PROFINET - The Solution Platform for Process Automation

PROFINET acquires more importance in process automation due to both its actual capabilities, and its newly developed and planned properties.

To achieve this objective, PI is working closely with well-known users of process automation on the technologies.

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PROFIBUS • PROFINET

Thanks to the degree of maturity achieved by the specified Ethernet technology in international standards, PROFINET enjoys an ever increasing acceptance in process automation.

With specific characteristics required by the process industry and reliability arise due to close cooperation and exchange between well-known users and manufacturers.

This white paper is an update of the first edition published in 2015 at ACHEMA.

The following changes have since been added:

- Requirement definition has been performed
- State of the Industry completed
- Update of the graphics
- Update of published standards
- Release Profile for PA Devices 4.0
- Solidification of two-wire Ethernet

We wish you an interesting and insightful read.

Contents

Table of Figures

1 Introduction

1.1 Why PROFINET?

The next generation in process automation

Industrial communication is one of the key technologies for modern automation. It is used to control and monitor machines and systems in manufacturing and production processes. Furthermore, it interconnects production islands and integrates adjacent tasks like logistics, quality assurance, and system maintenance to higher order business systems. In the future world of "Industrie 4.0", the Industrial Internet of Things, and Big Data, industrial communication is of even greater importance. Easy-to-handle solutions with high performance capability for real-time, availability, flexible topologies, and integration – even over long distances – are needed to make use of the many possibilities of the digital world.

Ethernet technology and IP-based communication are the current driving force behind intercon-nectivity and thus all types of information flow on a global scale. Factory automation-related industries are benefiting from this through better products that can be produced in shorter time and at lower cost. This is exactly the reason – in the sense of ensured competitiveness – why Ethernet is undergoing further development for use in industrial environments.

As it relates to the PROFIBUS & PROFINET International (PI) Organization, this concerns the currently ongoing step-wise replacement of PROFIBUS DP with PROFINET. This replacement is in full swing in factory automation with proven benefits for users: *"PROFIBUS DP is good, PROFINET has even more capabilities"*. 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, manufacturers and technologies. Plant owners and operators urgently want this complexity to be harmonized, the data and information systems to be fully integrated as well as easier to handle and therefore more reliable, and connect the generations of technologies together. PROFINET fully meets these demands:

- PROFINET is 100% Ethernet and thus provides an ideal environment for interoperability at all levels of a plant. And PROFINET is precisely defined in its specifications, which is also a requirement for full interoperability.
- As a uniform technology in a plant, PROFINET also affects personnel costs. There is less training expense, fewer specialists are needed, and plant operation is more transparent and thus more reliable and cost-efficient.

- PROFINET is 100% Ethernet and is therefore closely connected to the goal required of tight IT interaction with IT. This also of importance with respect to the generational change in the operating personnel with a higher acceptance of digital technologies.
- Energy savings are necessary to reduce costs! For PROFINET there are - as with PROFIBUS a wide selection of application-oriented "Profiles" to solve specific tasks. A very topical example is PROFIenergy, which enables energy saving during process-related standby periods of plant segments (robots, pumps, motors) and thus significant cost reductions.
- The handling of field devices must be simple and reliable. PROFINET has a number of intelligent mechanisms (e.g. automatic addressing and device replacement), which fulfils precisely this requirement.
- Security is a must, particularly in the process industry with its sensitive processes. PROFINET already has a multi-level security concept and, because it is 100% Ethernet, it also shares in future security developments from the IT world. PI is further developing the authentication and encryption of the PROFINET communication
- Operational safety and system availability are key topics in the applications of the process industry. PROFINET has been 'in the field' of factory manufacturing for many years, which largely eliminates both learning curve and "start-up costs" for the newcomer from the process industry. This is ensured with strict and extensive certification measures, and the "High Availability" functionality for process applications is also verified in the certification stage.

The answer therefore to the introductory question "Why PROFINET?" is as follows: As an Industrial Ethernet standard PROFINET offers plant operators and owners of process automation-related plants a large step forward in terms of standardization, integration, ease of use, security, and ease of use, security, cost reduction, and simplicity! PROFIBUS & PROFINET International (PI) continues to work intensively on a comprehensive solution for process automation that includes existing and new PI technologies.

The goal is the development of **PROFINET as the solution platform for process automation**.

This paper reports on the current state of technology development, today's available features and capabilities of PROFINET for process automation and provides an outlook on specifications in progress.

1.2 From Ethernet to PROFINET

Applying technological progress

Ethernet originated in a joint project by DEC, Intel, and Xerox in the 1970s. It was conceived as a transmission medium with bus structure between multiple data stations in the local area with identical authorization. The data rate was 3 Mbps in the beginning. The IEEE Standard 802.3 emerged from this in 1982. Then, rapid development in the 1980s yielded Ethernet with over 10 Mbps all the way to fast Ethernet with 100 Mbps. To date, data rates of 10 Gigabits per second, and more, have already been achieved. The term "Ethernet" describes both the hardware of the transmission medium (connectors, cables, distributors, etc.) as well as the data transmission (protocols, transmission forms, packet formats). Ethernet is an explicitly defined implementation of Layers 1 and 2 of the OSI Layer Model and is widely with different protocols on higher layers (e.g., HTTP or SMTP, well-known from the internet).

Industrial Ethernet designates, among other things, further developments on various layers of the layer model with the objective of making Ethernet suitable for use in industrial automation. Special properties of Industrial Ethernet include:

- Robust, industrial-grade components and products
- Development of protocols which fulfill industrial requirements (e.g. real-time capability)

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 and is thus also open for application of all Ethernet technologies and parallel operation of multiple Ethernet protocols.

The **functional scope of PROFINET** can be scaled, according to multiple layered Conformance Classes (CC) each building on the previous, for adaptation to different use cases (figure 1). These combine minimum application-oriented properties: CC-A includes the basic functions and is, for example, used in building automation. CC-B expands the functional scope to include network diagnostics and topology information; CC-B(PA) adds functions relevant 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 functions for implementation of IRT (Isochronous Real Time) communication and is thus the basis for clock-synchronized applications. A detailed description of the CCs is contained in the PI document "PROFINET IO Conformance Classes" [7.042 e].

The CCs with their defined contents are also the basis for **certification of the PROFINET devices** using a standardized test procedure in authorized test labs. Based on a positive test report, the device manufacturer receives a certificate which grants the right to brand the device with the PROFINET label. For plant builders and owners, the use of certified devices means time savings for commissioning and stable device behavior and, above all, interoperability during the entire period of use.

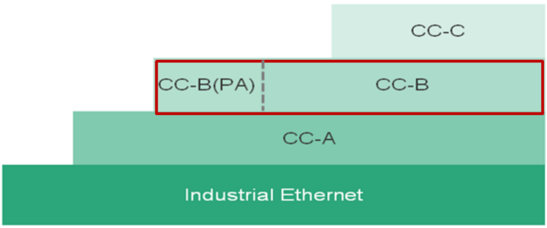

Fig. 1: Structure of the Conformance Classes (CC) of PROFINET

PROFINET recognizes the following **device families**: PROFINET controller (corresponds to PROFIBUS master class 1), PROFINET device (corresponds to PROFIBUS slave), and PROFINET supervisor (corresponds to PROFIBUS master class 2).

PROFINET is a platform with which the various sections of a plant or machine can be integrated into the automation landscape via an explicitly defined interface for communication and, in the future, for bus-powered devices in specific applications. This not only minimizes the number of different interfaces, but enables the exchange of information and knowledge (instead of data only) between the sections: For example, is a compressor, heat exchanger, or blower even capable of delivering the capacity needed for the setpoint? Or, what is the most economical operating point of a plant, given the status of the various units? PROFINET offers the comprehensive solution, with vertical and horizontal consistency, providing information rather than just data and all the advantages that an Ethernet standard offers.

1.3 Requirements of the Process Industry

Highest requirements must be met

Compared to factory automation, process automation places additional demands on communication technology. The plants, which extend over wide areas, have a lifespan of 15 to 40 years; and invariably run continuous production processes, where unplanned breakdown or disturbance would pose a serious hazard to people and environment, or a large financial loss. The desire of the operator is to create continuous access to both horizontal and vertical data and information flows. This results in the following requirements of the communication technology:

- Installation technology and field devices can be handled easily by skilled staff
- Installation in hazardous areas, including intrinsic safety protection (Ex i)
- Long cable distances (up to 1,000 meter)
- Freedom of design choice in the topology
- Robust connection technology and communication
- Redundancy concepts for critical components
- Dynamic reconfiguration of individual components during operation
- Largest possible convergence of networks and information

The communication interface is to be standardized in order to ensure the smooth interaction of components of different manufacturers. The communication interface and the systems for engineering, asset management, and plant control should have the following properties:

- Maximum reliability and availability
- Disturbance-free configuration during plant operation
- Easy handling, especially for device replacement
- Investment protection for existing plants, including changes of the process control technology
- Suitable for large quantity structures of 10,000 or more devices

A particular expectation of the chemical industry was addressed in a keynote speech at the 2014 NAMUR1 General Meeting: the merging of automation technology with the IT world, with the goal of protecting the competitive capability of chemical companies into the future. Together with the large plants in the chemical, petrochemical, and oil & gas industries, there are industry sectors with clearly lower requirements for, e.g., cable distances and explosion protection. These include the industries: food, environment, water and wastewater, life sciences, pharmaceuticals, etc.

PI defines the underlying technology for all listed requirements. The following sections provide an overview, starting from the current status of today's available technology and products, continuing with specifications already being implemented or about to be implemented and ending with planned further improvements. The further development of existing specifications and new definitions of technologies take aim at requirements that must be fulfilled in the future. The open and fact-based discussion in the PI committees leads to vendor-neutral, well-defined solutions for a heterogeneous process landscape.

2 Proven Today: PROFIBUS PA

Digital to the device

PROFIBUS PA is the fieldbus that enables long cable runs, and explosion protection and robustness for the harsh environments in process automation. It offers a complete digital integration of field instrumentation in control and asset management systems. Worldwide, PROFIBUS PA can be found today in many installations as a powerful and stable solution.

For the connection between field devices and controller the selection exists for a link or coupler typically over PROFIBUS DP (figure 2) or a proxy over PROFINET. The user benefit of PROFIBUS PA is amongst other things generated from three properties:

1. PROFIBUS PA is particularly suitable for process automation with both supply and data transmission in a simple, shielded two-wire cable. The consistently digital communication offers a significantly higher accuracy of data transmission and integrated mechanisms for the parallel transmission of control and measured variables, diagnostic and configuration data.

2. Installation techniques for explosion protection are well known in industry. In particular, proof of intrinsic safety provided by the FISCO model is especially simplified. Fewer simple installation rules and documentary proof and requires no additional calculations, offers the simplicity required by users.

3. The device profile standardizes the compatibility of devices, allowing device replacement regardless of manufacturer and software version. With the PA profile the user has the utmost freedom in the instrumentation of his system.

In addition, the duality of integration tools has already been concluded through the now completed and available, uniform FDI (Field Device Integration) technology finished. Naturally, this also supports PROFIBUS PA.

PROFIBUS PA is for all milestones in the life cycle of a process plant useful: for plant planning and plant construction as well as for installation, operation and maintenance of the facility. PROFIBUS PA fulfills this requirement through automated documentation and shortened and effective loop checks, reduced installation effort, simple proof of intrinsic safety for operation in potentially hazardous areas, demand-oriented maintenance, simple device replacement and other activities.

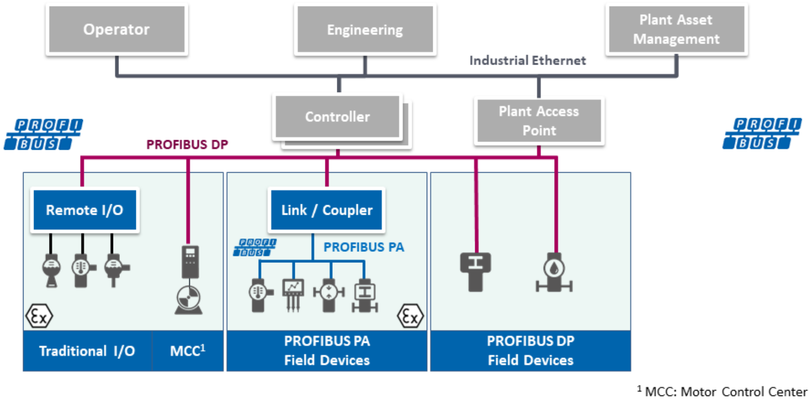

Fig. 2: Communication structure of a plant with PROFIBUS DP and PROFIBUS PA

3 PROFINET in Process Automation: Today and the Near Future

Planning and shaping the future today

There are already applications with PROFINET, especially in areas where PROFIBUS DP was used in either connecting to Remote I/O or Motor Control Centers. However, their use is still subject to certain restrictions because PROFINET functions such as "system redundancy" or "dynamic reconfiguration" are not consistently implemented in such products.

Figure 3 shows (from left to right) PROFINET devices such as Remote I/O and Motor Control Center (MCC), PROFIBUS PA field devices for Ex applications integrated via PROFINET with a proxy, and a switch connects PROFINET field devices for applications without explosion protection requirements.

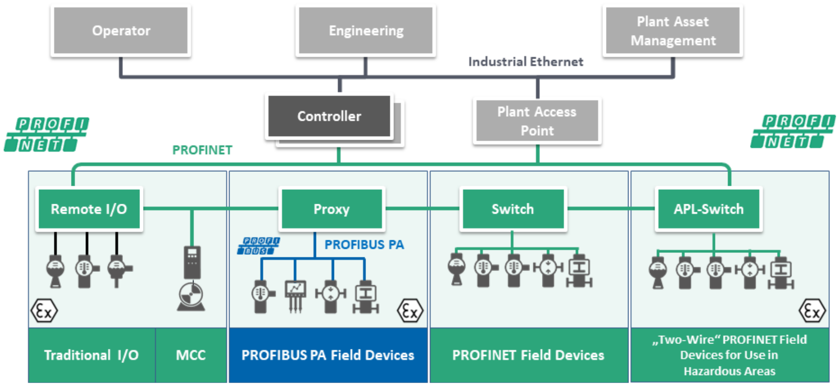

Fig. 3: PROFINET and PROFIBUS PA, and in the future with APL

This chapter describes the staged introduction of PROFINET into the process technology: 3.1 describes already existing and implemented PROFINET functions. 3.2 describes an overview of already completed specifications, which are currently being implemented into products. Important here is the integration of existing bus systems using proxy technology. In 3.3, the definition of topics is covered. Chapter 3.4 provides an outlook to the future. Protecting the existing investment enjoys special consideration in all projects.

Summary of user benefits:

- Automatic creation and checking of the topology (visualization)
- Accelerated commissioning and easy device replacement
- Easy configuring, even without an engineering tool
- Prevention of address conflicts
- Easier handling than 4...20 mA technology
- Continuity of diagnostic displays based on NAMUR NE 107

3.1 PROFINET Basic Functions

Proven PROFINET functions and technologies of importance to process automation and especially with field devices are: network configuration, connection technology, network diagnostics, topology display, detection of neighboring devices, device replacement and diagnostics. These functions enable automatic address configuration during device replacement, as well as the display of a plant, which can be used, for example, to ensure that a replacement device was connected at the correct port. The replacement device receives the same name and parameters as the replaced device. In addition, the topology display is used for diagnostic purposes and shows, for example, a wire break graphically at the corresponding location.

3.1.1 Network Installation

Easy network installation and fully integrated network diagnostics

Communication technologies in process automation plants; that is valid also for PROFINET and its connection techniques.

The large number of permitted topologies enables a network configuration of PROFINET to optimally meet the requirements in terms of spatial extent and plant 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 media redundancy and
- Tree as a combination of the above topologies

Today's defined and utilized connection technology meets the requirements for wiring these switching techniques.

The connection of PROFINET devices is carried out exclusively using switches as network components, which are often already integrated in the device (2 port interfaces). PROFINET-suitable switches must support bot "Auto-negotiation" and "Auto crossover" functions. As a result, communication can be established autonomously, and the physical cable designs are uniform. The connection between the participants (devices and switches) is possible up to a distance of 100 m using copper cable, whereas incorporating power cascading the cable length can be extended accordingly. For longer transmission paths, optical fiber or wireless radio links can be used.

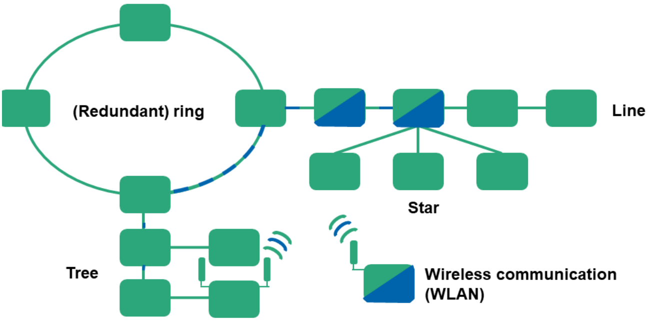

Fig. 4: Flexible network configuration of PROFINET

3.1.2 Network Management

In IT networks, the SNMP (Simple Network Management Protocol) has 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. SNMP must be implemented for devices of Conformance Classes B and C.

3.1.3 Network Diagnostics

PROFINET field devices use the LLDP (Link Layer Discovery Protocol) according to IEEE 802.1AB 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. In figure 5, the "delta" device is connected to port003 of "switch1" via port001. With this neighbor detection, a preset/actual comparison of the topology is possible and changes of the topology during operation can be recognized immediately. This is also the basis for the automatic naming during device replacement.

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

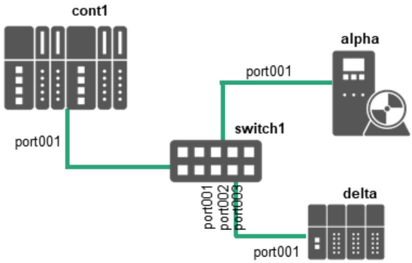

Fig. 5: PROFINET field devices know their neighbors

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

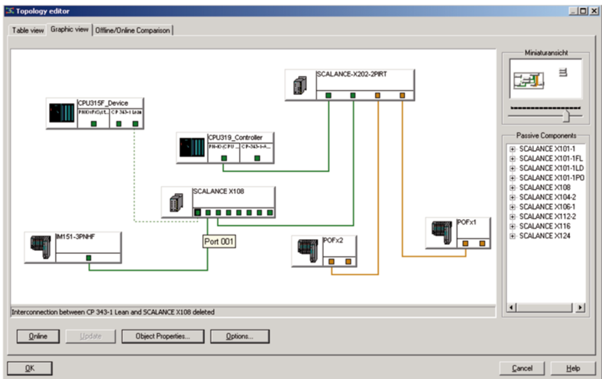

Fig. 6: Representation of the plant topology

3.1.4 Device Diagnostics

Uniform device diagnostics with NAMUR traffic light according to NE 107

Status-oriented maintenance is important for operation and maintenance of plants. It is based on the capability of devices and components to determine their status and to communicate using standardized mechanisms. To this end PROFINET provides a system for reliable signaling of alarms and status messages from the devices to the controller. This diagnosis model (figure 7) covers system-defined events such as removal/insertion of modules and the signaling of malfunctions such as a wire break that are detected by the control mechanisms. Besides the "good" and "faulty" status, the underlying status model also knows the optional levels "maintenance required" (e.g. when media redundancy is lost) and "maintenance demanded". The module also distinguishes between diagnostic alarms (events within a device or component) and process alarms (events in the process, e.g. limit temperature exceeded). The document "Diagnostics with PROFINET" [7.142 e] contains further information.

To ensure a uniform display of the different diagnostic messages, the results of the PROFINET diagnosis model have been assigned to the diagnostic display according to the NAMUR NE 107 (figure 8). This leads to a uniform display for all devices in a plant.

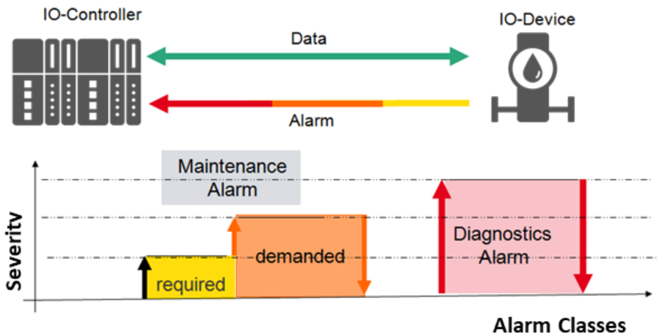

Fig. 7: PROFINET diagnosis model for signaling faults with different priority

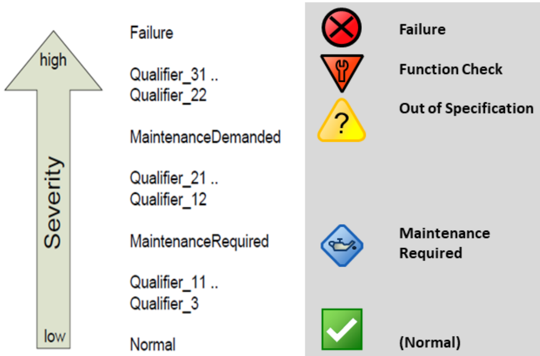

Fig. 8: Assignment of the PROFINET device diagnostics to NAMUR NE 107 requirements

3.1.5 Device Replacement

Simplified device replacement, easier than 4...20 mA

The replacement of PROFINET field devices can be performed easily and reliably. The basis for this is the cyclic exchange of neighborhood information of the devices. If a device fails, its neighborhood is known. A replacement device that is "nameless" to start is inserted, and the controller searches for the explicitly identifiable neighbor device of the defective device. As a result, the replacement device can be assigned the same position in the network, the same address, and the same parameter set as the failed device. In addition, the address and positioning of the device is also shown in the diagram of the plant topology and can be verified once installed. Altogether, this enables fast and reliable device replacement even without an engineering tool.

This continuous visualization of the network and the related ability to immediately detect, for example, address conflicts lend support to plant commissioning, modification and expansion. The result is significant time savings compared to past procedures.

3.1.6 Security

For secure networking within a large factory or over the Internet, PROFINET provides a graduated security concept (figure 9). This can be adapted to the application through configurable upstream security zones. As a result, this frees PROFINET devices from being overloaded with security mechanisms. Furthermore, the concept can be optimally adapted to the changing security requirements over the plant's lifetime and to technical innovations. Individual devices and whole networks can be protected from unauthorized access. This is accomplished by security modules that allow networks to be segmented and, thus, also separated and protected. Only explicitly identified messages reach the devices located inside such segments from the outside (figure 10). For more information, see the PI document "PROFINET Security Guideline" [7.002 e].

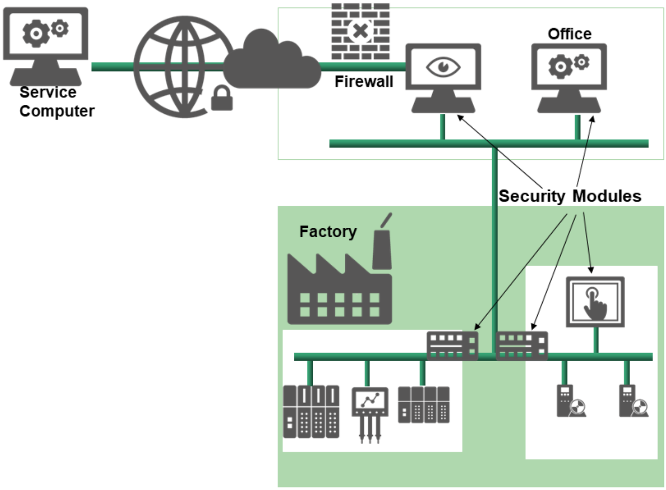

Fig. 9 : Access to machines and systems using secure connections

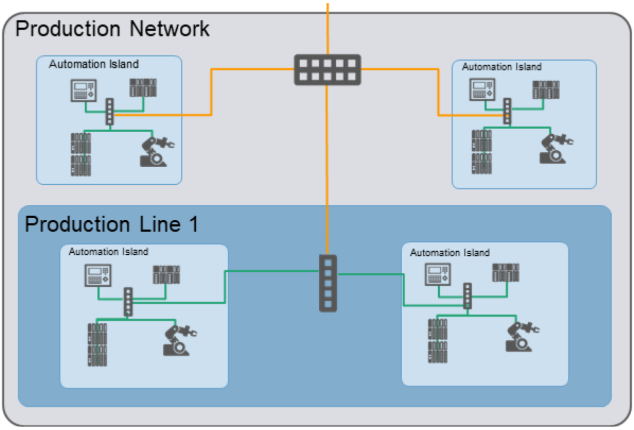

Fig. 10: Segmentation of the network

3.1.7 Safety (SIL)

Two solutions for optimum safety

A consistent communications path must be possible for safety-relevant applications. One possibility for this already exists today in the form of safety with 4…20mA/HART using Remote I/O or Proxy; another solution can be based on PROFIsafe.PROFIsafe is the protocol defined in IEC 61784-3-3 for implementing functional safety (fail-safe). PROFIsafe is recognized by IFA and TÜV, and can be used with PROFIBUS and PROFINET alike. As a result, elements of a fail-safe controller can be transferred directly with the process control data on the same network. Additional wiring is not needed. An introduction to PROFIsafe can be found in the system description [4.342 e]. The specification„PROFIsafe on PROFIBUS DP and PROFINET IO“ is available at [3.192 e].

3.2 Process Applications with PROFINET Technology Thanks to Well Thought out Concepts

For the implementation of PROFINET in the process industry, the following essential specifications are provided and implemented, further information can be found in the document "High Availability for PROFINET" [7.242 e]:

- **Dynamic reconfiguration** for changes without disturbing the running plant operation
- **Media and system redundancy** for very high availability
- The **proxy technology** for investment protection through transparent integration of existing systems such as PROFIBUS PA and other communication technologies in PROFINET

What sounds like a theoretical approach is actually a reality thanks to the commitment of the numerous manufacturers. The scenario shown in the figure 2 in form of a combination of PROFINET and PROFIBUS PA is just one example of this technological continuity and implementation of practical requirements.

The practical deployment of the tremendously important interoperability between field devices and components from different manufacturers, can only be achieved if the manufacturers hold themselves to the exact defined specification - and that's exactly what is ensured with a certification program.

3.2.1 Dynamic Reconfiguration

Continuous operation without interruption: 24/7

Changes in running operation (dynamic reconfiguration) refers to the feature based on redundant communication connections that enable problem-free access in the plant installation without a restart of devices or controllers and with no effect on the communication in the network. This applies to actions taken on or with compact devices as well as to modular devices and proxies (figure 11, starting from left).

Examples: change of device configuration, device replacement, addition or repair of components, change of parameters, etc. See also the PI document "PROFINET Dynamic Reconfiguration (Configure in Run)" [7.112 e].

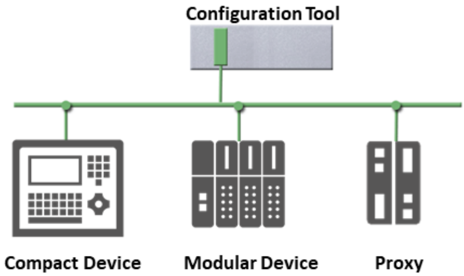

Fig. 11: Universal use of dynamic reconfiguration

3.2.2 Redundancy Solutions

Two concepts for high availability

High system availability is ensured by high performance PROFINET redundancy solutions for communication and devices. Standardization ensures the interoperable behavior of devices of different manufacturers.

Media redundancy connects the several physical communication paths of the PROFINET devices: Devices and controllers (figure 12). In case of failure of a communication path (for example, a cable break), a second communication path is automatically used. See the PI document "PROFINET Media Redundancy" [7.212 e] for additional details.

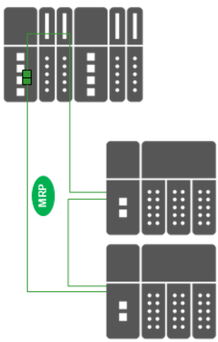

Fig. 12: Media redundancy

Summary of user benefits:

- Electrical ring topology possible
- No additional hardware needed
- Combination with system redundancy possible

In the case of system redundancy a PROFINET device establishes more than one communication relation with a redundant controller. A distinction is made here between different ways of implementing system redundancy. S2 system redundancy (figure 13, left) describes a compact PROFINET device, such as a field device, that can be operated on a system with high availability with no need of additional hardware. R1 and R2 system redundancy (figure 13, center and right) refers to the redundant realization of the communication interface of a modular PROFINET device for example, with a Remote I/O. R2 system redundancy achieves maximum plant availability through its 4 paths between the controller and device. Support of system redundancy is mandatory for PROFINET devices of process automation in CC-B(PA). For more information, see the PI document "PROFINET System Redundancy" [7.122 e].

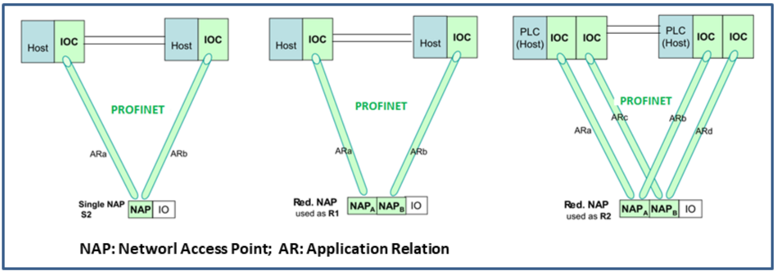

Fig. 13: System redundancy

Summary of user benefits:

- Availability is accurately scalable by the user
- Various methods of system redundancy can be implemented
- Maximum availability through 4-path redundancy (R2 system redundancy)

3.2.3 Sequence of Events (SoE)

Precise cause analysis based on time stamping

In large plants, the ability to record the actions, alarms and status messages to a sequence of events is often required. With its high-accuracy time stamping, PROFINET provides a standardized (IEEE 1588) solution including archiving and control. For more information, see the PI documents "PROFINET Specification" [7.702 / 2.712 / 2.722 / 2.742 e].

3.2.4 Proxy Technology

Migration strategies for the installed base

With proxy technology, existing plant sections can be integrated into a PROFINET infrastructure (figure 14). For process automation, this incorporates the existing fieldbus systems PROFIBUS DP/PROFIBUS PA, FOUNDATION Fieldbus H1, HART and others.

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

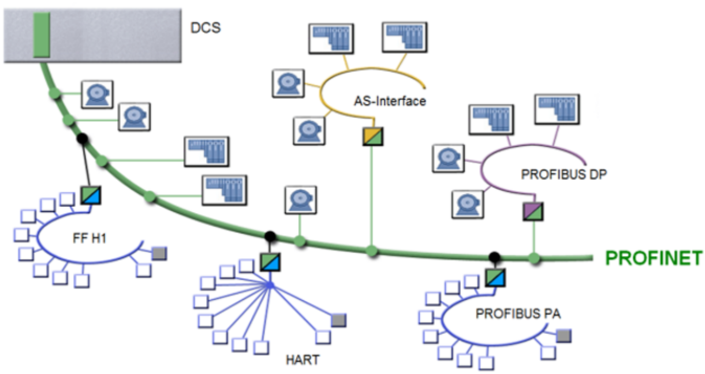

Fig. 14: Investment protection through integration of plant units using proxies

Summary of user benefits:

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

3.3 Freshly Published: Profile for PA Devices

Using the Profile for PA Devices with PROFINET

The "Profile for PA Devices" (current version PA 4.0) is the generic device profile of PI for process field devices. It ensures uniform behavior of PA devices of various types and from different manufacturers during engineering and operation with PROFIBUS PA.

Requirements and expertise of manufacturers and users (including the consideration of the "Core Parameter" for easy device replacement) were included in this revised profile version. The profile 4.0 is additionally independently defined of the physical layer and protocol. This creates for PROFIBUS and PROFINET systems a uniformly applicable Profile for PA Devices 4.0. The PROFIBUS PA Profile 3.02 remains usable and certifiable, so that the investment in existing plant equipment is protected.

Examples of the resulting user benefits include:

- Significantly easier and uniform processes for engineering, installation, commissioning, and replacement of devices. For example, profile devices will be commissioned according to a uniform procedure. Moreover, the requirements of NE 131 for the "NAMUR Standard Device" are met.
- For vendor-neutral configuration of field devices in the control system, devices with the Profile for PA Devices offer a standard interface in the form of the "neutral channel", which represents the combined functions of the devices and provides these in an expanded GSD file for device integration.
- The proven NAMUR NE 107-based diagnosis model is retained and is being revised and adapted in dialog with all industry participants.
- The transmission of large data quantities made possible by Industrial Ethernet expands the former data exchange into an information exchange. As a result, not only data and keywords but also meaningful information from the entire plant is made available to the operator.
- The unit of the measured value is synchronized between the field device and the control system.

3.4 The Solution Platform at a Glance

In the short-term and medium-term, PI sees two technologies as keys for process automation: PROFIBUS PA for plants with long cable distances and hazardous areas and PROFINET devices with currently available interfaces in compact plants and selected industry sectors.

In the medium term, two-wire Ethernet devices based on APL, Advanced Physical Layer, can also replace PROFIBUS PA field devices - see chapter 4.

3.4.1 PROFIBUS PA on PROFINET via Proxy

Consistent investment protection through proxies

As already presented in section 2, PROFIBUS PA is today's established, up-to-date, and future-proof solution for process automation. Digital to the last mile, suitable for use in hazardous areas, bus-powered, with the PA Profile 3.02 reflecting the needs of process automation, implementation of NAMUR NE 107 – and most recently – the state-of-the-art support of FDI for PROFIBUS PA. Through the use of proxies (figure 14 and 15), it becomes possible to combine the strengths of two technologies already industry proven for years and ensure investment protection for other established technologies over the long term.

3.4.2 PROFINET Field Devices

With PROFINET down to the field level

Some industry sectors, such as food, environment, and life sciences, have hybrid installations in which technologies of factory and process automation are used in parallel. Often there are no demands for explosion protection or very long cable lengths so that the interface and installation technology established in the factory automation can be used. For the process devices used in these applications, PROFINET will be able to gradually replace the usual PROFIBUS DP (figure 14) with the optional use of PoE (Power over Ethernet). This solution enables users to have a consistent information flow, a seamless integration into automation systems, and open access for device configuration and diagnostics via Ethernet.

4 Outlook - Ethernet down to the Field Level: From a Vision to Reality

Currently under development is an Advanced Physical Layer (APL) for Ethernet, to be used in process-automation and -instrumentation, to deploy field devices in remote and hazardous locations. This physical layer is based on new chapter editions on existing standards, namely IEEE 802.3 and IEC 60079.

A working group of the IEEE Standards Association is defining the specification for a two-wire Ethernet (based on 10BASE-T1L). This would allow extended range and use in hazardous areas. The draft of such an IEEE 802.3cg based expanded standard would also specify applications with short distances and include a solution for auxiliary power.

In parallel, the APL project is focused on an expansion of 10BASE-T1L for use in potentially explosion hazardous areas (zone 0 and 1 / division 1), thereby enabling the introduction of Ethernet into process automation. The APL project is supported by several significant suppliers to the process industry: ABB, Endress + Hauser, Krohne, Pepperl + Fuchs, Phoenix Contact, Rockwell Automation, Samson, Siemens, R. Stahl, Vega and Yokogawa. In addition, the project cooperates with leading Standard Development Organizations (SDOs) for industrial communication: PROFIBUS & PROFINET International (PI), ODVA, and the FieldComm Group.

Among the most important aspects of this parallel project is the objective, the incorporation in relevant IEC standards for installation of Ethernet devices in potentially explosion hazardous areas, as well as protocol-independent conformance testing for an intrinsically-safe adaptation of 10BASE-T1L. Installations requiring ignition protection increased safety are also easily possible.

4.1 Trusted Installation and Infrastructure

APL is the robust, two-wire, powered Ethernet physical layer based on 10BASE-T1L plus extensions for operation in the demanding conditions and in hazardous areas of process plant. It enables a direct connection of field devices to Ethernet-based systems, so that process industries can benefit from a convergence of their OT (Operational Technology) and IT (Information Technology) systems. It also uses a switch-based architecture and prevents unwanted influences between devices that are also connected to the same network.

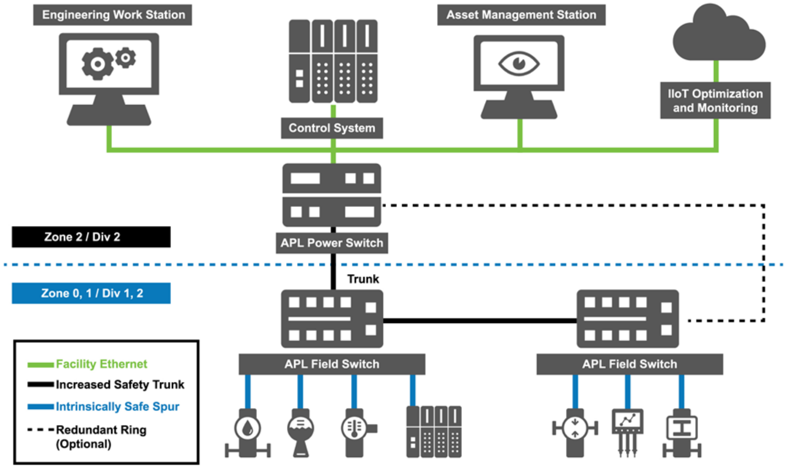

Fig. 15: Ethernet in the field

Ethernet down to the field level uses technologies and options already established in the process automation market. This includes the proven trunk-and-spur topology, as shown in figure 15. It can power up to 50 field devices with a maximum of 500 mW per device intrinsically safe. Widespread and established cable infrastructures are specified to migrate existing equipment for future Ethernet connectivity. The most important functions are highlighted in the following table.

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

Fig. 16: Technical features of Ethernet to the field

4.2 Protection in Hazardous Environments

The methods of ignition protection follow the well-known electrical installations ground rules. The trunk uses the type of protection "increased safety" and is able to transfer the maximum permissible power into the hazardous area.

Intrinsic safety is supported at the spurs. The validation of intrinsically safe connections are similar to FISCO, so that for every connection one simple validation method with no additional calculation is possible.

4.3 Infrastructure

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

- APL power switches provide connectivity between all standard Ethernet networks and field devices and provide the APL field switches and field devices with power. They are typically in the control room or a junction box. Switches and power supply can also be configured in a redundant layout.

- Field-level APL switches are designed for installation and operation in explosion hazardous areas (typically zones 1 and 2 or division 2). Usually they are powered by the APL power switch and distribute both the communication signals and the electrical energy via spurs to the field devices.

4.4 Instrumentation, Actuators and other Field Devices

Field devices with APL interface allow easy integration into higher-level systems. Manufacturers can simply integrate APL into their existing product portfolio, for example in level and flow meters, temperature and pressure transmitters, valve positioners or analyzers for liquids and gases.

The APL technology also provides a simple connection in hazardous areas for novelty devices such as IP cameras and wireless access points, allowing timely and comprehensive monitoring for maintenance and troubleshooting.

4.5 Simple Devices and Installed Base

Potential-free contacts, proximity switches, temperature sensors, simple solenoid valves and other monitoring equipment often require a connection to higher-level control systems. For some of these components Ethernet connectivity may not be necessary or economically justifiable. For such applications, remote I/O systems provide a gateway for the future.

Field devices with two-wire Ethernet connectivity will become the standard. The migration of older devices to the new technology is going to be easy because the basic Ethernet infrastructure already exists. All the certified installation and operational solutions in potentially hazardous environments can also be operated with the future Ethernet all the way to the field level.

4.6 The APL Ecosystem

APL is a significant investment by industry partners, such as manufacturers of field devices, suppliers of automation systems and suppliers of infrastructure components. They all share the same vision of a single, common and transparent physical layer for the Ethernet in the area of process automation. With APL communication based on established IEEE and IEC standards, which is certified for every region of the world a broad market acceptance is anticipated.

APL is a fundamental technology that allows a broad and innovative product development. From engineering offices to module- and plant constructors, from service providers and data suppliers to the end user everyone benefits from the digitization of process equipment.

With their ability to provide Ethernet communication with a single supply over a two-wire cable, the new and easy-to-use physical layer will enable a completely new generation of field devices and infrastructure components that simplify process technology and allow completely new applications. One would recognize practically no boundaries.

5 Accompanying Technologies and Measures

5.1 Uniform Device Integration through FDI

The duplication ends

A situation of this type is to be avoided for PROFINET through the new FDI technology according to IEC 61804, for which the first tool was introduced at the 2015 Hanover Fair. The FDI technology combines the strengths of the two previous technologies, adds the harmonization of the EDDL dialects and is optimized for uniformity of the host representations. There is exactly one device package for each field device (device package, figure 16). This is a binary coded file containing a description of the data and functions of the device based on the latest harmonized EDD description language together with the description of the user interface (UI) and optional appendices. "Common FDI host components" ensure that device integration packages are processed the same in various FDI hosts. A cross-protocol development environment is available for developing FDI device packages for PROFIBUS, PROFINET, FOUNDATION Fieldbus H1, and HART devices.

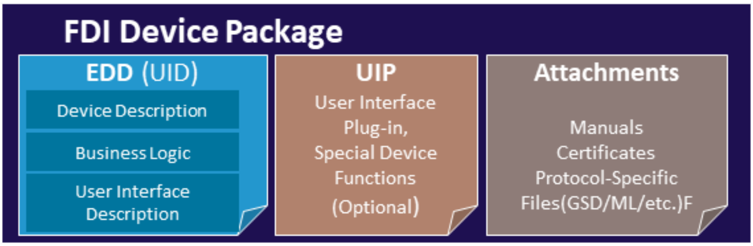

Fig. 17: The FDI technology building blocks

5.2 'Certified People' Assure the Introduction of PROFINET in PA

Worldwide uniform training by PI

Devices, systems, and plants can only deliver their full performance with professionally trained staff. This requires thorough education and periodic training for developers and planners, and operating and maintenance personnel. PI has offered this for decades in the form of training courses and technology workshops for engineers and technicians. Participants receive a certificate on successful completion. The course providers, namely PI Competence and Training Centers, are periodically audited. This ensures high quality and uniform training standard worldwide.

This offer, which the market makes intensive use of, is based on the PI network spanning the globe about 25 Regional PI Associations (RPAs), more than 30 Training Centers (PITC) and about 10 PI Test Labs, and 60 Competence Centers (PICC) in 2018, which enables the local training of users "close to home". The network bundles the comprehensive expertise of almost 1,500 member companies and the practical experience in automation technology accumulated over 25 years and makes both available to attendees in the training courses.

'Certified People' for PROFINET in the PA

The global PI training infrastructure is used for all technologies developed and supported by PI and increasingly for PROFINET in process automation. Specific plans exist to expand the long-standing program of PROFINET courses with topics for use in process technology. Likewise, the proven training program for PROFIBUS DP and PROFIBUS PA will be expanded to include add-on blocks from the PROFINET world. As a result, courses will be offered for new users in addition to advanced courses for already certified engineers and technicians. The goal of this "qualified personnel concept" is to enable users of PROFINET in process automation to make use of the new technology and its technical and economic benefits as quickly as possible.

6 Summary

Purposefully developed, proven, future-proof, and easier than 4...20 mA

PROFINET is the logical technological advancement of the successful PROFIBUS fieldbus into today's leading communication technology based on Industrial Ethernet. This enables a cost-effective migration to PROFINET due to the direct reuse of knowledge and the option for an incremental approach. Reasons for this migration are as follows:

- PROFINET is a global industry standard and is 100% standard Ethernet, which enables use of all web technologies.
- PROFINET has proven itself for years in factory automation and in machine building, thereby ensuring a high level of operational reliability.
- PROFINET has placed a very high value on user expectations regarding ease of use and has significantly surpassed the highly-praised conventional 4...20 mA standard.
- Through the use of proxy technology, PROFINET allows reuse of existing plant systems and thus provides excellent investment protection.
- Based on its network and diagnostics management, PROFINET provides optimal solutions for key issues of the process industry such as easy device handling and detailed diagnostics from devices and the network.
- PROFINET is switched Ethernet and thus satisfies the demand of process industries for flexible plant topologies spread over a wide area.
- Through high-performance redundancy solutions, PROFINET ensures a very high availability of the plant. The availability can be scaled to suit the requirements of the user.
- PROFINET implements seamless horizontal and vertical integration for data and information.
- PROFINET enables transmission of large data quantities in real-time, thus paving the way for future tasks in connection with the Internet of Things.
- PROFINET and its associated functions are explicitly specified, which ensures the interoperability of devices of different manufacturers.
- PROFINET will support the new physical layer for two-wire Ethernet and thus also find application in the Ex area.

PROFINET as a solution platform for process automation timely provides all technology and tools required by process industries to fulfill the need for integrated automation of plants based on Industrial Ethernet. The major first step is the application PROFINET in new process automation plants and new plant sections with tools for integration of the installed base of 4...20 mA, PROFIBUS PA, and other bus systems. Technologies for a horizontally and vertically integrated PROFINET automation solution for process technology will be developed in the near future. All steps allow the further, improved integration and use of digitally available information and make a significant contribution to further increasing the efficiency of companies and therefore their competitive position in the market place.

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