availability is essential. As a result, the automation systems must be optimized during operation and, if necessary, devices must also be replaced or measuring points added. Profinet networks can already be configured during operation. The function is called Dynamic Reconfiguration (DR) and is linked to the Configuration in Run (CIR) Profibus function.

The requirement for redundant systems also follows from permanent plant availability. If components in the system fail, which can never be ruled out entirely, the process must continue uninterrupted.

Intrinsically Safe Ethernet: APL and 100BASE-TX-IS

Using Ethernet in hazardous Zone 1 or 0 (Class 1 Division 1 or Class 1 Division 2) in an intrinsically safe manner is a technical challenge. In the case of interlinked devices, it must be ensured that outputs do not add up. In addition, this technology must be interoperable with all vendors. In a joint working group, the automation companies involved and the respective user organizations (Profibus International PI, ODVA, FieldComm Group) have set themselves the goal of removing these obstacles and developing a standard for a two-wire intrinsically safe Ethernet. Communication and power supply take place via the same line, as is the case with the Foundation fieldbus and Profibus-PA fieldbus. This future standard of an intrinsically safe two-wire Ethernet is referred to as the Advanced Physical Layer (APL). This is still in the specification/standardization phase (as of 03/2020). The aim is to enable APL Ethernet connections up to the field devices in order to eliminate the downsides of H1 bus physics that exist up to now, such as the effects of network disturbances or the limited number of participants per segment.

At the same time, work is being conducted on a standard for intrinsically safe Ethernet on a 4-wire basis at 100 Mbps. However, 100BASE-TX-IS is intended less for connecting individual field devices, but with its high data capacity for transmitting data from APL nodes to higher-level systems.

Both intrinsically safe Ethernet standards will probably still exist for a long time in parallel with classic 4 mA to 20 mA technology. For cost reasons alone, not all field devices are likely to be equipped with their own APL interface. And even in cases where field devices are upgraded with an APL interface, the data must be processed at an overlaid level using high-bandwidth Ethernet networks. Regardless of which technology is used at the field level, it is most likely for the I/O level that Ethernet solutions will become widespread there.

Ethernet in hazardous areas:
Excom Ethernet for Zone 2 (Class 1 Div. 2)[i]
Turck offers its excom I/O system with Ethernet for installation in Zone 2 (Class 1 Div. 2)[i]. The system can pick up signals from up to Zone 1 or 0 (Class 1 Div. 1)[i] in the intrinsic safety ignition protection type. The Ethernet cable is connected in the Ex-nA ignition protection type. If the gateways are de-energized or if work is carried out with a hot work permit, the Ethernet connectors on the gateway can be removed or inserted during operation. All other components such as power supply units, gateways or I/O modules can be replaced during operation without a hot work permit.

Advantages and Opportunities of Industrial Ethernet in the Process Industry

Due to the undeniable advantages over fieldbus systems, Ethernet will also prevail in process automation in the face of all these technical challenges.

These advantages are:
- Being future-proof
- Internationality
- High bandwidth and connection to the IIoT
- IIoT and process industry
- Parallel data access
- Simple handling, equal network access, high number of stations
- Media diversity
- Topology diversity: Lines, ring and tree structures
- Possibility of numerous redundancy concepts

Being future-proof
Being future-proof is of the utmost importance in the PA world, where plants are in operation for over 20 to 30 years. Ethernet as the physical basis is by far the most widespread communication standard today. Not least because of the rapidly accelerating digitalization, it is most likely that Ethernet will be supported for a very long time in the future.

The connection capability of Ethernet solutions to the emerging APL also contributes to the technology being future-proof. Investments in Ethernet technology remain connectable to APL technology, as transmission between the two standards via switches will be easy to achieve. APL, however, also shows that one cannot wait for the establishment of a new standard when important investments are due today. That is why one is well advised today to rely on a

system that supports Ethernet by standard or can be extended to Ethernet. This allows companies to protect their own investments and reap the benefits of the technology.

Internationality
Ethernet as a physical standard is used and accepted worldwide. Although regional differences still exist in the distribution of different Ethernet protocols, they are all based on the same physical standard and the same network structure, unlike the fieldbuses. Topologies can be implemented in Ethernet independently of the physical layer of the fieldbus.

High bandwidth and connection to the IIoT
In particular, the high bandwidth of up to 100 Mbps distinguishes Industrial Ethernet from its fieldbus predecessors. Real-time data and IT data can be transmitted almost simultaneously via a common medium and thus link IT and OT. Ethernet can therefore also connect process plants to the IIoT. In this case, this means that process plants can also become assets whose processes can be analyzed in real time or downstream on the basis of data. Although the development of the algorithms has not yet been completed, it is clear that Ethernet systems ensure preparedness for future developments in the field of algorithms and AI.

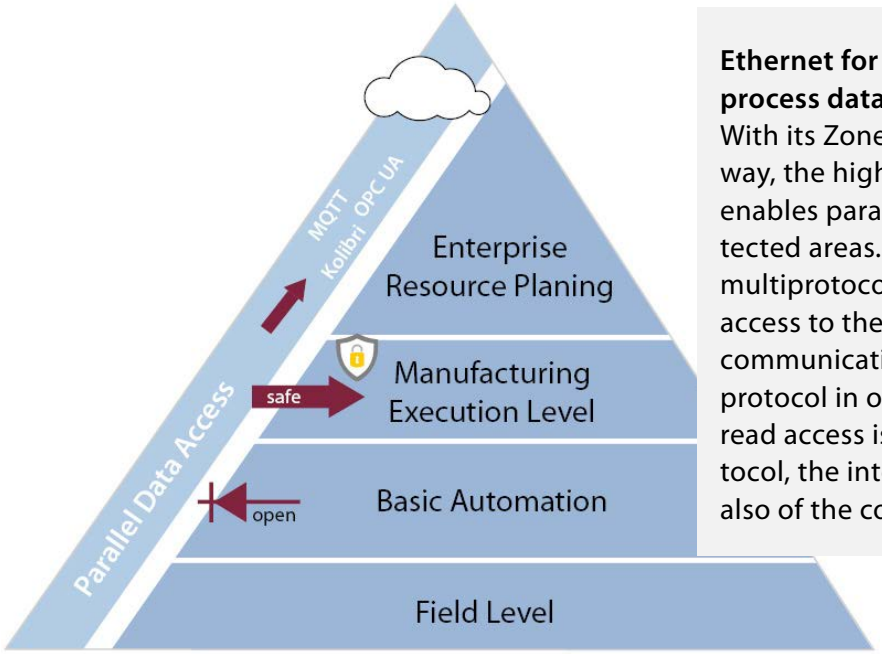
Multiprotocol
One gateway, three protocols – Turck's multiprotocol I/O devices recognize the master after power-up and automatically adjust to the respective Profinet, Modbus TCP or Ethernet/IP protocol. The excom I/O system also uses this proven standard and can collaborate with all control systems that support Ethernet/IP, Profinet or Modbus TCP.
For example
- Siemens
- Honeywell
- Rockwell
- Yokogawa
- Emerson
- Supcon
- ABB

The data volumes generated by contemporary field devices today cannot be transferred with sufficient performance using existing fieldbus technology. However, since fast data transfer is a prerequisite for connecting process plants to the Industrial Internet of Things, the use of Ethernet is essential at the latest from the I/O level of the plant.

IIoT and process industry
The key promise of the IIoT is the networking of smart industrial systems in order to make operational and productive processes more efficient – be it through self-optimizing systems, through better forecasting of events and aligning the operational assets to these forecasts, or by optimizing production resources in response to downstream data analysis.

At this point, plant operators soon face the question of the security of networked plants. If all processes are designed for maximum availability and security, the direct connection of process plants to IT networks comes with security risks. Despite encryption and firewalls, plant operators do not want to open up the possibility of manipulation, economic espionage or other digital threat scenarios. The situation is similar to a dilemma: The need to network equipment for up-to-date data analysis is pitted against a security risk that must be ruled out. The way out of the dilemma is called: parallel data access.

Parallel data access
Today, all data from the field and I/O levels is combined in the control systems of the plants. Giving external IT systems direct access to the PCS for data analysis is unusual and comes with the mentioned risks. During parallel data access, data from the field devices can be transferred in parallel from the I/O level to outsourced IT systems. This is not done via an additional physical channel, but in a separate industrial Ethernet protocol, which runs on the same physical conductor in addition to the protocol used for the control system. The interface in the I/O system is designed so that this second protocol is granted only read access. Controlling access is reserved solely for the PCS. This concept is being pursued by different manufacturers. The NAMUR has presented this approach as NAMUR Open Architecture (NOA).
Thanks to parallel data access, also from the hazardous area, the process data of the control system can be systematically separated from analysis data. In addition to the security aspect, this architecture offers a further advantage: In terms of monitoring and optimization (M+O), your plant benefits from the short innovation cycles of the IT world and can rely on the safety and reliability of OT (operational technology).



Ethernet for excom opens parallel access to process data
With its Zone 2 (Class1 Div. 2)[i] Ethernet gateway, the highly available excom I/O system enables parallel data access in explosion-protected areas. This is made possible by Turck's multiprotocol standard, which grants read access to the gateway in parallel with user data communication via an alternative Ethernet protocol in order to access the data. Since only read access is granted via the secondary protocol, the integrity of the I/O system and thus also of the control system remains secure.

Parallel data access enables full access and use of all process data with a high degree of manipulation security of the controllers and control systems

Simple handling, equal network access, high number of nodes
The handling of Ethernet technology is well-known. The wide-spread use in the office and private user area pays off here. Industrial users are not starting from scratch in industrial automation in the process industries. The Ethernet hardware is also widely known, especially classic Ethernet cables with RJ45 connectors. The costs for the hardware are limited and comparable to the costs of corresponding fieldbus solutions. However, handling is easier than with fieldbuses. Networks are easier to expand and terminating resistors are not required. All network participants have equal rights in the Ethernet network. Another advantage is the large address range in Ethernet networks, which allows for an almost unlimited number of participants.

Media diversity
Although copper will generally remain the standard medium for Ethernet transmission in process automation, it should be noted that the technology can also be communicated via other media such as fiber optic or wireless connections like WLAN. Here, too, the technology shows increased flexibility compared to the fieldbuses.

Note: Do not use office Ethernet components!

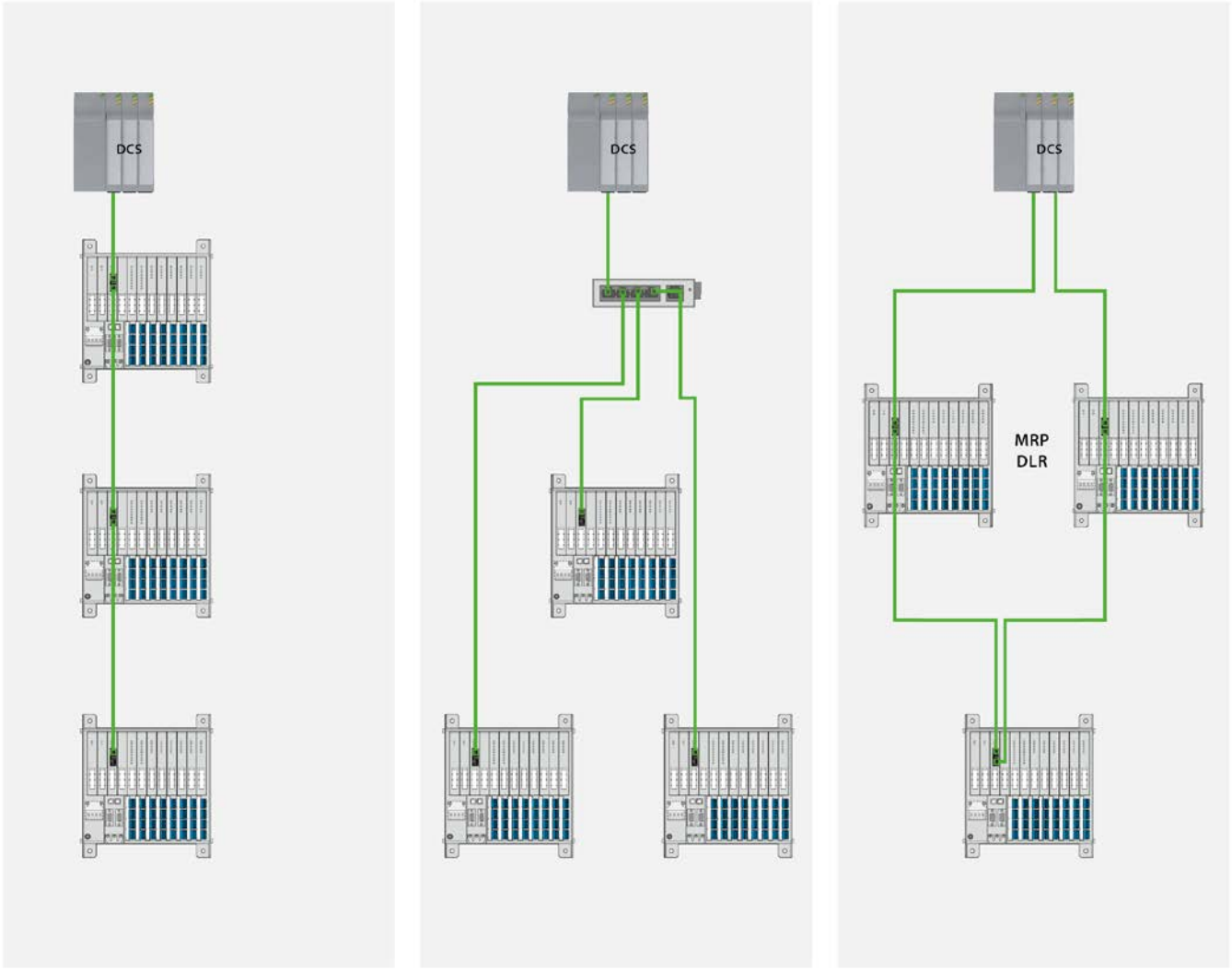
In both factory automation and process automation, office Ethernet hardware is not suitable for use in industry. In addition to the requirements regarding the protocol, the components must be able to cope with the physical challenges typical of the industry and be resistant to chemicals, oils, dust, shocks, vibrations, temperature fluctuations, etc.

Topology diversity: Line, ring, star and tree structures
A well-known topology from automation is the line. This is used in extensive automation plants. For this purpose, most Ethernet stations have an integrated switch, which simplifies the construction of a line topology. In addition, a line topology offers cost savings, as no additional switches are required and the wiring costs remain manageable. The downside of this topology is that it is usually not possible to replace or add new participants without interruption.

This option, on the other hand, is offered by ring topologies. To this end, the line to the ring is closed. However, a ring protocol must be integrated so that the message frames are not forwarded indefinitely in a circle. In a ring, all stations must be MRP (Profinet) or DLR (Ethernet/IP) enabled. In addition, a Ring Manager (Profinet) or Ring Supervisor (Ethernet/IP) is required in the ring, which is usually integrated in the controller or in the switch.

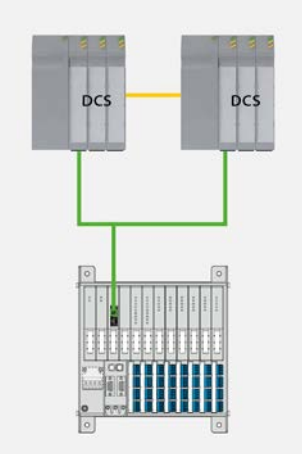
If several participants are connected from a switch, a star topology is established. A tree topology can be formed from the connection of several star-shaped networks. One advantage of this topology is that devices can be added or replaced without a reaction. The downsides are the higher installation and hardware costs.

The long distances in many process plants can be bridged by cascading switches. An Ethernet connection (point to point) is limited to 100 m. By connecting switches, larger distances can be overcome if fiber optic cables are not to be used.



The variety of topologies and combinations enables flexibility that classic fieldbuses cannot offer. From left: Linear topology, star topology, ring topology

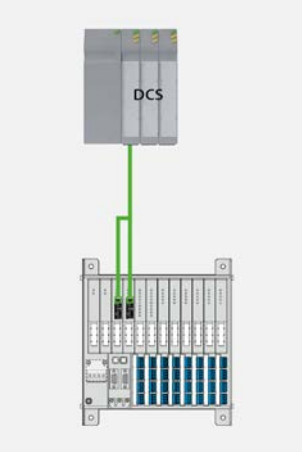
Numerous redundancy concepts possible
Redundancy concepts were well established in the fieldbuses, but were always limited to the respective fieldbus. The industrial Ethernet protocols show a diverse redundancy landscape. Ring redundancy is particularly well established in Profinet (MRP) and Ethernet/IP (DLR). In addition, Profinet has specified further redundancies to ensure interoperability between different manufacturers. This includes the redundancy concepts S2, R1 or R2 for Profinet.
The other industrial Ethernet protocols have not specified any redundancies. However, users of these protocols can create redundancies by using remote I/O systems that establish redundant structures with control systems. For example, Turck's excom I/O system offers such proprietary redundancies for different control systems.



S2 redundancy is the redundancy standard currently most widely used

Two masters with one gateway
If a controller and a field device only communicate via a single connection (S1), there is no redundancy. However, if a Profinet device supports communication relationships to the primary controller and its backup via this connection, this is classified as S2. It is the most commonly used form of system redundancy. If the main controller fails, the physical twin automatically takes over.

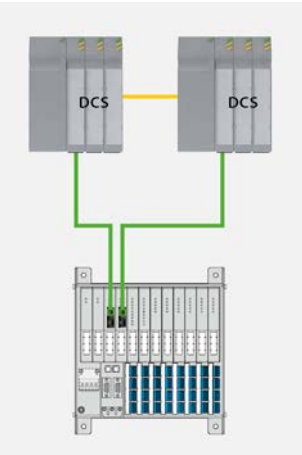
One master with two gateways
No standard has been specified for this redundancy concept in the Profinet context. But this redundancy also reduces the likelihood of a failure. The advantage: It is more cost-effective than other redundancy concepts and significantly increases availability at the connection level between the process control system and decentralized peripherals.



A cost-effective redundancy variant: One controller communicates with two redundant gateways

Two masters and two gateways
The greatest availability is ensured if both the master and the gateway are operated redundantly. The gateway only communicates with one master in this scenario. The two masters negotiate internally who is the master and who is the backup master. With Profinet, this system redundancy is specified as R1. For EtherNet/IP or Modbus TCP, no corresponding redundancy standard of a comparable type has been defined so far. However, users of these systems can establish R1-like redundancies with I/O systems such as excom.

A further redundancy variant has both gateways in a communication relationship with both masters. This system redundancy is specified under R2 for Profinet, but has still not been implemented by any manufacturer at this point (07/2020). R2 achieves the highest level of security through the four-way connection, but is also at the highest level of complexity.



The system redundancy shown here is supported by the excom I/O system

Summary
Experts are certain that Ethernet will also spread in the process industry and become widely accepted in the long term, but opinions on the pace of this process differ. As there are currently no solutions that could already prove themselves in industrial process applications, the decision for an Ethernet solution is still difficult today. It is recommended to choose a system that is open to and prepared for the many possible developments. One of these systems is Turck's excom I/O system. The entire system has already been in use for decades and is regarded as a proven tool in the process industry, especially in hazardous areas. In spring 2020, the Ethernet gateway for use in Zone 2, GEN-3G, was introduced for excom. Even those customers who are already using an excom system with a classic fieldbus gateway are ready for a switch to Ethernet technology thanks to the comprehensive system compatibility. A replacement of the gateway is sufficient. The present periphery and field wiring can continue to be used without any problems. Only the fieldbus cables for the connection between the I/O system and control systems would need to be replaced with Ethernet cables. However, this step will take place at some stage anyway if your plant is to reap the Ethernet benefits mentioned above.

Turck's excom I/O system

Advantage of system approval
Even with extensions, excom does not require fresh approval, because the entire system is approved for its corresponding hazardous area. Users can therefore exchange or even supplement gateways or I/O cards flexibly. The operators can carry out the necessary re-evaluation of the temperature in the system housing themselves without an external test site.

Turnkey solution optimized according to customer requirements
excom systems are installed and wired for you in your control cabinet or individual enclosure, taking account of your specific requirements. Individual cable glands, terminals, system connectors and other components can be installed directly. Depending on the project, the factory acceptance test (FAT) can be performed directly at Turck's site. Your benefit: You only need one partner for your turnkey I/O system.

High packing density
With up to 960 signals on five module racks in a standard control cabinet, excom's packing density is the world leader. Ex isolation is already integrated in the I/O system. Control cabinets for interface technology are thus completely superfluous, as are I/O cards in the control system. This space advantage can be decisive, especially in retrofit projects. excom can connect up to 192 binary or 96 analog signals via a single IP address. Three module racks for 8, 16 and 24 modules ensure that the space is optimally used in every installation, whether in a single enclosure or in the large I&C control cabinet.

Author | Jorge Garcia is Product Manager for Process Industry Fieldbus Systems at Turck

Sources

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Further information

Technology Page: Ethernet in Hazardous Locations
Flyer: excom I/O System

[i] FM approval for excom Ethernet gateways expected to be granted early 2021

Contact
Hans Turck GmbH & Co. KG | 45466 Mülheim an der Ruhr, Germany
T +49 208 4952-0 | F +49 208 4952-264 | contact@turck.com

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