The Digital Platform for Process Automation

June 2024

PROFIBUS • PROFINET

Contents

The digital platform for process automation

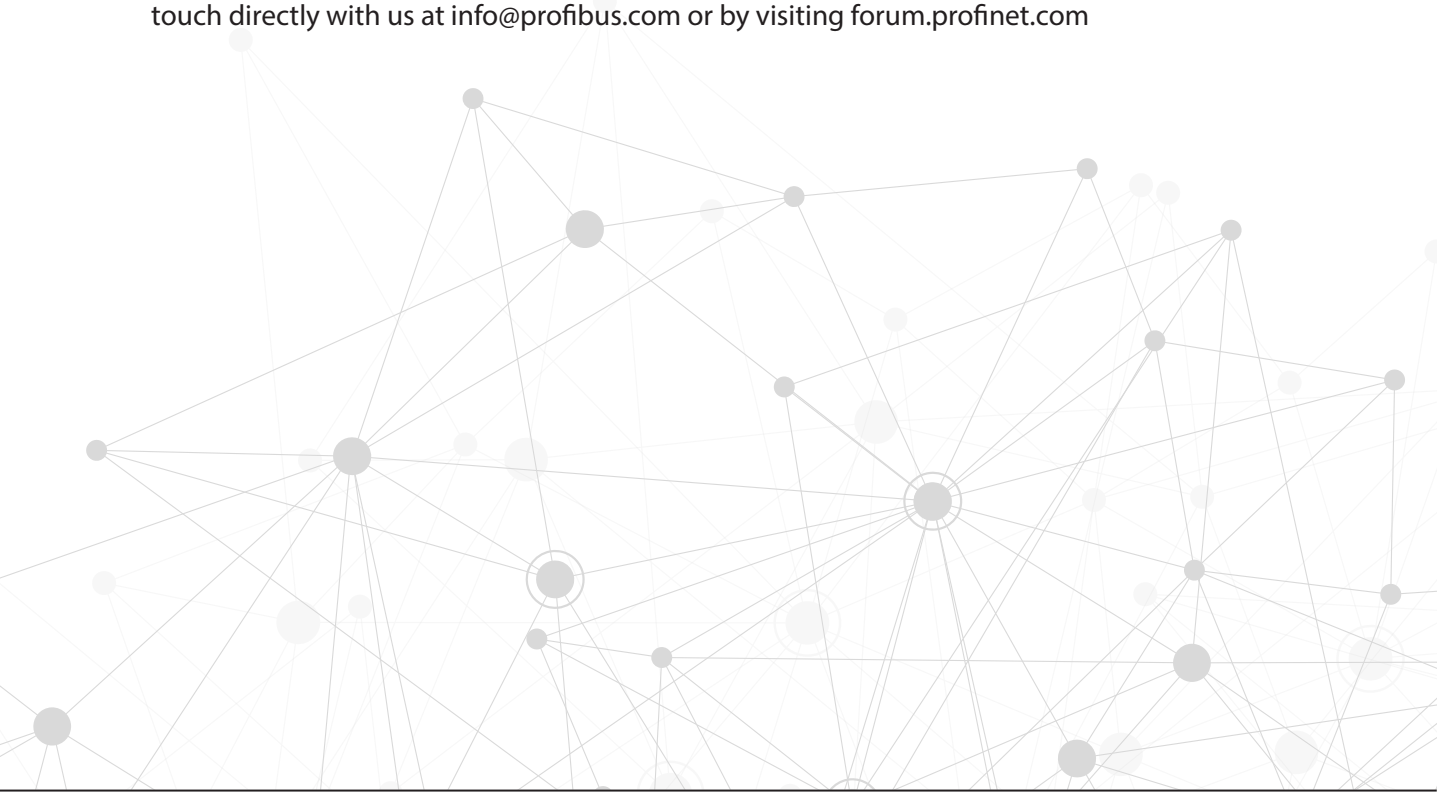
As a state-of-the-art network technology, PROFINET delivers multiple capabilities that can greatly advance a plant's performance when it comes to process automation. From the initial stages of engineering through to commissioning, seamless operation, and responsive service, PROFINET offers advanced solutions underpinned by solid collaborations with industry-leading companies and organizations.

As Ethernet standards – and particularly the Advanced Physical Layer (APL) – have reached unprecedented levels of maturity, PROFINET is quickly becoming a key solution for process automation innovation. With its growing acceptance and adoption, PROFINET is reshaping the landscape of process automation through technological features that are finely tuned to meet the strict demands of the industry, enhancing reliability and driving operational excellence.

The latest update of this white paper, released in 2024, includes essential information about the most recent technologies and developments, including:

- Current state of the process industry
- Latest governing standards
- Enhancements of Profile for PA
- Profile RIO for PA
- Adoption of two-wire Ethernet
- Support of Ethernet-APL (and SPE)
- TSN technology and new conformance classes
- Conformance with information models and MTP technology

We hope that the information presented on the following pages provides the insights needed to help you improve and enhance your operations. For more application specific questions, please feel free to get in touch directly with us at info@profibus.com or by visiting forum.profinet.com



1 Introduction

1.1 The Needs of the Process Industry

Meeting the strictest requirements

In contrast to factory automation, process automation imposes distinct requirements on communication technology due to the nature of its operations. Process plants, often stretching across vast areas, sustain operations for 15 to 40 years, with continuous production cycles. Consequently, any disruptions can adversely impact profitability, operational safety and environmental integrity. To meet the stringent requirements of the processing industry, communication technologies should fulfill the following criteria:

- Offer reliable access to horizontal and vertical data flows
- Offer simplified installation procedures for new technologies and field devices
- Comply with hazardous area installation standards, including intrinsic safety requirements
- Meet functional safety requirements through adequate Safety Integrity Levels (SILs)
- Provide support for extended cable distances of up to 1,000 meters
- Ensure compatibility with various topologies to accommodate diverse plant layouts
- Be robust to maximize availability
- Feature redundancy capabilities for critical components and applications
- Offer dynamic reconfiguration capabilities for individual components during operation
- Offer a standardized communication interface to facilitate seamless interaction among multiple vendor components

Key properties that communication interfaces and systems for engineering, asset management and plant control need to meet include:

- Maximum reliability and availability to minimize downtime
- Disturbance-free configuration processes during plant operation
- User-friendly handling, particularly for device replacement tasks
- Investment protection for existing plants, allowing for changes in process control technology
- Scalability to support extensive structures incorporating 10,000 or more devices

Furthermore, with the merge of operational technology (OT) and information technology (IT) becoming increasingly vital for the competitiveness of process companies – supporting sectors such as chemical, petrochemical, oil and gas, food & beverage, pharmaceuticals, life sciences, environment as well as water and wastewater treatment industries – selecting a communication technology that supports this convergence is paramount. This ensures seamless integration and data exchange between operational and enterprise systems, driving efficiency and innovation in process industries.

1.2 From Ethernet to PROFINET

Defining technological progress

Industrial communications technologies are essential to creating and benefiting from modern automation systems. Traditionally, they have been used to control and monitor individual machines and systems in manufacturing processes. However, they can do more. They can connect islands of automation on the shop floor as well as integrate other associated tasks such as logistics, quality assurance and system maintenance to higher enterprise levels. In the digitalized world of "Industry 4.0", the Industrial Internet of Things and Big Data, industrial communications are of even greater importance. Easy-to-handle solutions that can deliver advanced real-time performance as well as high availability, flexible topologies and optimum integration – even over long distances – are needed to take advantage of the many possibilities that digitalization offers.

Ethernet technology and IP-based communications are the current driving forces behind interconnectivity and, in turn, all types of information flow on a global scale. Industrial Ethernet is currently the most popular technology to establish reliable, high-speed communications for industrial and process automation. Key attributes linked to Industrial Ethernet include:

- Robust, industrial-grade components and products
- Continuous development and enhancements of protocols that fulfil industrial requirements, e.g. real-time capabilities

Industries that leverage factory automation technologies are benefiting from higher quality products that can be manufactured in shorter timeframes and at lower cost. This ability to enhance the competitiveness of an organization is the reason why Industrial Ethernet is undergoing further development.

Similar trends are evident in process automation. Process-related systems are typically complex in structure, consisting of different sub-systems, with numerous devices and differing topologies, all originating from various technologies and vendors. Plant owners and operators urgently want this complexity to be harmonized. In this way, data and information systems can be fully integrated as well as easier to handle. This means that they can be more reliable while also providing backwards compatibility, enabling various generations of technology to be connected.

PROFINET is the open Industrial Ethernet-based standard developed and maintained by PROFIBUS+PROFINET International (PI). PROFINET is standardized in IEC 61158 and IEC 61784 and, as a universal communication technology, covers all requirements of automation technology. PROFINET is 100% Switched Ethernet according to IEEE 802.3. As such, it is open to applications of all Ethernet technologies and can operate in parallel with other Ethernet protocols.

The functional scope of PROFINET can be scaled according to multiple layered Conformance Classes (CC). Each of these builds on the previous one to support different use cases (figure 1). These classes combine minimum application-oriented properties.

CC-A includes the basic functions and is suitable for use in building automation, for example. CC-B expands the functional scope to include network diagnostics and topology information. CC-B(PA) adds relevant functions for process automation, such as redundancy and optional "dynamic reconfiguration" (changes to the controller configuration while the operation is running). CC-C further expands the core capabilities to enable the implementation of IRT (Isochronous Real Time) communications. Thus, it offers a solid foundation for clock-synchronized applications. The latest conformance class D (CC-D) is based on Time-Sensitive Networking (TSN) for PROFINET. It increases the available functionalities for real-time communications with functions such as "streams", "scheduled traffic" or "preemption". A detailed description of all the different conformance classes and their capabilities can be found in the PI document "PROFINET IO Conformance Classes" [7.042 e].

The pre-defined functions and contents of the CCs also serve as the cornerstone for certifying PROFINET devices, an activity that is performed through a standardized testing procedure conducted in authorized test labs. Upon receiving a favorable test report, the device manufacturer is awarded a certificate, which grants the company the right to brand the device as PROFINET-compatible. For plant builders and owners, the use of certified devices means time savings during commissioning, stable device performance and, above all, interoperability throughout the entire operational lifespan.

Attribute / Conformance class	A	B	B(PA)	C	D
Real-time data exchange	X	X	X	X	X
Alarms and diagnostics	X	X	X	X	X
Network topology support	X	X	X	X	X
SNMP support		X	X	X	X
Dynamic reconfiguration			X	X	X
Redundancy			X	X	X
High-speed real-time data exchange				X	X
Time-Sensitive Networking (TSN)					X

Fig. 1: Structure of the Conformance Classes (CC) of PROFINET

PROFINET recognizes the following device families: PROFINET controller, which corresponds to PROFIBUS master class 1, PROFINET device, which is equivalent to PROFIBUS slave, and PROFINET supervisor, corresponding to PROFIBUS master class 2.

PROFINET offers a platform for the seamless integration of different segments within a plant or machine into an automation ecosystem through an explicitly defined communication interface. Additionally, it aims to accommodate bus-powered devices in specific applications in the future. This not only minimizes the number of necessary interfaces, but it also enables the exchange of data as well as information and knowledge between the different sections. For example, it can help shed light on whether a compressor, heat exchanger or blower can deliver the capacity needed for the setpoint. Similarly, it can help identify the most economical operating point of a plant, given the status of the various units. PROFINET can offer all this together with all of the established advantages that an Ethernet standard can provide.

1.3 The Advantages of Using PROFINET

The Next Generation in Process Automation

PROFINET offers an ideal solution for process automation applications, addressing the industry's unique demands with precision and efficiency.

- **Interoperability and standardization:** As a 100% Ethernet-based technology, PROFINET ensures seamless interoperability across all plant levels. Its well-defined specifications guarantee full compatibility among diverse systems and devices
- **Cost reduction and operational efficiency:** Implementing PROFINET as a uniform technology across a plant significantly reduces operational costs. It minimizes the need for extensive training and interdisciplinary expertise, while enhancing transparency and reliability in plant operations. This results in improved cost-effectiveness
- **Operational technology (OT) and information technology (IT) integration:** PROFINET supports a seamless transition between OT with IT, leveraging the strengths of both domains to create a cohesive and efficient operational environment
- **Energy savings with PROFIenergy:** PROFINET offers application-oriented profiles like PROFIenergy, which can deliver substantial energy savings and cost reductions during process-related standby periods for equipment such as robots, pumps and motors
- **Ease of use and reliability:** PROFINET incorporates intelligent mechanisms to ensure simple and reliable handling of field devices. Tools for automatic addressing and simplified device replacement streamline operations and maintenance
- **Advanced cybersecurity measures:** PROFINET's multi-level security concept includes ongoing developments in authentication and encryption, ensuring robust protection for sensitive processes
- **Operational safety and system availability:** With decades of experience in manufacturing applications, PROFINET brings proven reliability and safety to the process industry. Its rigorous certification measures guarantee maximum safety and high availability, critical for process applications

In addition, PI continues to enhance its offerings, ensuring that PROFINET remains at the forefront of process automation technology, delivering cutting-edge, value-adding solutions.

PROFINET is the established digital platform for process automation

This paper discusses the current state of technology development, available features and capabilities of PROFINET for process automation. It also provides an outlook on some specifications in development.

2 Choices of Physical Layer for PROFINET in Process Automation

Ethernet with an Advanced Physical Layer (Ethernet-APL) is a robust, two-wire, powered Ethernet physical layer that was developed for data transmission in process automation and instrumentation. Based on new chapters added to existing global standards, namely IEEE 802.3, IEC TS 63444 and IEC 61158-2 and IEC TS 60079-47, Ethernet-APL was designed to help deploy field devices in remote and hazardous locations. PROFINET has adopted this physical layer and can therefore be utilized in all areas of process industries.

The leading standard development organizations (SDOs) for industrial communications, such as PI, ODVA, OPC Foundation and the FieldComm Group now collaboratively maintain the technology, providing documentation and supporting materials. Joint working groups with suppliers and end users involved define strategies, applications and scenarios to maximize the benefits. Many suppliers now provide systems and instrumentation featuring PROFINET over APL.

2.1 Trusted Installation and Infrastructure

Ethernet-APL makes it possible to set up a direct connection from field devices to Ethernet-based systems, so that process industries can benefit from convergent systems where OT and IT are merged. This is possible through a switch-based architecture that prevents unwanted influences between devices that are connected to the same network.

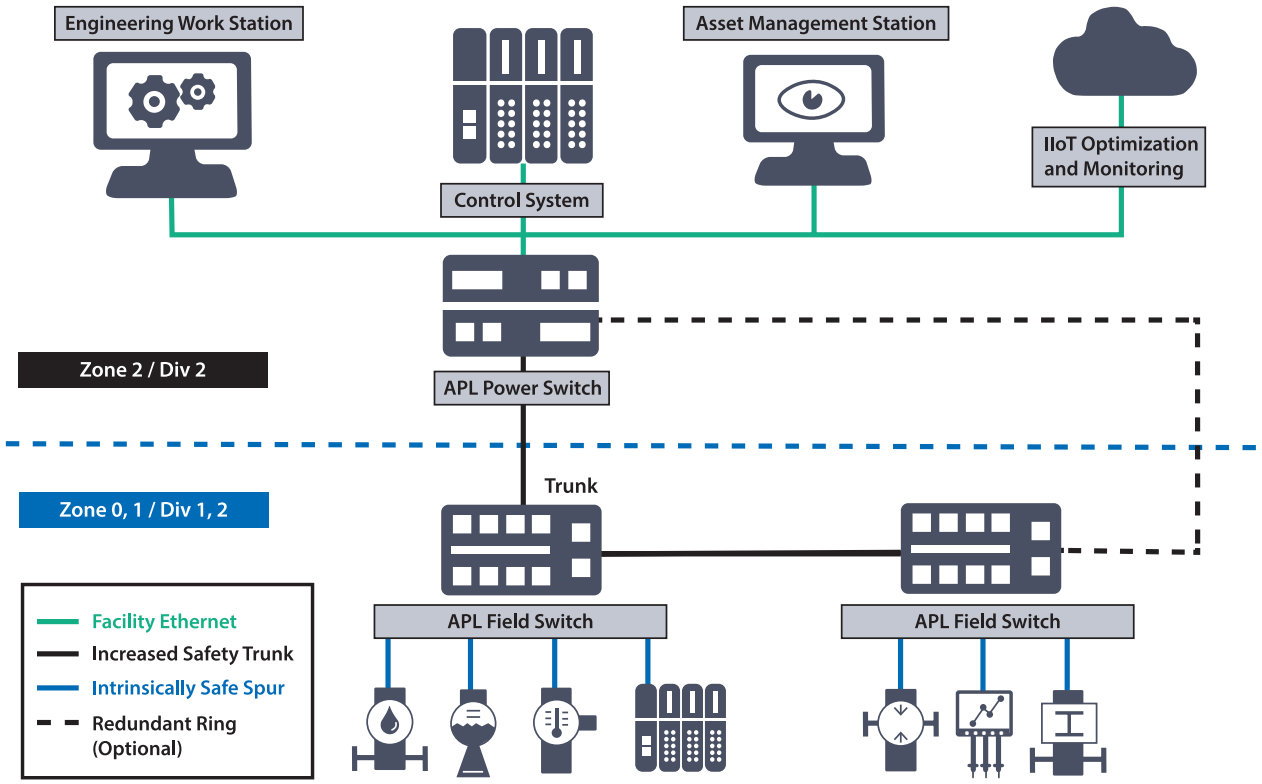


Fig. 2: Ethernet in the field

Ethernet-APL uses technologies and options suitable at the field level that are already well established in the process automation industry. These include the proven star and trunk-and-spur topologies, as shown in figure 2. As a result, network segments with more than 200 devices can be installed. Also, all devices can be powered over the network with up to 500 mW per device in Zone 0 or 1 (power class A) and 1.11 W in Zone 2 (power class C). A power class B with 1.17 W for Zone 0 or 1 is in preparation. Supporting compatibility and future-oriented capabilities, widespread and established Ethernet-APL cable infrastructures are specified to migrate existing equipment. Ethernet-APL's most important functions are highlighted in figure 3.

Parameter	Specification
Standards	IEEE 802.3 (10BASE-T1L) IEC 60079
Power supply output (Ethernet APL power switch)	Up to 60W (92W in preparation)
Switched thernet	Yes
Redundant cables and switches	Optional
Reference cable type	IEC 61158-2, Type A
Maxium trunk length	1,000m
Maximum spur length	200m
Speed	10 Mbps, full duplex
Hazardous area protection	For all zones and divisions With intrinsic safety at the device

Fig.3: Technical features of Ethernet to the field

2.2 Protection in explosive atmospheres

The methods of ignition protection from Ethernet-APL follow the well-known electrical installations ground rules. The trunk of trunk-and-spur topologies deliver the eb and ec increased safety protection levels and transfer the maximum permissible power of 60 W, and soon 92 W, in hazardous areas.

Intrinsic safety ia, ib and ic are supported on the spurs. The verification of intrinsically safe connections is based on the recently developed and standardized two-Wire Intrinsically Safe Ethernet concept (2-WISE), as defined by IEC TS 60079-47. This aligns with the Fieldbus Intrinsically Safe Concept (FISCO) from IEC 60079-11 and -25, meaning that for every intrinsically safe connection, it is possible to rely solely on one simple verification method with no additional calculations.

2.3 Infrastructure

In addition to cables and connectors, an Ethernet-APL infrastructure essentially contains up to two basic components:

1. The APL field switches are designed for installation and operation in hazardous areas, typically Zone 1 and 2 or Division 2. In star topologies, they are DC powered and interconnected to the Ethernet backbone in a line or ring topology. They distribute both the communication signals and intrinsically safe power via spurs to the field devices. In trunk-and-spur topologies, the field switches are powered by the APL power switch over the trunk.

   A load and scalability test showcased an Ethernet network with 240 measuring devices including flow, pressure, temperature and level sensors, with three different DCS systems via switches and infrastructure. All test runs were performed with maximum network design. Scalability and fault tolerance were successfully verified. All relevant requirements such as total network load or redundancy switchover times were met or even exceeded during the tests. The test result was accordingly clear: Ethernet-APL can be used under realistic conditions.

2. For trunk-spur topologies (in preparation), the APL power switches provide connectivity among all standard Ethernet networks and field devices. They also provide the APL field switches as well as the APL field devices with power over the trunk network. APL power switches are typically set up in the control room or junction boxes. Power and field switches can also be configured in a redundant layout ring topology. The distance between power switch and field switches can be up to 1000 m.

3 PROFINET in Process Automation

With its real-time communication capabilities, PROFINET is the leading industrial Ethernet protocol for communications between devices in automation systems. It ensures reliable data transmission, supports various network topologies and provides device configuration as well as diagnostics capabilities. PROFINET enhances productivity, efficiency and flexibility in processes automation and supports the latest integration technologies and information models.

3.1 PROFINET Basic Functions for Process Automation

Proven PROFINET functions and technologies of importance to process automation, especially when using field devices include network configuration, connection technology, network diagnostics, topology display, detection of neighboring devices, device replacement and supplementary diagnostics. These functions enable users to benefit from automatic address configuration when replacing devices. In addition, they offer plant visualization tools, which can be used, for example, to ensure that a replacement device is connected to the correct port. The new device receives the same name and parameters as the replaced device. In addition, the topology display can be used for diagnostic purposes, helping to identify wire breaks and their location.

3.1.1 Network Topologies

Easy network installation

The large number of permitted topologies with PROFINET enables users to set up a network configuration that best meets the specific requirements of a plant, in terms of spatial extent and availability, including redundancy of the transmission path.

Topologies supported are (figure 4):

- Line that primarily connects field devices with integrated switches in the field
- Star with a centralized PROFINET switch located in the control cabinet
- Ring, primarily for the realization of redundancy
- Tree as a combination of the above topologies

The connection of PROFINET devices is carried out exclusively using switches as network components, which are often already integrated in the devices through two port interfaces. PROFINET-suitable switches must support both "auto-negotiation" and "auto-crossover" functions. As a result, communications can be established autonomously, maintaining uniform physical cable designs. The connection between participants, i.e. devices and switches, is possible up to distances of 100 m using copper cables, while simultaneously having power transmitted along the cable length. For longer distances between the control room and field junction boxes, optical fiber or wireless radio links can be used.

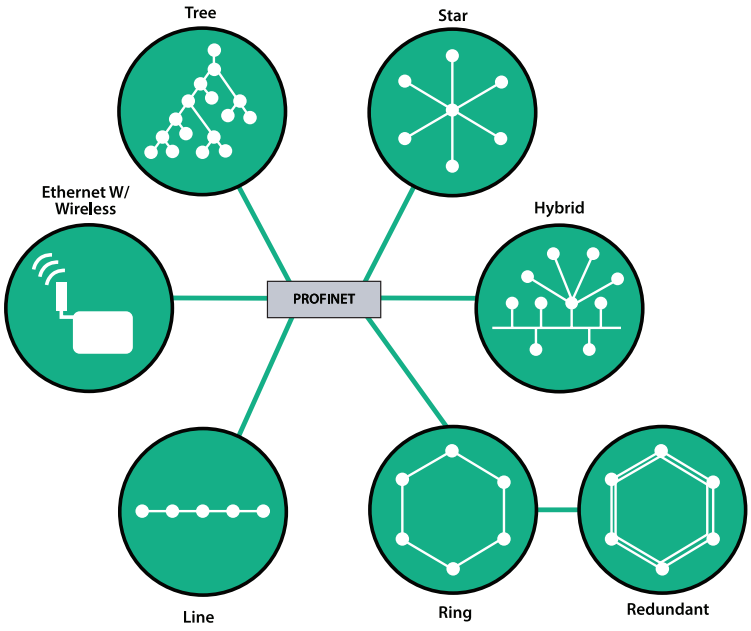


Fig. 4: Flexible network configuration of PROFINET

3.1.2 Network Management

In IT networks, the Simple Network Management Protocol (SNMP) established itself as the de facto standard for maintenance and monitoring of network components and their functions. For diagnostic purposes, this protocol can read-access network components in order to read out statistical data pertaining to the network as well as port-specific data and information for neighborhood detection.

Most PROFINET devices support this protocol for network diagnostics and measurement. In particular, SNMP is implemented in all devices of Conformance Classes B and C. As a result, users can leverage standard SNMP tools to read out topology information, network statistics and other related network details.

3.1.3 Network Diagnostics

PROFINET field devices use the Link Layer Discovery Protocol (LLDP), as defined by the IEEE 802.1AB standard, to exchange the available addressing information via each port. This allows the respective port neighbor to be explicitly identified and the physical structure of the network to be determined. Moreover, with PROFINET even physical layer diagnostics can be included into asset management systems.

In figure 5, the "delta" device is connected to port003 of "switch1" via port001. With this neighbor detection, a preset or actual comparison of the topology is possible, and changes to the topology during operation can be recognized immediately. This also forms the basis for automatic naming in device replacement.

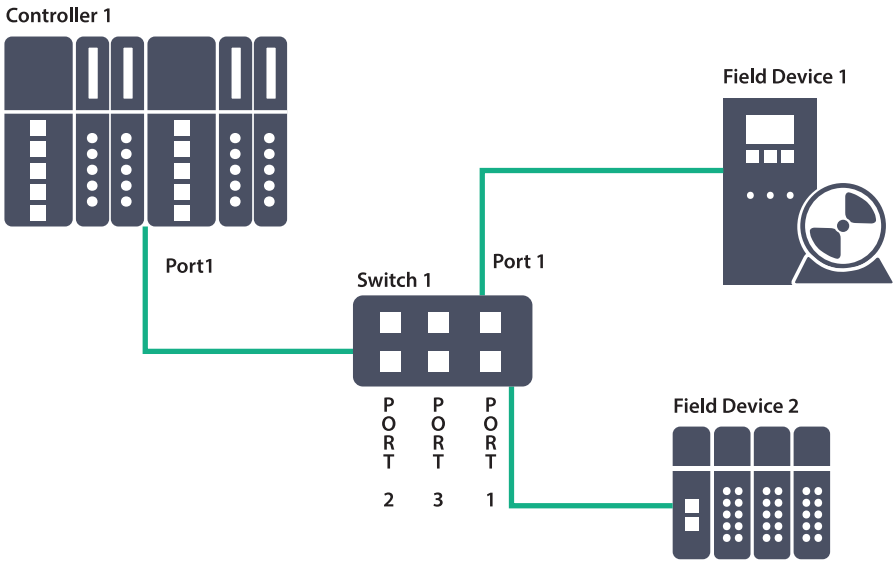


Fig. 5: PROFINET field devices are aware of their neighbors

The collection of the information obtained via neighborhood detection using the LLDP protocol enables a graphical representation of the plant topology and port-specific diagnostics (figure 6).

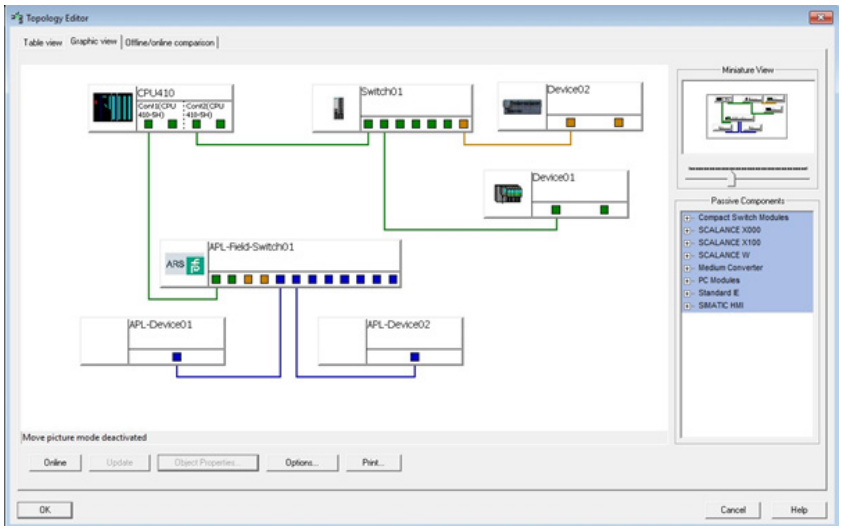


Fig. 6: Representation of a plant topology

3.1.4 Device Diagnostics

Uniform device diagnostics in line with NAMUR NE 107 standard on status signal is important for plant operation and maintenance. It is based on the capability of devices and components to determine their status and communicate using standardized mechanisms. To this end, PROFINET provides a system for the reliable signaling of alarms and status messages from any device to the controller. This diagnostic model (figure 7) covers system-defined events, such as removal/insertion of modules and the signaling of malfunctions like wire breaks that are detected by the control mechanisms. In addition to recognizing 'good' and 'faulty' statuses, the underlying status model also incorporates optional levels, such as 'maintenance required', e.g. in the event of redundancy loss, and 'maintenance demanded'. The module also distinguishes between diagnostic alarms, i.e. events occurring within a device or component, and process alarms, i.e. events taking place in the process, such as threshold temperature exceeded. The document "Diagnostics with PROFINET" [7.142 e] contains further information on this topic.

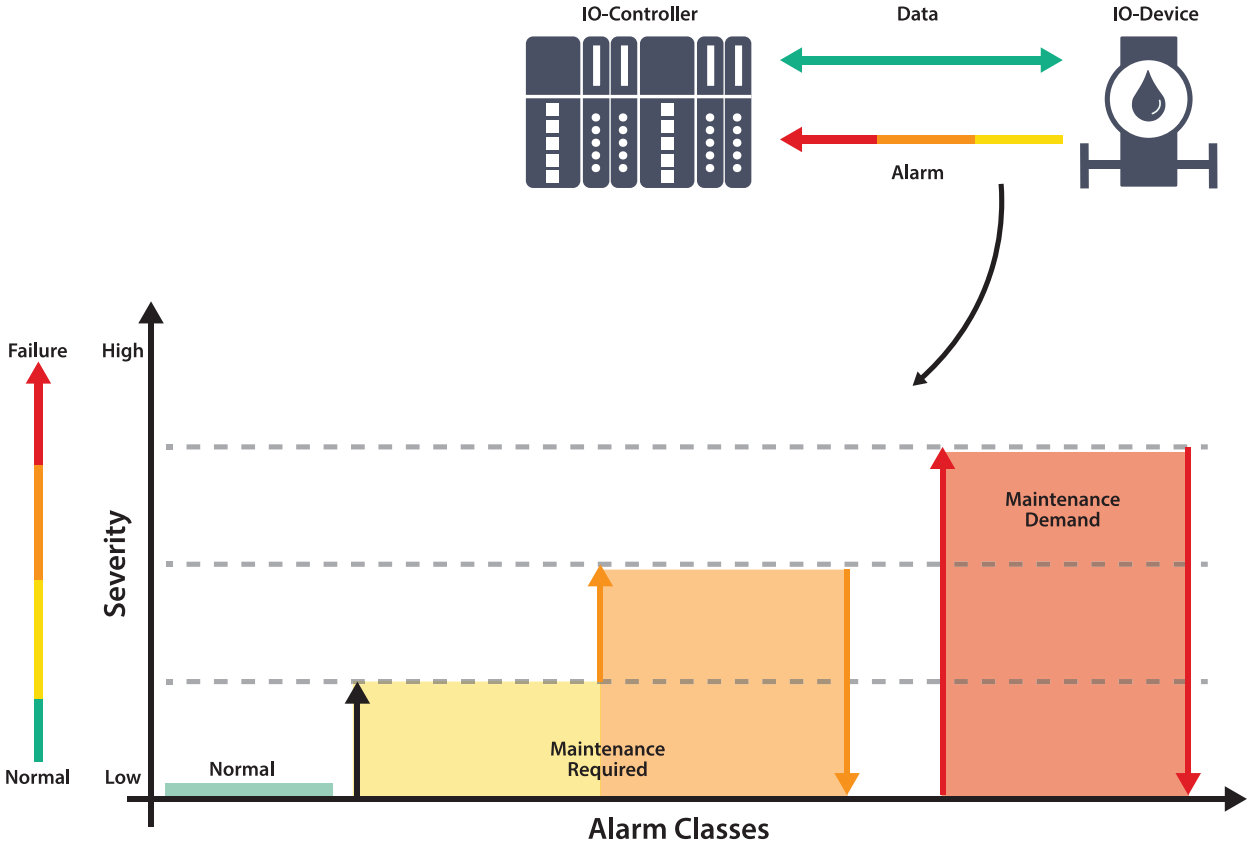


Fig. 7: PROFINET diagnostic model for signaling faults with different priorities

3.1.5 Compatibility with Information Models and Technologies

PROFINET demonstrates significant compatibility with various information models, technologies and standards enhancing its capabilities in various process automation applications. Leading models include the Open Platform Communications Unified Architecture (OPC UA), General Station Description (GSD), the Process Automation Device Information Model (PA-DIM) as well as Module Type Package (MTP).

OPC UA is a machine-to-machine communication protocol that ensures secure, reliable data exchange. PROFINET's integration with OPC UA facilitates seamless interoperability between devices and systems from different manufacturers, promoting a unified communication framework across the automation landscape. This compatibility delivers real-time data access and control, critical for optimizing industrial automation processes and maximizing operational efficiency.

GSD files are essential for configuring and integrating PROFINET devices within an automation system. These files provide detailed information about the device's capabilities focusing on its communication parameters and functions. PROFINET's compatibility with GSD files simplifies device integration, reducing configuration time and minimizing the potential for errors during setup.

FDI is an integration technology supporting a uniform integration of field devices in various host systems. These files provide detailed information about the device's capabilities focusing on the application parameters and functions. With FDI, a device with a device package can be used by any user across all life cycle phases from planning and commissioning through to operation and maintenance. (FDI - www.profibus.com)

Additionally, PA-DIM offers a standardized data model for process automation devices, ensuring consistent information representation across different systems. PROFINET's alignment with PA-DIM supports the integration and management of devices to deliver a more streamlined and efficient automation environment.

Finally, PROFINET's alignment with the MTP standard for the modularization of plants greatly helps process industries to design plants with modular equipment, facilitating integration and offering greater flexibility for future modifications. MTP-enabled equipment can "plug & play", significantly reducing commissioning time and enabling swift adjustments to processes. As a result, it is possible to streamline operations and enhance adaptability in production environments.

3.1.6 Security

For secure networking within a large factory or over the Internet, PROFINET provides a graduated security concept (figure 8). This can be adapted to any application through security zones that can be configured upstream. As a result, PROFINET devices are freed from being overloaded with security mechanisms. Furthermore, the concept can be adapted to address changing security requirements over a plant's lifetime and to align to technical innovations.

Individual devices and whole networks can be protected from unauthorized access. This is accomplished via security modules that allow networks to be segmented and, thus, separated and protected. Only explicitly identified messages reach the devices located inside specified segments from the outside (figure 9).

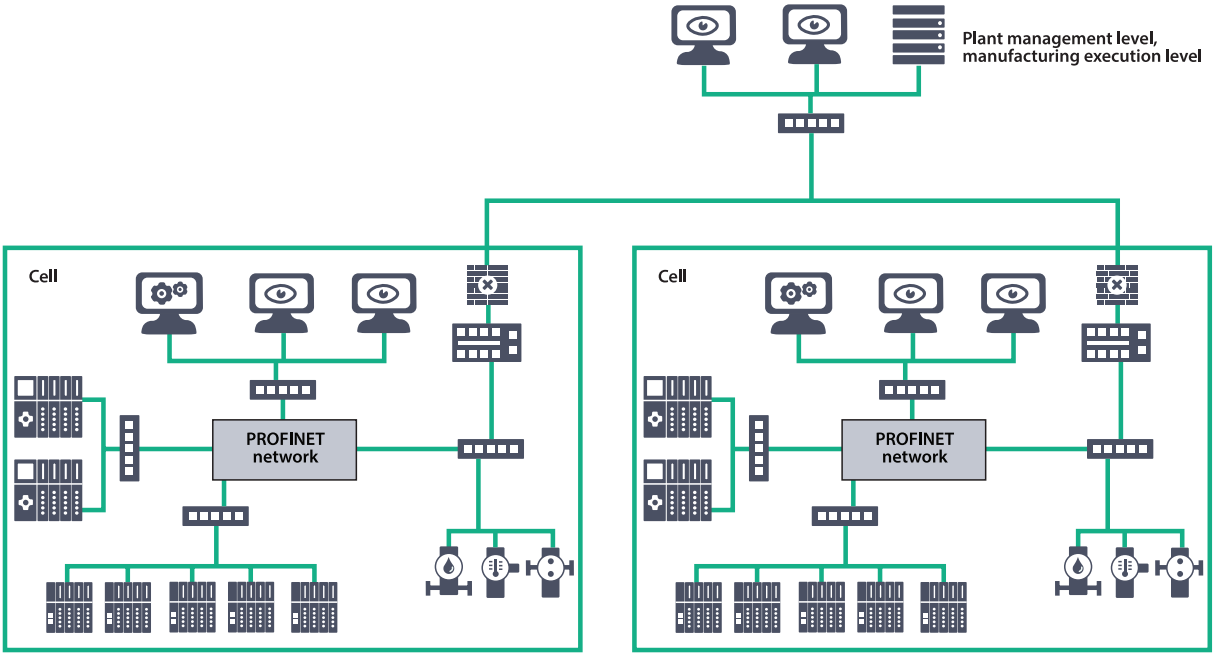


Fig. 8: Connection of several cells to a superimposed level

The use of a defense-in-depth strategy is generally recommended for a PROFINET-based network. Among other elements, this involves the combination of various layered protective measures in order to secure the boundary between the automation and enterprise-level networks. Due to the real-time requirements of PROFINET networks, and to ensure backward compatibility, security-specific extensions to the PROFINET protocol were not made in the past.

Recently, with stricter requirements placed on OT security and the spread of Ethernet-based field communications, e.g. via Ethernet-APL, sensors and actuators have been required to support secure communications too. Besides, the increasing likelihood of cyber-attacks targeting real-time protocols necessitates the addition of integrity protection for PROFINET-based networks, as mandated by IEC 62443-4-2.

PROFINET-Security defines three security classes. Security Class 1 is described in detail in the document "Security Class 1 for PROFINET-Security", Order No. 7.312, which focuses on defining the integrity protection of GSD files. Classes 2 and 3 add integrated cryptographic protection of industrial communications, so that secure application relationships can be set up and implemented with public key certificates. Security Class 3 also offers additional features for secure real-time communications through data encryption. The white paper "OT security for production plants with PROFINET - A classification of IEC 62443 for operators, integrators and manufacturer" Order No. 7.342 discusses this topic in detail.

With these security extensions to the PROFINET specification, PI laid the foundation for secure real-time communications. Stack manufacturers should integrate the corresponding mechanisms to provide device vendors with the tools to deliver secure products.

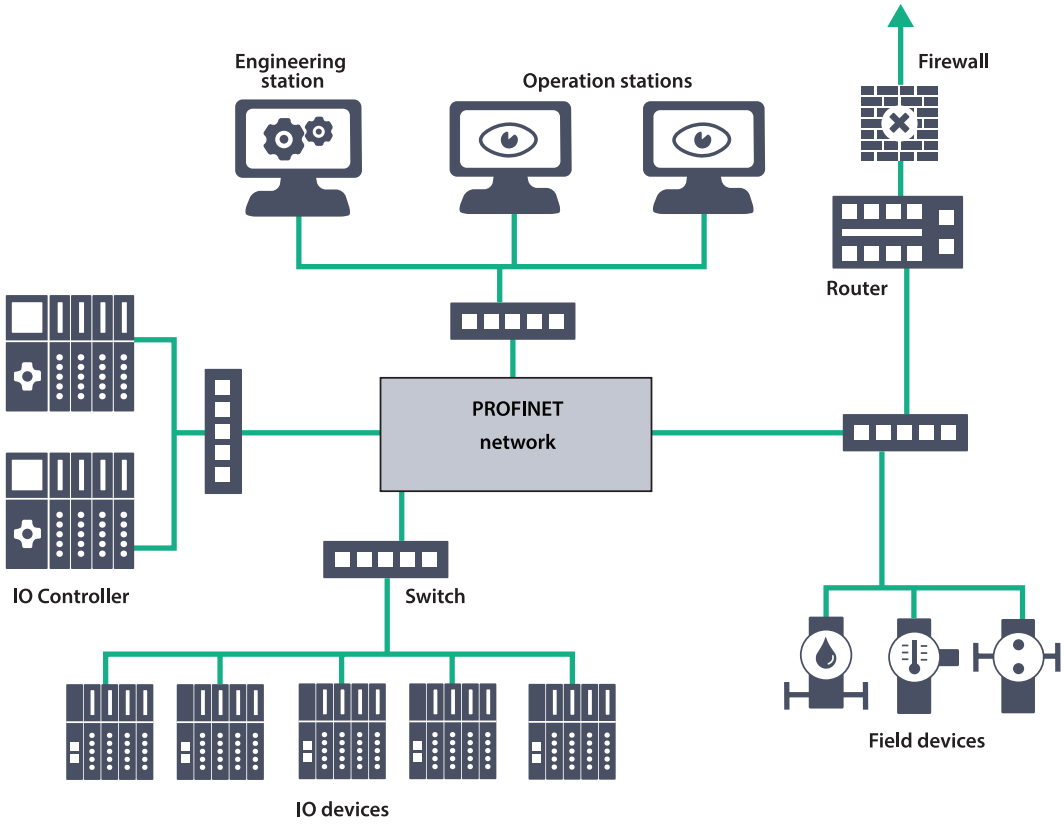


Fig. 9: Flat structure within a production cell

3.1.7 Functional Safety

The solutions for optimum safety

Functional safety aims to reduce the risks associated with the incorrect functioning of machinery. Traditionally, functional safety systems have relied on separately wired circuits that are expensive to build, commission and maintain.

PROFINET offers a consistent communications path for safety-relevant applications. PROFIsafe is the profile defined by IEC 61784-3-3 for implementing functional safety and ensuring the integrity of failsafe signals between safety devices and a safety controller, thereby meeting all relevant safety standards.

Specifically, such measures include the highest safety categories: up to SIL 3 as defined by IEC 61508 / IEC 62061, Category 4 according to EN 954-1, or PL "e" from ISO 13849-1. PROFIsafe is designed to operate independently of the physical layer, whether that channel is copper wire, fiber optics or wireless. PROFIsafe is approved by IFA, TÜV as well as other bodies and can be used with PROFIBUS and PROFINET alike.

As a result, elements of a failsafe controller can be transferred directly with the process control data on the same network and additional wiring is not needed. As not all PROFINET devices support PROFIsafe, users must carefully select their safety components. More details about PROFIsafe can be found in the system description [4.341 d / 4.342 e].

3.2 PROFINET Enhancements for Process Automation

For the implementation of PROFINET in the process industry, the following specifications are available:

- Dynamic reconfiguration for changes to the system without disturbing operations
- Redundancy for the physical layer
- System redundancy for instruments and controllers
- Time synchronization among devices on the network
- PA Profile describing similar attributes for similar instruments
- Simple device replacement

High-performance, standardized PROFINET solutions ensure reliable operations and high availability for system, devices and communications infrastructures. Standardization ensures the interoperability of devices from different manufacturers. Further information can be found in the document "High Availability for PROFINET" [7.242 e].

3.2.1 Dynamic Reconfiguration

A typical and very challenging production requirement is that process automation systems must run continuously without interruptions. Emergency stops must be avoided unless there is imminent danger to people, the plant or the environment. An optional feature of PROFINET that supports this need is Dynamic Reconfiguration (DR), which enables users to reconfigure, insert, remove or replace devices or modules without stopping the control application. Thus, there is no need to shut down or interrupt the network for plant repairs, modifications or expansions.

As DR is an optional feature in PROFINET products, to use it, the engineering tool, controller and any device involved must support it. However, mixed networks with DR and non-DR instrumentation are possible. Controllers and instruments that support DR can be changed while the automation system remains in operation. For example, it is possible to:

- Change device settings, e.g. set points or alarm thresholds
- Replace devices for repair
- Modify the system by adding or decommissioning instruments

DR applies to actions taken on or with compact devices, proxies and modular devices, such as remote I/O.

DR requires devices to support redundant application relationships (ARs). An AR is essentially the communication channel that brings devices together to communicate with each other. Fig 10 illustrates the user interaction and changes in AR when modifying the configuration of a device.

1. The controller and the device are running under a specific AR
2. The user defines a new configuration, and the engineering tool establishes a second AR (DR-AR) with the new configuration, but the original AR still controls the IO
3. Then, the engineering tool initiates the switchover. The second AR (DR-AR) becomes the new controlling AR
4. Finally, the existing AR is removed and the new AR is relabeled from DR-AR to AR

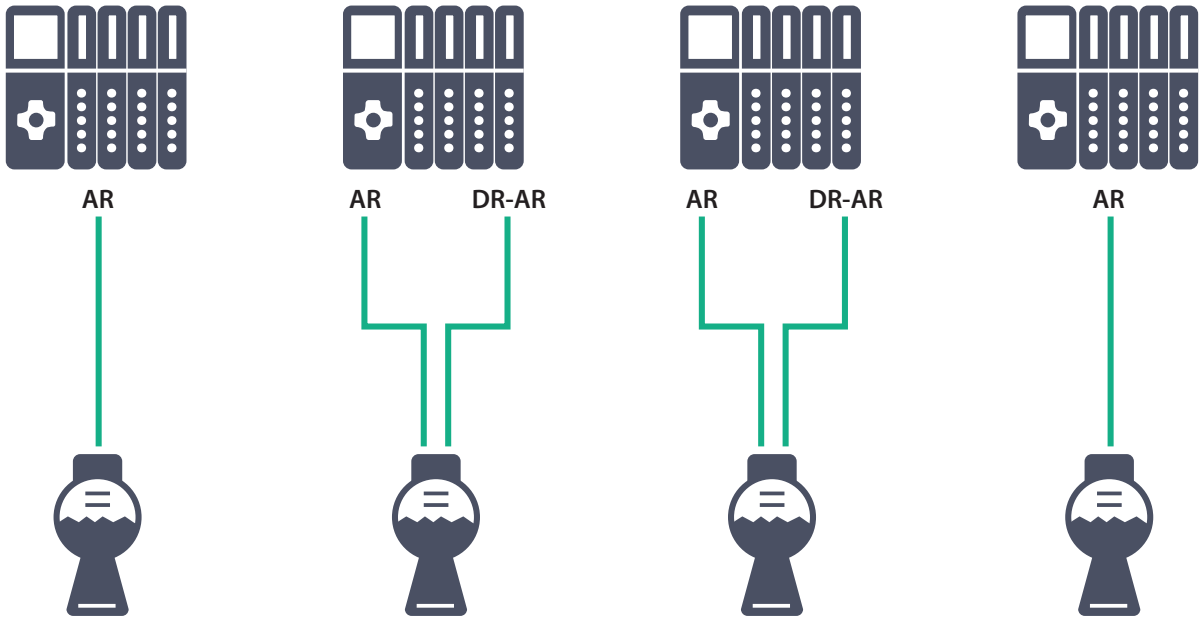


Fig 10: Changes in application relationships for dynamic reconfiguration of a device setting

3.2.2 Ring Topology for Media Redundancy

Ring topologies establish media redundancy. If a wire breaks in one section of the ring, there is a secondary connection to the network. Figure 11 shows an example of a ring topology within a network consisting of multiple topologies.

Generally, Ethernet should not be connected in a ring without any sort of management, as without managing the ring, Ethernet packets can go in circles forever, using valuable bandwidth. PROFINET offers a solution by managing ring topologies with two defined redundancy classes: Media Redundancy Protocol (MRP) and Media Redundancy for Planned Duplication (MRPD).

To set up an MRP ring, all nodes must support MRP and at least one node must support MRP manager capabilities. If the transmission link in the ring is interrupted, the ring manager immediately activates the alternative communication path. The recovery time is in the millisecond range.

Similarly, to set up an MRPD ring, all nodes in the ring must support MRPD and at least one node must support MRPD manager capabilities. In an MRPD ring, all nodes also support PROFINET Isochronous Real-Time (IRT), e.g. CC-C devices. Each sender in an MRPD ring transmits two equal frames to the receiver in opposite directions around the ring. In case of a network failure, one frame will still arrive at the receiver. Therefore, MRPD ensures non-stop connectivity with a recovery time of zero.

These two options deliver a number of benefits to users such as no additional hardware required and the ability to combine with system redundancy. The design of the ring topology is flexible in that it can mix and match any physical layer: Ethernet, Ethernet-APL or fiber optics.

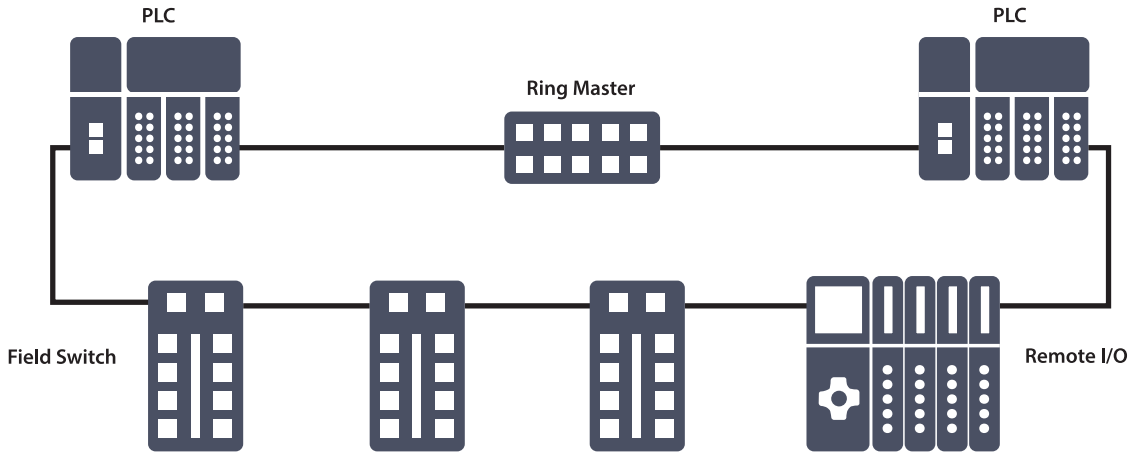


Fig. 11 Media redundancy

3.2.3 System Redundancy for Instruments and Controllers

With PROFINET system redundancy, a device establishes redundant application relationships with its communication partners. Depending on the specific availability needs, users can select from three types of system redundancy, which are described in figure 12 and table 1.

According to PROFINET's terminology, a network access point (NAP) is the label for the physical and logical connection to a network. Every device provides at least one NAP. To combine system redundancy with ring redundancy, any instrument requires two NAPs.

Label	Device NAP	Controller	Controller NAP
S2	Simplex	Redundant	Simplex
R1	Redundant	Redundant	Simplex
R2	Redundant	Redundant	Redundant

Table 1

S2 system redundancy (figure 12 left) describes a compact PROFINET device, such as a field device, that can be operated without additional hardware on a system with redundant controllers or PLCs for high availability. R1 and R2 system redundancy (figure 12, center and right) refer to the redundancy of the communication interface. This could be a modular PROFINET device, such as a remote I/O. R2 system redundancy achieves maximum plant availability through four paths between controller and device. Support for system redundancy is mandatory for PROFINET devices for process automation in CC-B(PA).

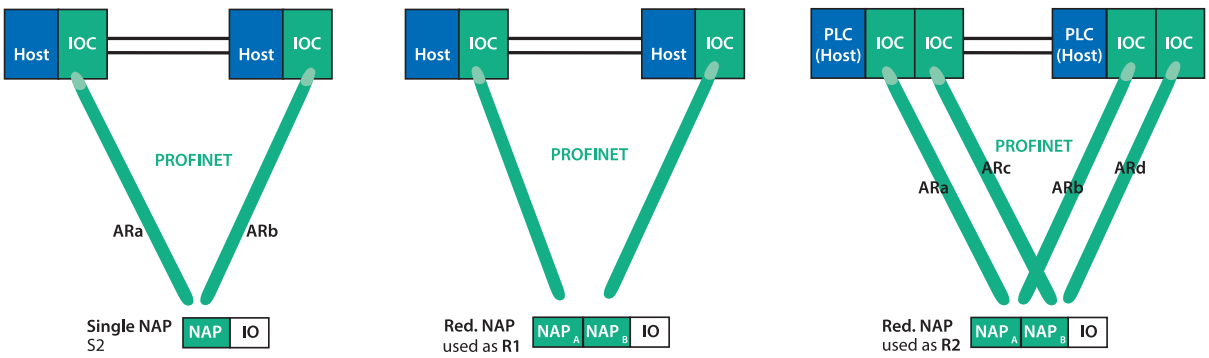


Fig. 12: Types of system redundancy

PROFINET's system redundancy features and functions help users by enabling the implementation of various solutions for system redundancy, ensuring availability to conform to the requirements of the plant, and maximizing availability through 4-path redundancy (R2 system redundancy).

3.2.4 Sequence of Events (SoE)

Precise cause analysis based on time synchronization and stamping

In large plants, the ability to record the actions, alarms and status messages to a sequence of events (SoE) is often required. Time synchronization among devices on the network ensures high-accuracy time stamping. PROFINET provides a standardized solution based on IEEE 1588, which includes functions for archiving and control. For more information, please read the PI documents "PROFINET Specification" [2.702 / 2.712 / 2.722 / 2.742 e].

3.2.5 The PROFINET Profile for PA Devices

Using the Profile for PA devices with PROFINET

The PROFINET Profile for Process Control Devices, often referred to as the PA Profile, is the generic device profile for process field devices. It uniformly describes the behavior of similar PA devices of various types, even if available from different manufacturers. A profile GSD represents the combined functions by device type, such as temperature, pressure, level, flow or valve position.

The PA Profile defines both the measured value and unit to be synchronized between the field device and the control system. It meets the requirements of NE 131 for the "NAMUR Standard Device", including core and start-up parameters. All attributes in combination enable easy device engineering, commissioning and replacement.

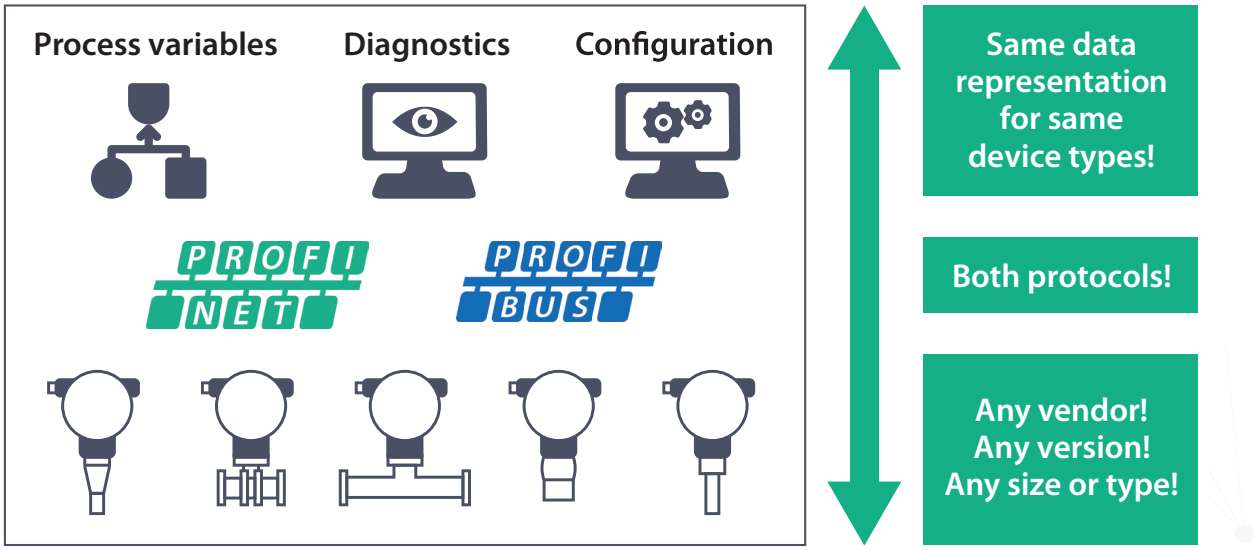


Fig. 13: PROFINET over APL

PA Profile 4 is the latest version available, and it is uniformly applicable to PROFIBUS and PROFINET systems. Additionally, the widely supported PROFIBUS PA Profile 3.02 remains available and certifiable, so that any investment in existing plant equipment is protected. Furthermore, a profile for remote I/O was added recently, called RIO for PA. It describes IO devices and modules for use in process automation specifically and their mapping to PROFINET IO. The profile defines minimal and typical requirements for such devices and modules. RIO for PA is based on the latest PA profile for devices (PA Device Profile 4) and transfers the successful profile concept to remote I/O technology. Using the RIO for PA profile, remote I/Os from different suppliers will have behave in a vendor neutral manner in regard to engineering and operation. The advantages are similar to the PA Profiles and include simplified commissioning as well as standardized diagnostics according to NE107. Different to the PA Profile, the RIO for PA profile does not support exchange of remote I/Os from different vendors, due to their variability and modularity.

Resulting user benefits are:

- Standardized, easy, and uniform processes for engineering, installation, commissioning and replacement of devices
- No engineering required during device replacement
- Vendor-neutral configuration of field devices in the control system via a standard interface

3.2.6 Simple Device Replacement

Simplified device replacement, even easier than a 4-20 mA current loop

The Simple Device Replacement feature of PROFINET is a unique capability within the industry that facilitates the fast and effortless replacement of PROFINET devices in an automation network. A device can be replaced with a new or different device without requiring any user configuration. Users can rely on a standard, straightforward operating procedure.

Simple Device Replacement is typically based on the PA profile, automatic network discovery and neighbourhood detection. The user replaces the faulty device with a new one and the controller automatically detects the presence of the new device based on its type and location on the network. The controller then assigns the appropriate IP address, name and related configuration to the replacement device. To successfully utilize the Simple Device Replacement feature, there are three requirements:

- The replacement device must be the same model as the one it is replacing. This ensures compatibility and proper functionality within the network.
- The replacement device must have a blank name. This helps avoid conflicts with existing device names in the network.
- The controller must support the Simple Device Replacement feature. This functionality needs to be available in the specific controller being used.

Users have the option to bypass the requirement of a blank name, as some controllers provide a function that supports name overwrite. If this option is enabled, the replacement device can have the same name as the one it is replacing.

Simple Device Replacement in PROFINET simplifies the process of replacing faulty devices within an automation network by automating configuration and eliminating the need for manual intervention and reconfiguration. Users in process industries have stated that it is even easier than exchanging a device with a 4-20 mA interface.

User benefits include:

- Simple standard operation procedures
- No need for engineering tools or manual network reconfiguration
- Automatic parametrization during device start-up

3.3 Protecting Investments in Existing Equipment

Many existing plants utilize PROFIBUS Decentralized Peripherals (DP) in their control rooms with Remote I/O for 4-20 mA field devices and Highway Addressable Remote Transducer (HART) technologies. PROFIBUS Process Automation (PA) is used for full digital communications with field instrumentation. PROFIBUS PA is the digital communication infrastructure that enables long cable runs, explosion protection and robustness for the harsh environments that are typical of process automation applications. Based on the same protocol, it offers complete digital integration of any type of field communication into control and asset management systems. As such, it helps to protect existing installations and optimize their total cost of ownership while bridging the gap to new technologies, such as PROFINET over APL. This has helped the solution gain acceptance and popularity among device vendors.

3.3.1 PROFIBUS PA on PROFINET via Proxy

Uniformity in engineering and configuration activities is ensured through FDI, which supports PROFIBUS PA. Proxy technology provides integration in PROFINET-based higher-level systems while maintaining interoperability with controls, infrastructure and instrumentation. Systems are thus able to automate or support various workflows through key features. These include automated documentation, shortened and effective loop checks, reduced installation effort, simple verification of intrinsic safety for operation in potentially hazardous areas, demand-oriented maintenance and simple device replacement.

Through the use of proxies (figure 14), it is possible to combine the strengths of technologies already proven in the industry and ensure investment protection for other established technologies over the long term. More precisely, with proxy technology, existing plant sections can be integrated into a PROFINET infrastructure (figure 14). For process automation, proxies can incorporate existing fieldbus systems, such as PROFIBUS DP/PROFIBUS PA, FOUNDATION Fieldbus H1 and HART, among others.

Proxies are gateways that represent devices in a standardized and structured manner in the PROFINET network. The control systems can use them to access the field devices cyclically as well as acyclically. Functions of the fieldbus systems, such as diagnostics and configuration, can be used as native properties in the PROFINET world.

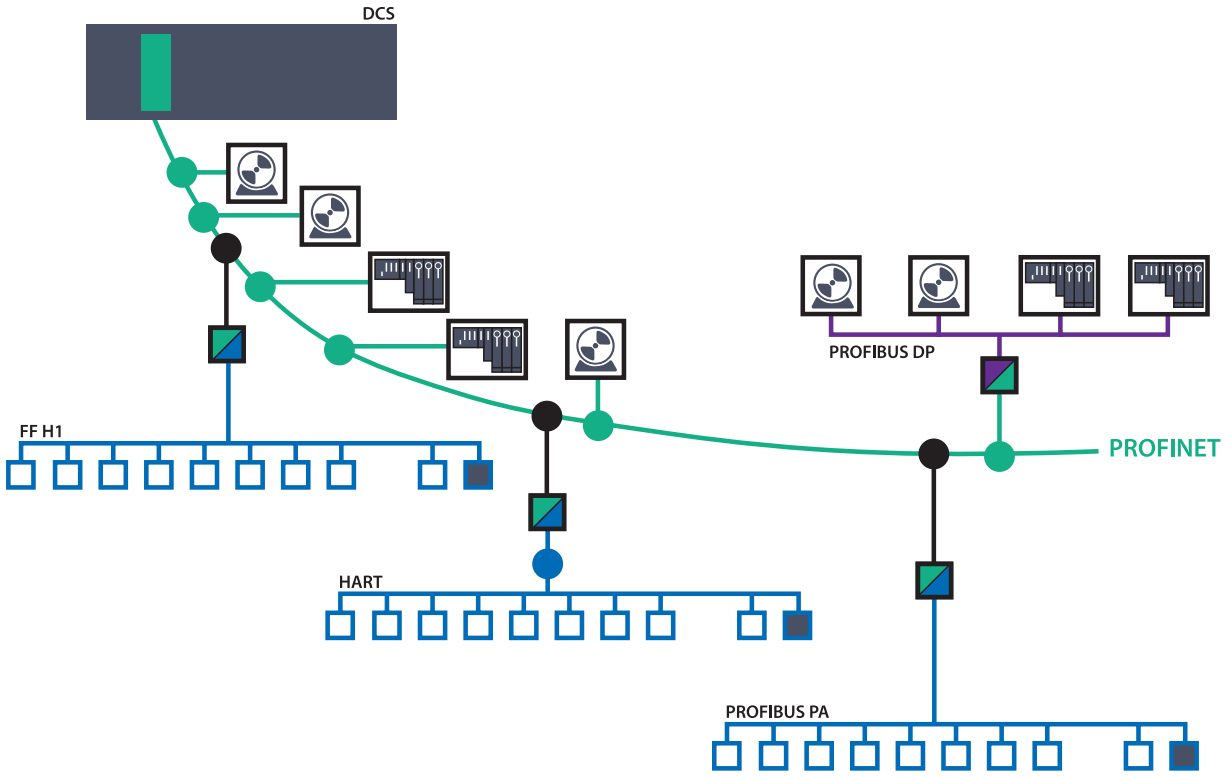


Fig. 14: Asset protection through proxy-based integration of different plant units

Summary of user benefits:

- Integration of existing fieldbuses and installed base
- 100% asset protection for device manufacturers and end users
- Supports stepwise upgrade of PROFIBUS systems to PROFINET systems
- Standardized engineering
- Suitability for applications in hazardous areas

3.3.2 PROFINET to Field Devices

With PROFINET down to the field level

For several years, PROFINET, in combination with remote I/O, has been used for the integration of conventional 4-20 mA and HART devices into the digital backbone. PROFINET can now connect seamlessly to any device through different physical layers.

For installations in Zone 1 explosive atmospheres, options for communication networks include copper cables and optical fibers. Copper cables can use intrinsically safe protection (100BASE-TX-IS) or increased safety protection (Ex eb). Alternatively, optical fibers can utilize optical inherently safe protection (Ex op is) or optical protected protection (Ex op pr). For the systems used in these applications, PROFINET is able to gradually replace the conventional PROFIBUS DP and PA (figure 15). This solution enables users to have a consistent information flow, a seamless integration into automation systems and open access for device configuration as well as diagnostics via Ethernet. New developments also support remote I/O technology, such as the FDI technology "FDI for RIO" and a new "RIO for PA" profile.

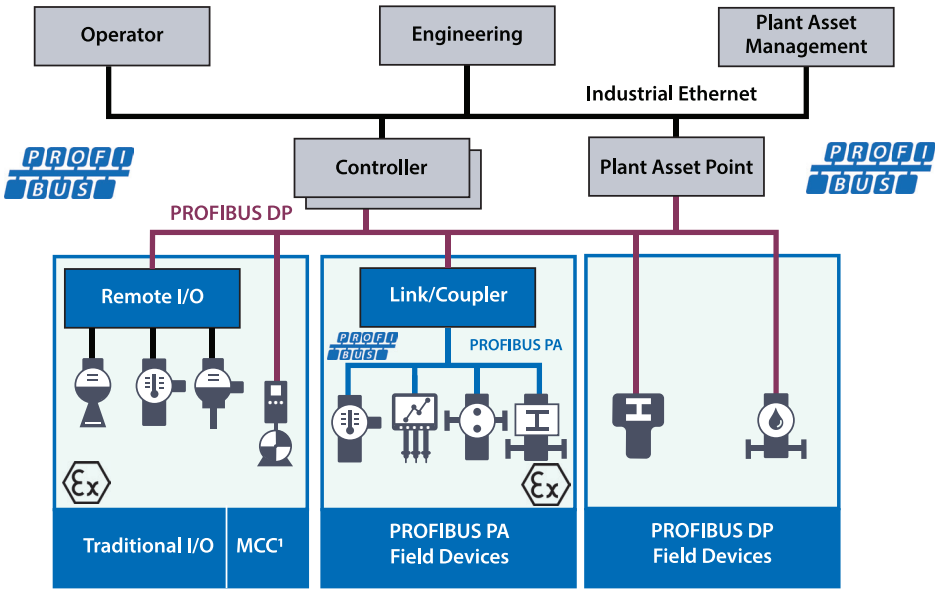


Fig. 15: Communication structure of a plant with PROFIBUS DP and PROFIBUS PA

4 Certification Ensures Quality

Ensuring the quality of a technology from the beginning is important for PI. Therefore, the well-known PROFINET certification process was established and made mandatory for PA devices right from the start. The following test areas are applied to PA devices to ensure conformity and interoperability:

- PROFINET standard certification tests, performed using an Automated RT-Tester, also known as ART
- Robustness testing through network load test
- Interoperability assessment through defined test setup
- Consistency of the GSD using a GSD Checker

All automated PROFINET tests for PA devices are available to every PI member for free in the aptly "Test Bundle" that can be found on the PI webpage. Device manufacturers can perform all tests as part of their development process and benefit from a fast and effective certification process at PI's test labs.

5 Summary

Purposefully Developed, Proven, Futureproof and Easy to Use

PROFINET stands as a robust and adaptable networking solution tailored to the needs of process automation applications. Thanks to its key features, it can help industry players enhance operational efficiency and control.

Two of PROFINET's notable advantages are its flexibility and scalability, backed by its nature as a switched Ethernet technology. This feature makes it possible for the technology to adapt to various industrial environments and networks while ensuring long-term viability and adaptability. Its seamless integration capabilities facilitate interoperability with a wide range of devices and systems, simplifying the incorporation of new technologies.

Furthermore, PROFINET is a global industry standard that is well established in factory automation and in machine building, thereby ensuring a high level of operational reliability. As a 100% standard Switched Ethernet solution, it supports the use of all web technologies, maximizing data transfer, compatibility and interoperability across different systems and devices.

In addition, PROFINET's compatibility with PROFIBUS and legacy solutions through proxies offers backward compatibility, maximizing and protecting existing assets. This compatibility streamlines the transition to PROFINET, offering a solid backbone to futureproof plants and operations. Additionally, PROFINET's support for device replacement ensures smooth upgrades and reduces downtime during migration processes. Even more, advanced diagnostic and maintenance features contribute to reduced downtime and maintenance costs, enabling predictive maintenance and rapid troubleshooting.

Security is another critical area where PROFINET excels, offering robust measures to protect against cyber threats and ensuring the integrity and confidentiality of process data. This focus on security, combined with its high performance and reliability, makes PROFINET an ideal choice for the process industry, where safeguarding operations and data is paramount.

Functional safety, essential in process automation, is also supported by PROFINET. The solution aligns with current standards, such as SIL, and offers protocols to maintain safe operation of industrial processes. Even more, it supports the physical layer for two-wire Ethernet, and as such, it is suitable for use in hazardous areas and potentially explosive atmospheres. Thanks to these capabilities, PROFINET ensures compliance with safety standards and mitigates risks associated with process automation.

By leveraging PROFINET, companies in the process industry can enhance their operations, maximize efficiency, reduce downtime and improve control. As a result, they can optimize resource utilization and minimize costs, ultimately driving higher profitability. Additionally, PROFINET's support for innovation and technological advancements helps companies to stay ahead of the curve and maintain a competitive edge in a rapidly evolving market landscape.

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