

PROFINET
Commissioning

Guideline
for PROFINET

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Prepared by PI Working Group PG3 "Installation Guides PROFIBUS and PROFINET" in Committee B.

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1 Introduction

1.1 Preface

The aim of this guideline is to support you when commissioning PROFINET systems. It also provides guidance on the verification of the correct installation of PROFINET systems. Moreover, this commissioning guideline helps with detection and location of possible errors. As a result, this guideline addresses topics relevant not only to commissioning staff but also to service personnel.

The information is presented in an easy to understand format. You will nevertheless need some PROFINET experience when commissioning or troubleshooting a PROFINET system. Additionally, some experience in planning PROFINET systems is considered as useful. Certified PROFINET training is provided by accredited Training Centers PITCs across the world and is highly recommended for those involved with all technical aspects of PROFINET.

This guideline does not deal with PROFINET planning and installation. Please refer to the “PROFINET Installation Guideline” (Order No.: 8.072) and the “PROFINET Design Guideline” (Order No.: 8.062) for details of these subjects. Also, the PROFINET operational principles are beyond the scope of this document. If such information is required, please see the appropriate documents published by PROFIBUS Nutzerorganisation or comparable technical literature.

This Commissioning Guideline does not replace any previous documents. It is intended as an application-oriented complement to the other guidelines. The previous PNO documents therefore continue to be valid.

1.2 Safety instructions



The use of the PROFINET Commissioning Guideline may involve handling hazardous materials or tools or involve dangerous work. Due to the many and diverse applications of PROFINET, it is not possible to take all options or safety requirements into consideration. Each system makes different demands.

In order to competently judge possible dangers, you must inform yourself about the safety requirements of the respective system before starting your work. Special attention must be paid to the laws and regulations of the respective country in which the system will be operated. You shall also observe general health and safety requirements of the company for which the system is being installed.

In addition, the manufacturer supplied documentation for the PROFINET components used must be considered.

1.3 Liability exclusion

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This document has no normative character. It may be useful in certain operating environments, in certain technical constellations or when used in certain countries to deviate from the given recommendations for action. In this case, the installer and operator of the installation should weigh up the advantages and disadvantages of the recommendations made in the specific application and, if deemed appropriate, decide on the implementation of a different solution if necessary.

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1.4 PNO documents

[APL2021] Ethernet-APL Engineering Guideline

Order No.: 8.122, Version 1.11, Dec. 2021

[APS2021] Ethernet APL Port Profile Specification

Order No.: 2.662, Version 1.0, June 2021

[EMI2021] Functional Equipotential Bonding and Shielding of PROFIBUS and PROFINET

Order No.: 8.102, Version 3.1, Sept. 2022

[PNO2022] PROFINET Installation Guideline

Order No.: 8.072, Version 2.12, Sept. 2022

[PND2022] PROFINET Design Guideline

Order No.: 8.062, Version 1.53, Sept. 2022

[PSD2018] PROFINET System Description - Technology and Application

Order No.: 4.132, Version: November 2018

[PCI2021] PROFINET Cabling and Interconnection Technology

Order No.: 2.252, Version 5.0, May 2021

[PLM2008] Physical Layer Medium Dependent Sublayer on 650 nm Fiber Optics

Order No.: 2.432, Version 1.0, January 2008

1.5 Referenced standards

This document refers to:

[IEC 61918]:2018

Industrial Communication Networks - Installation of communication networks in industrial premises.

[IEC 61784-5-3]:2018

Industrial communication networks - Profiles - Part 5-3: Installation of fieldbuses - Installation profiles for CPF 3

[ISO / IEC 11801-1]:2017

Information technology - Generic cabling for customer premises – Part 1: General requirements

[IEC 60793-1-40]:2019

Optical fibers - Part 1-40: Measurement methods and test procedures - Attenuation

[IEC 61300-3-4]:2012

Fiber optic interconnecting devices and passive components - Basic test and measurement procedures - Part 3-4: Examinations and measurements – Attenuation

[IEEE P802.3cg]: 2019

IEEE Standard for Ethernet Amendment 5: Physical Layer Specifications and Management Parameters for 10 Mb/s Operation and Associated Power Delivery over a Single Balanced Pair of Conductors

1.6 Symbols and their meaning

This document contains various images intended to help the reader understand the text. Additionally, symbols are used for structuring the text. These symbols mark especially important passages in the text or combine text to form text sections.

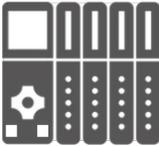
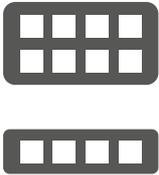
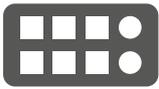
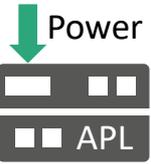
1.6.1 Symbols for structuring the text

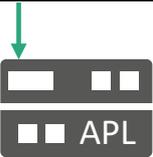
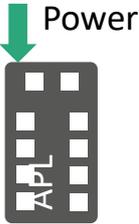
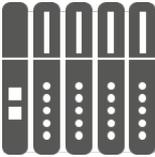
Table 1-1: Symbols for structuring the text

Symbol	Name	Meaning
	Tip	Used to mark a recommendation and / or summary of the current topic.
	Important	Used for information which, if not observed, may result in malfunctions during operation.
	Instruction	Used for direct instructions.
	Danger!	Used to mark a danger to life and health. The observance of an instruction marked in this way is extremely important!

1.6.2 Symbols for components

Table 1-2: Symbols for components

Symbol	Name	Meaning
	Operator console	Command and control station
	Supervisor	An engineering station or PC with commissioning and diagnostic functions for PROFINET
	Controller	A device (typically a control unit) that initiates the IO data traffic.
	Switch	Device for the interconnection of several PROFINET devices. Eight respective four ports for copper media.
	Switch	Device for the interconnection of several PROFINET devices. Six ports for Copper-Media plus two ports for fiber optic media
	APL power switch	Ethernet switch. Converts Industrial Ethernet to Ethernet-APL. Needs auxiliary power to power the subordinate APL network. Indicated by thick amber arrow.

	<p>APL switch with unpowered trunk¹</p>	<p>Ethernet switch. Converts Industrial Ethernet to Ethernet-APL. Does not power the subordinate APL network.</p> <p>Note: This device might need auxiliary power for internal supply. This is indicated by thin amber arrow.</p>
	<p>APL field switch without auxiliary power supply</p>	<p>This Ethernet-APL field switch connects to the APL Trunk to Ethernet-APL field devices (Spurs) and provides power for the APL field devices connected to the switch. Receives energy via a powered trunk</p>
	<p>APL field switch with auxiliary power supply</p>	<p>This Ethernet-APL field switch with auxiliary power supply connects the Industrial Ethernet with the Ethernet-APL field devices (Spurs) and provides power for the APL field. The switch is connected to auxiliary power and does not receive power either via the unpowered APL trunk nor the industrial Ethernet.</p>
	<p>Device</p>	<p>A locally assigned field device that is allocated to a PROFINET controller. This can be e. g. a remote IO, a drive or a panel display</p>

¹ Not yet specified in [APS2021]. Subject to future development

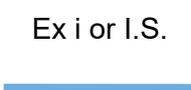
		
 <p>APL</p>	<p>APL field device</p>	<p>APL field device, (e.g. temperature transmitter, pressure transmitter, flow transmitter, positioner), with Ethernet-APL interface. Device is powered and communicates via Ethernet-APL. Transmitters with external power supply (four wire transmitters) are possible, but will not be handled separately</p>
	<p>WLAN / WiFi access point</p>	<p>A device that allows changing over from wired to wireless communication. The description WLAN access point will be used in this document</p>
	<p>Diagnostic PC</p>	<p>A PC used for diagnosis and monitoring.</p>
	<p>Device with WLAN</p>	<p>Local field device with WLAN.</p>
	<p>Media converter</p>	<p>Converter from one physical medium to another.</p>
	<p>TAP</p>	<p>Abbreviation of “Test Access Point”.</p> <p>Device for reading the network traffic without causing any impact</p>
	<p>Video camera</p>	<p>Device for image-based monitoring (Non real time communication)</p>

	Control station	Standard PC (Non real time communication)
	Server	Server computer, e.g. for backup tasks. (Non real time communication)

1.6.3 Symbols for PROFINET cables

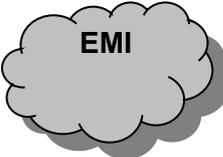
Table 1-3: Symbols for PROFINET cables

Symbol	Name	Meaning
	Standard Ethernet	Standard Ethernet connection which does not involve the PROFINET protocol
	PROFINET cable	PROFINET Industrial Ethernet TP standard cable with copper wires sheath color: green The dotted line indicates a connection with increased determinism requirements.
	FO	Fiber-optic internal cable sheath color: green. Note: for the benefit of a better distinction of copper cables and FO cables the FO cables are illustrated in orange in this guideline, even though the cable sheath is usually green. The dotted line indicates a connection with increased determinism requirements.
APL 	Ethernet-APL cable	Ethernet-APL connection without Ex qualification. The dotted line indicates a connection with increased determinism requirements. Sheath color: not defined
APL Ex e 	Ethernet-APL with increased safety (Ex e)	Ethernet-APL connection that can run in areas with explosive atmosphere. Increased safety (Ex e / non incendive).

		The dotted line indicates an inactive ring redundancy connection for increased availability requirements.
	Ethernet-APL with intrinsic safety (Ex i)	Ethernet-APL connection that can run in areas with explosive atmosphere. Intrinsic safety.
	Conductive link	Electrically conductive link

1.6.4 Symbols for areas

Table 1-4: Symbols for areas

Symbol	Name	Meaning
	EMI	Area where the occurrence of electromagnetic interference (EMI) must be expected.
	Weather	Area in which weather impact must be expected (outdoor area), especially when using a WLAN.

2 Measurement and diagnostic tools



This chapter will introduce some simple diagnostic tools. These tools can help check the correct installation and operation of PROFINET copper cables and fiber optic (FO) cables. The diagnosis of the wireless LAN is also considered. These tests are especially important for the final inspection of the cabling. Moreover, the tools can help detect faults occurring during operation.

Functional test of copper cabling

In the functional test of the copper cabling the network cables are checked using the appropriate measuring instruments. The various testers that are available provide different functionality. Some testers not only check the installation and cable parameters, but also determine both the PROFINET nodes connected to the network and the protocols used. In order to be able to use a cable tester of this kind, it must be possible to connect the tester to the PROFINET copper cable via a RJ45 connector. Additionally, these instruments can be connected through adaptor cables, for example, to be able to measure cables with M12 connector plugs.

Measuring FO cables

The simplest measuring procedure for FO cables is attenuation measurement. This method allows the testing of the FO cable by determining the signal attenuation between two connection points. Some measuring instruments provide additional measuring methods. These methods are more complex than attenuation measurement. However, they provide the user with additional information on the FO cable. As with copper cables, the measuring instrument connectors may vary.



According to IEC 61784-5-3 the check of a PROFINET cabling does only require simple standard measurement devices. The procedures to use such devices will be described briefly.

WLAN measurement

WLAN measurement helps to evaluate the WLAN site and allows troubleshooting.

Diagnosing the PROFINET network

The network analysis plays a major role for PROFINET. This section describes various diagnostic methods and gives recommendations for performing acceptance tests of PROFINET networks.

Diagnosing the grounding and the connections

This type of diagnosis allows evaluating the grounding and connecting equipment of automation plants.

2.1 Measuring the copper cabling

This chapter shows the test options for PROFINET copper cables. In addition to that, some function testers with a different scope of features will be described. A distinction is made between:

- **Simple cable testers (verification),**
- **Function testers (qualification),**
- **Acceptance testers (certification).**

2.1.1 Cable testers

Cable testers have been designed for easy testing of Ethernet installations. The testers available on the market are different in terms of their functions, their functional range and especially their operation. For this reason these instruments cannot be described here in detail.

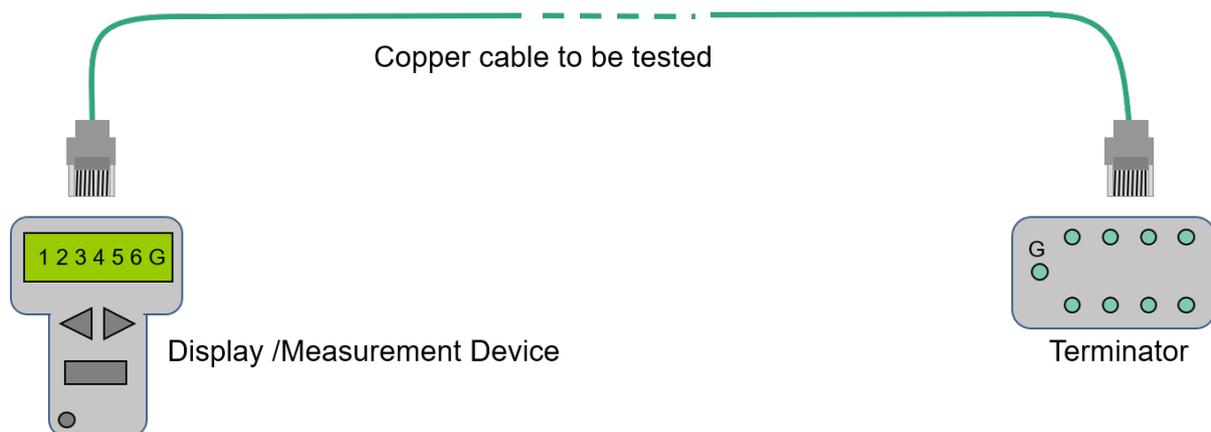


Figure 2-1: Basic test setup for a simple cable test

Figure 2-1 shows the basic test setup for simple cable testing of a PROFINET copper cable. Substantially, this is an electrical cable test, i.e. a test for proper connection or short-circuits and impermissible split pairs. The testers do not verify the cable parameters nor do they check whether data packages are transmitted or not. Testers of this kind can be used in the installation phase to check the cabling for proper connection / short circuits and the connectors for correct pin assignment.



The cable tester presented here is a standard Ethernet tester. No special PROFINET tester is used



The physical layer for Ethernet-APL differs from the 100Base-TX physical layer typically used for PROFINET. A standard Ethernet tester cannot be used to test an Ethernet-APL cable. Use a tester suitable for Ethernet-APL.



When using a cable tester for PROFINET networks made up of PROFINET copper cables (100Base-TX with 2x2 wires), the cable tester will indicate a proper connection for the single conductors 1, 2, 3, 6 and the shielding conductor (G), only. In PROFINET networks acc. to 1000Base-T all wires and the shield must be connected properly. Please note that no wire pair crossing is required for PROFINET as the active network components provide for autocrossover.

2.1.2 Function testers

Whilst a simple cable tester solely checks the cabling for proper electrical connection, a function tester verifies the cabling route under consideration of the aspects of actual Ethernet data transmission.

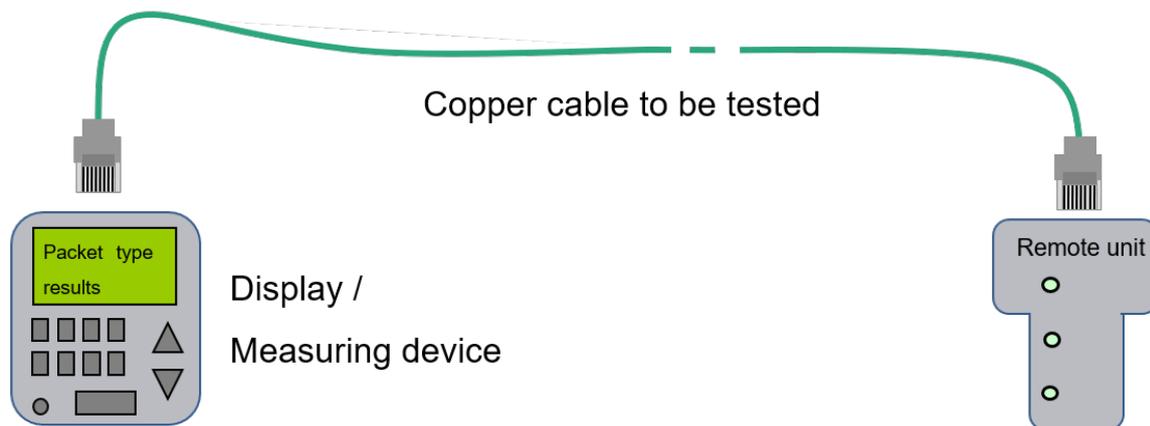


Figure 2-2: Functional test of cabling

This measuring device transmits predefined data packages via the cable. A remote unit acts as the counterpart that responds to these packages.

Alternatively, there are devices that directly verify the transmission parameters relevant for Fast Ethernet transmission at the time level and can indicate the error location in case of time-outs.

Depending on its type the function tester can also identify other active devices like switches or network nodes on the network using the corresponding diagnostic network protocols (e.g. ICMP, see chapter 6.5).

In this case you can derive from the delivered measuring data whether Ethernet data packages can be properly transmitted via the route or not.

2.1.3 Acceptance testers

In special cases it is necessary to perform not only a simple functional test using a function tester, but also a detailed measurement of the cabling parameters (e.g. cable length, attenuation, crosstalk, etc.). Such a measurement allows the determination and documentation of various cable parameters. These measurements are especially helpful if problems should occur after a long operating period, allowing the documented values from the acceptance test to be used as reference values.

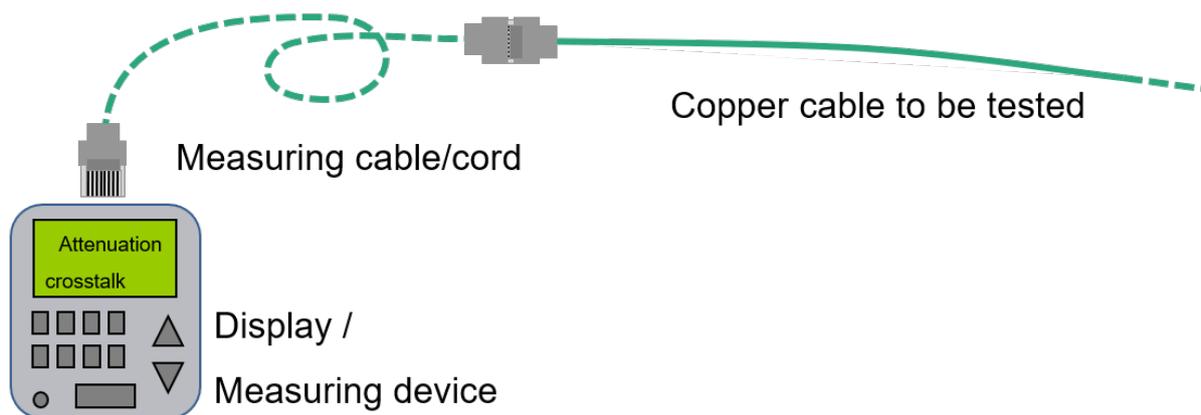


Figure 2-3: Extended acceptance test of cabling

In compliance with the applicable standards and regulations, the cable connector is usually not considered for the measurement. For field-configurable connectors, however, it is recommended to measure the connector itself including the contacts. For this reason special measuring profiles are available for PROFINET which allow the connectors to be included in the measurement (end to end link measurement). Note that with this measuring method you have to use special measuring cords or adaptors if required in order to prevent any unwanted impact on the measuring results.



The PROFINET component approach does not require a mandatory acceptance test for verifying the cabling when using PROFINET components with manufacturer declaration. You can nevertheless perform an acceptance test if you like in order to

- measure and document the cable length,
- measure and document the attenuation and other essential cable parameters.

- check the Power over Ethernet functionality.

This will provide you with reference data that you can use for later cable verifications if required.



Not all acceptance testers provide a PROFINET test profile. Check if your measuring instrument provides the appropriate PROFINET test profiles.



For more detailed information please contact your measuring instrument manufacturer. Read the manufacturer instructions before operating the measuring instrument.



In case the insertion loss of a line segment is less than 4 dB at the measured frequency, the measurement values for the near end cross talk (NEXT) has only informative value. This issue is known as the 4 dB rule. Especially when dealing with short cables the insertion loss will be usually smaller than 4 dB.



Ethernet APL defines a two-wire cable to connect sensors and actuators to PROFINET. Please note that the cable parameters differ from the PROFINET cable used for the 100Base-TX with 2x2 wires. Please check the Ethernet-APL Engineering Guideline [APL2021] for further details on Ethernet APL cabling and cable parameters. A standard Ethernet tester cannot be used to test an Ethernet-APL cable. Use a tester suitable for Ethernet-APL.

2.1.4 Summary



It is important to mention that the measuring instruments normally used for Ethernet networks are suitable for this purpose.



Applying cable testing methods

For simple applications (e.g. link testing in the installation phase) simple cable testers will do. Acceptance tests, however, require more advanced instruments which not only measure all the specific parameters (e.g. attenuation, crosstalk, etc.) of a link, but also document the measured values.

Find out which measurements you can perform on your own and for which measurements it might be necessary to employ an external service company.

Increasingly complex measuring instruments, high training requirements and the required experience with these measuring instruments may be good arguments for purchasing external services.

2.2 Measurement of FO cables

This chapter describes the options for evaluating your FO cabling. Please note that the PROFINET component approach described in chapter 2.1 is also valid here.

2.2.1 Attenuation measurement of FO cables

The most important measurement variable of a FO cable is the attenuation of the fiber. This measurement is performed through the insertion loss measurement (Figure 2-4). This measuring method determines losses in the optical fiber and/or its connections. Light is inserted via reference fiber 2 into one end of the fiber. At the other end a calibrated receiver is connected via reference fiber 1 to the fiber to be tested. The receiver measures the received light quantity and determines the losses occurred. The attenuation or insertion loss is usually specified in dB. Reference fiber 2 (at the sender) is wound with several winds on a mandrel with a defined diameter. The so formed mode mixer causes the correct distribution of light in the reference fiber and avoids the emission characteristic of the transmitter from influencing the measurement result.

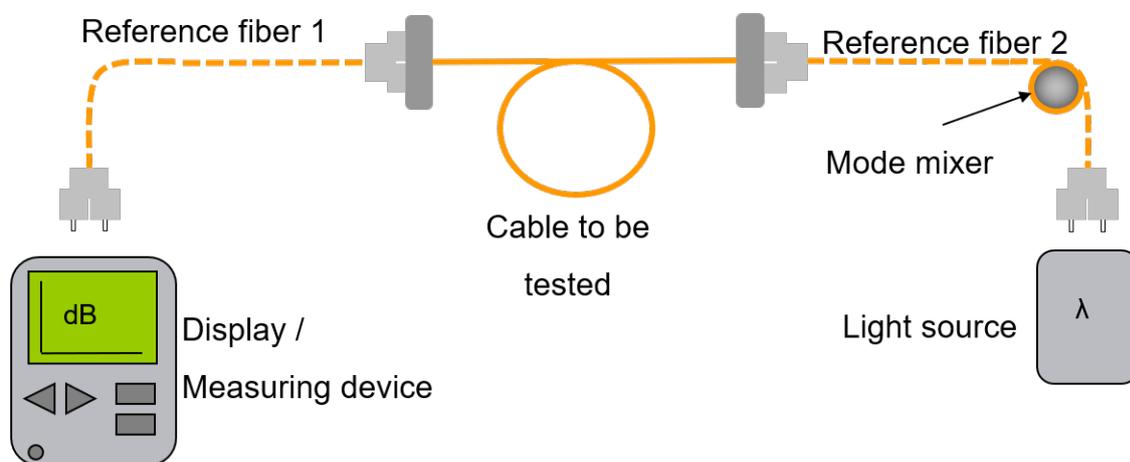


Figure 2-4: Attenuation measurement principle

The following basic criteria are valid for evaluating an FO cable:

- Which fiber type has been used? (single-mode fiber, multi-mode fiber, hard cladded silica, plastic optical fiber)
- Which connector type is used?
- What is the approximate length of the cable route?

How much the signal is attenuated by the individual PROFINET fiber types depends on the fiber types used. For details see Table 2-1 which shows the permissible limit values and the wave length used for operation.

Table 2-1: Maximum permissible attenuation values for a FO-cable PROFINET end to end link

	Single-mode glass fiber	Multi-mode glass fiber	PCF fiber	POF fiber
Typical wavelength	1310 nm	1300 nm	650 nm	650 nm
Max. permissible end to end link attenuation	10.3 dB	62.5/125 μm : 11.3 dB 50/125 μm : 6.3 dB	4.75 dB	12.5 dB

The measurement is performed in two steps. The first step involves calibrating the measurement setup of the tester. To calibrate the tester, the two reference fibers shown in Figure 2-4 are connected directly to each other and a reference measurement is taken. The receiver measures and stores the light power of the received light as a reference value for a line without any attenuation.

In the second step the reference fibers get disconnected and the fiber to be tested gets inserted. The tester performs the measurements of the actual fiber being tested and the received light power is then compared to the reference value; the difference is displayed as the attenuation of the fiber.

Deficiencies at the connectors or reference fibers influence the result of the measurement. Therefore only selected components can be used as reference fiber, where the connectors should have a more or less ideal characteristic. Especially the connector polishing, which must be of a very high quality. It is recommended to use the reference fiber for a maximum of 500

reference measurements. After this, the connectors must be re-polished. Handle the reference fiber with special care and check the fiber end surfaces approximately after every 20th measurement for possible damage. After 2000 reference measurements the reference fiber should be replaced. Please follow the manufacturer instructions. For more information and explanations please refer to the IEC 60793-1-40 and IEC 61300-3-4 standards.



To connect to the fiber to be tested, only special reference fibers may be used. These must be purchased as reference fibers from the vendors. It is recommended to mark the reference fibers accordingly and record the fibers used in the test protocol.

The measurement must be performed at the same wavelength that is to be used in the plant installation and with a measuring receiver corresponding to the transmitter. Transmitter, receiver and the FO-cable must all be matched.



The specified limits for the maximum end to end link attenuation include a reserve. But please consider possible measurement tolerances and tolerances of your measurement equipment. These tolerances have to be included when considering the maximum allowed end to end link attenuation.



Please consider that the comparatively high attenuation of Plastic Optical Fibers (POF) in conjunction with multiple connectors will reduce the maximum distance of the fiber optical connection.

Please observe the directions in the PROFINET Planning Guideline, Order No.: 8.062.

2.2.2 OTDR measurement

Besides the attenuation measurement (insertion loss measurement) there is a second measurement method for FO cables called OTDR measurement (OTDR = Optical Time Domain Reflectometer). This method can be used to locate the location of faults in a FO cable link.

The OTDR injects a signal into the fiber by using a launch fiber. At the end of the cable route a receive cable is connected. In order to minimize measuring errors, the launch and receive cables must correspond to the measured FO cable.

A fraction of the signal will be reflected from any connections or any defects or faults along the FO cable. The OTDR can be used to measure the amplitude and delay of the reflected signal. The reflected signal amplitude shows the severity or expected influence of the reflection and the delay can be used to determine the location of the reflection generating fault.

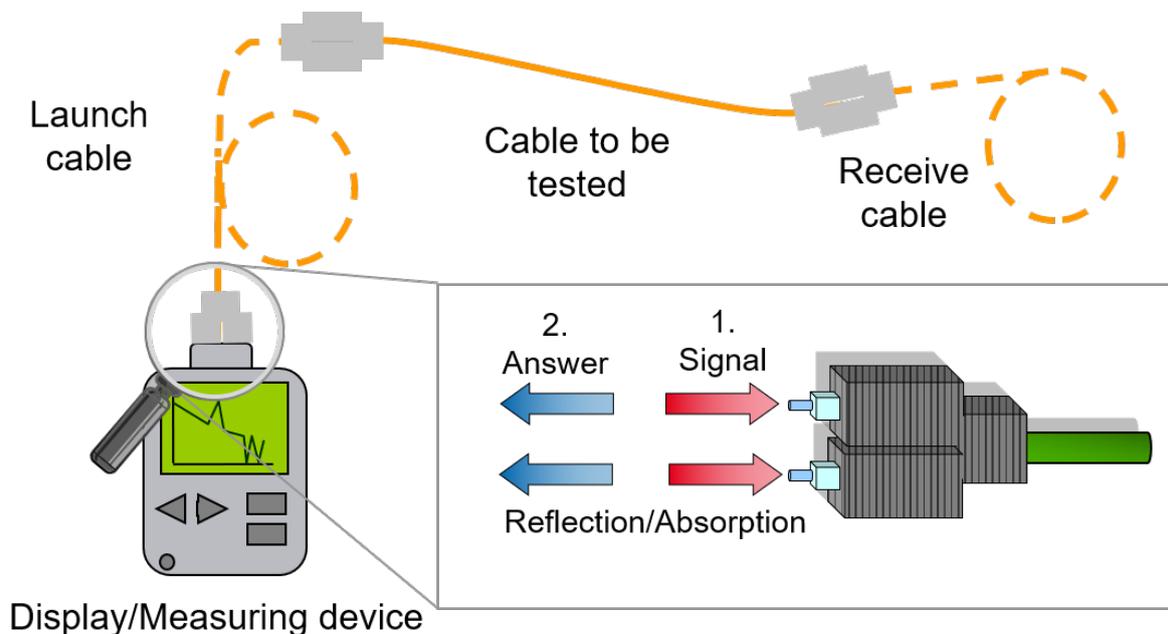


Figure 2-5: OTDR measuring principle

The evaluation of the measurement results requires some experience as the results are not indicated as plain text messages. Usually, the measuring results are indicated as graphics. Figure 2-6 shows an example of measurement results to be interpreted.

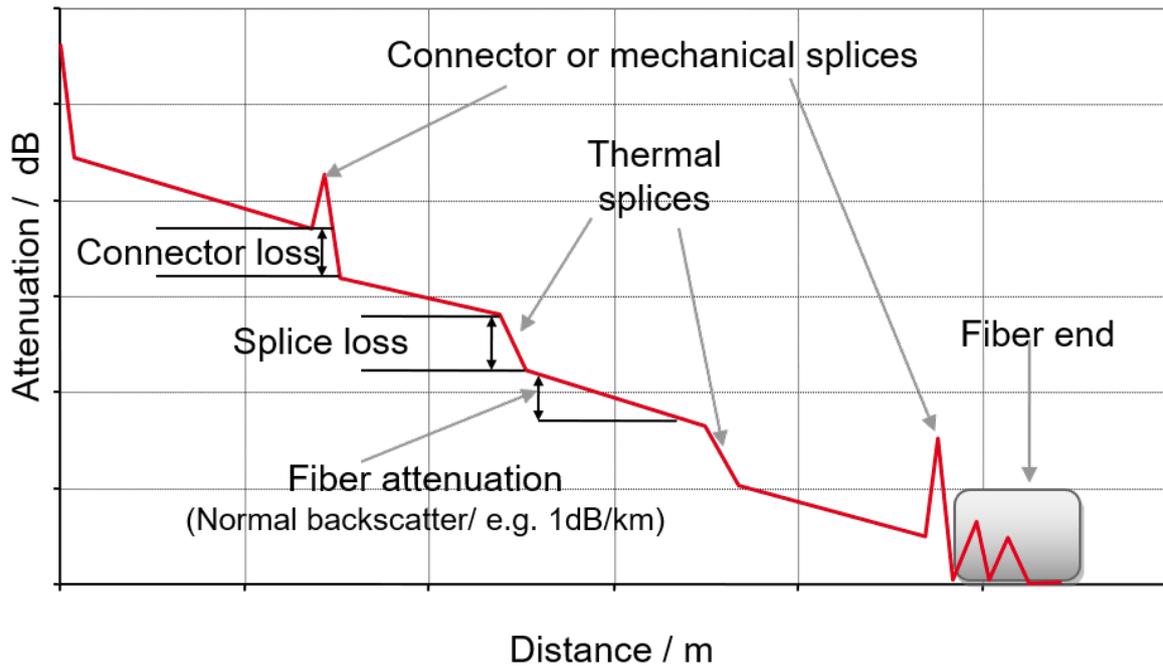


Figure 2-6: OTDR measurement, example

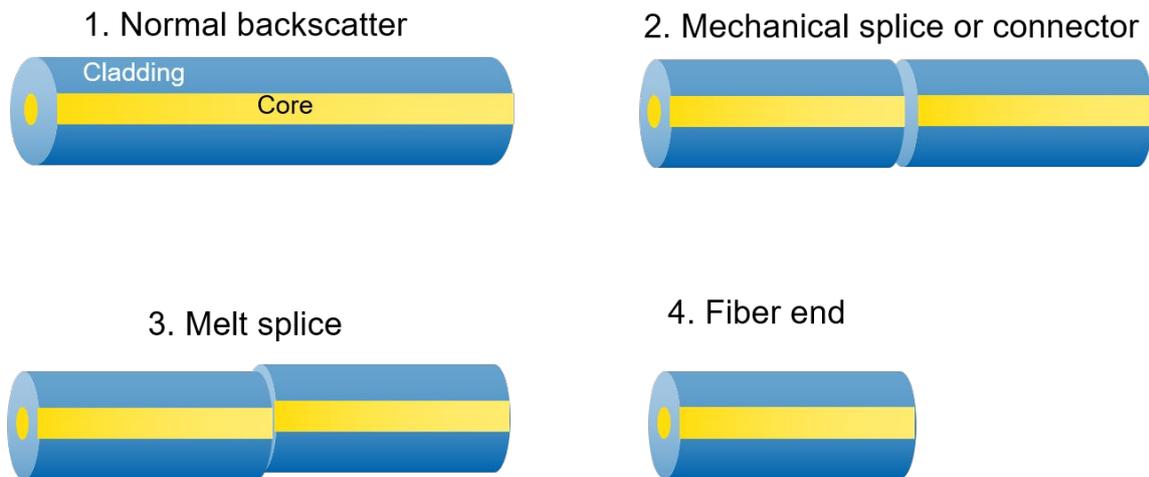


Figure 2-7: OTDR fiber setup

Figure 2-7 shows typical fiber connections and a fiber end. These typical optical fiber connections may show various impairments that can considerably affect the transmission behavior. These impairments may result in backscattering and additional attenuation. The impairments may be due to splice connections or to direct damage of the fiber itself caused by excess bending, ruptures or cracks. Each of the impairments listed above causes its own typical reflection characteristic and, thus, can be directly identified and analyzed during the OTDR measurement.

2.3 Diagnosing the PROFINET network

PROFINET allows for more extensive networks and more flexible topologies when compared to conventional fieldbuses. As a result the diagnosis and monitoring of the network infrastructure are getting more and more important.

In addition to the existing Ethernet diagnostic functions PROFINET provides supplementary standardized network diagnoses. These diagnoses can be downloaded using either the engineering tool or a web server that is usually directly integrated in the components.

2.3.1 Communication and Peripheral errors

It is useful to divide faults on PROFINET systems into communication errors and peripheral errors.

Communication errors are concerned with the network and can include faulty wiring or connectors, water ingress, incorrect topology, wrong device name or IP address, excessive network loading etc.

Peripheral errors are concerned with the device inputs and outputs (sensors and actuators). Peripheral errors can include faulty sensor or actuator wiring, loss of output power or even mechanical problems such as a sticking valve etc. Peripheral errors do not affect communications.

PROFINET provides extensive and standardized diagnostics that can report and locate many peripheral errors. Peripheral errors are normally detected by the device and are reported using PROFINET alarms.

Communication errors can also be reported by the devices, but also managed switches and other network components can report communication errors.

2.3.2 Diagnostic functions in the engineering tool

Various engineering tools allow checking specific items.

Among these are:

- Calculation of cyclic PROFINET network load.
- Checking of the topology (accessibility of nodes, connected ports and matching of the planned and actual topologies).
- Firmware revision level and the operating condition of components.

Such items can help in the diagnosis of communications errors.



It is normally possible to obtain diagnostics and determine values directly from the engineering tool.

2.3.3 Diagnosing a PROFINET device

PROFINET provides a comprehensive diagnostic concept without requiring additional tools. The devices automatically indicate errors or important events by alarm messages.

Besides the standard diagnostic information provided by the PROFINET devices themselves (alarm messages), status information can be obtained by reading such data from the devices using standardized mechanisms (SNMP, PDev) at any time via an engineering tool.

Often the device vendors will also offer a web server for directly accessing the data via a commercial browser. Usually, the web server of a device can be accessed via the device IP address.

Example To access the web browser of a device with the IP address 192.168.0.2, enter “192.168.0.2” or “http://192.168.0.2” in the web browser address line. Any web browser can be used.

Special statistics in switches, including those integrated in the devices, are very important for the acceptance test and routine maintenance of PROFINET networks. The following information can usually be read:

- the transmitted data volume

- the number of rejected packets
- the operating condition of switch ports (transmission rate, full/half duplex)

Such information can help to diagnose communication errors.



PROFINET devices provide diagnostic data as a standard; usually you can read this data directly via a web browser by entering the device IP address.

2.3.4 Diagnostics using an analysis tool

Compared to the diagnostic functions implemented in the devices themselves, analysis tools can provide additional advanced diagnostic options.

Possible diagnostic functions are:

- Determination of the network load
- Determination of the network load composition (ratio of real-time and non real-time communication, etc.)
- Analysis of the PROFINET communication cycle with a high time resolution
- Data traffic statistics
- Recording of data traffic
- Recording and evaluation of communication problems
- Configuration and status analysis



Diagnostic tools with special software and hardware allow for a deeper and more detailed network analysis.

In general, we distinguish between passive and active diagnostic methods, which may also be combined if required.

With passive diagnostic methods the data traffic is recorded and evaluated without causing any impact, whereas with active diagnostic methods the network is analyzed by reading data from the PROFINET devices and network components. An active diagnosis potentially provides a wider range of functions. However, with this method the possible impact on the communication has to be considered. Pay special attention to the explanations in the chapters 2.3.4.1 and 2.3.4.2 below.

With both methods you can perform not only temporary network diagnoses, for example for acceptance testing or troubleshooting, but also permanent monitoring.



Permanent monitoring allows early detection of communication and configuration problems and helps to prevent system downtime.

2.3.4.1 Passive Diagnosis

For passive diagnosis the data streams transmitted in a network must be collected and analyzed in an appropriate location with no impact on the communication. There are two options:

- Port mirroring
- Test Access Point (TAP)

With **Port mirroring** the switch mirrors the data streams of a selected port to a monitoring port. This allows analysis of the data streams on the monitored port using an analyzer connected to the mirror port, as shown in Figure 2-8.

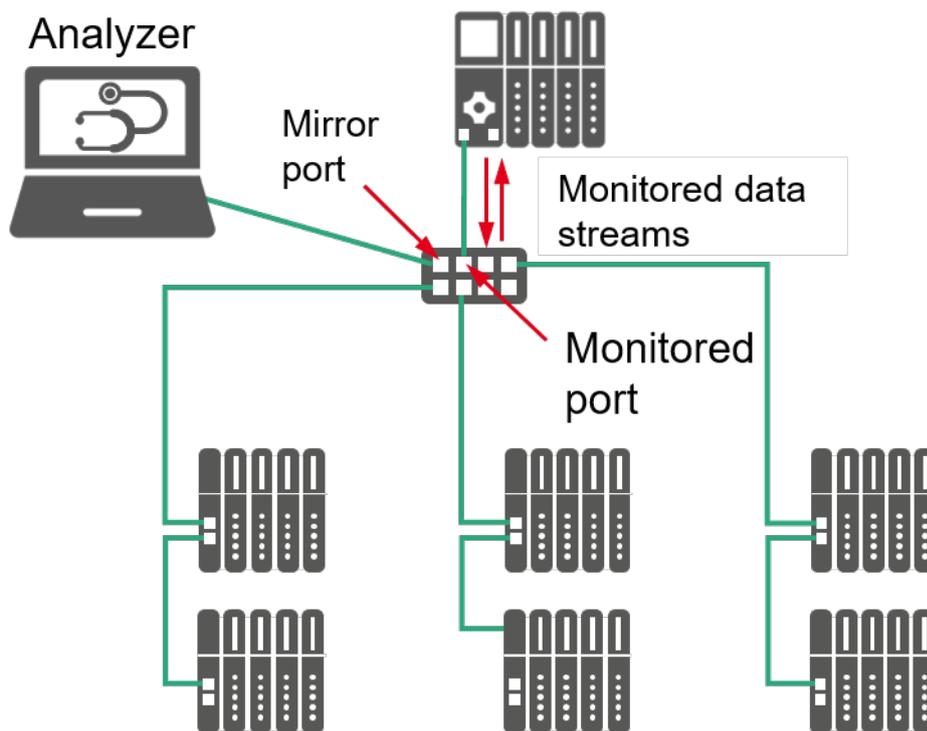


Figure 2-8: Reading data traffic by port mirroring

The switch that is used must support port mirroring. Both the transmitted and received data of the monitored port are copied to the mirror port. The mirror port's data rate thus limits the data volume that can be analyzed. The total volume of incoming and outgoing data must not exceed the data rate of the monitoring port. Note that data cannot normally be written to the mirror port that is it can only be used as a monitoring port. Some tools may therefore require connection to two ports on the switch: one mirror port for monitoring and one normal port for writing data to the network devices.



Port mirroring provides a simple method for reading data streams.

The used switch must support port mirroring, and a free port must be available on the switch.

Only data that passes through the switch can be collected. Which data streams can be recorded depends on the installation location of the switch.

The data packets output at the monitoring port may be differentiated from the initial packets by their structure (VLAN tag) and time assignment.



The physical layer for Ethernet-APL differs from the 100Base-TX physical layer used for PROFINET. Therefore, it is not possible to connect a laptop with a diagnostic tool directly to an Ethernet APL Port. The diagnostic PC needs to be connected to a 100Base-TX port in the connection between the APL field switch and the controller instead.

A **TAP** (abbreviation of “Test Access Point”) is used to take out the data stream to be analyzed without the limitations regarding the data rate and change of packet contents known from the port mirroring method. The TAP, as shown in Figure 2-9, is inserted directly into the network link.

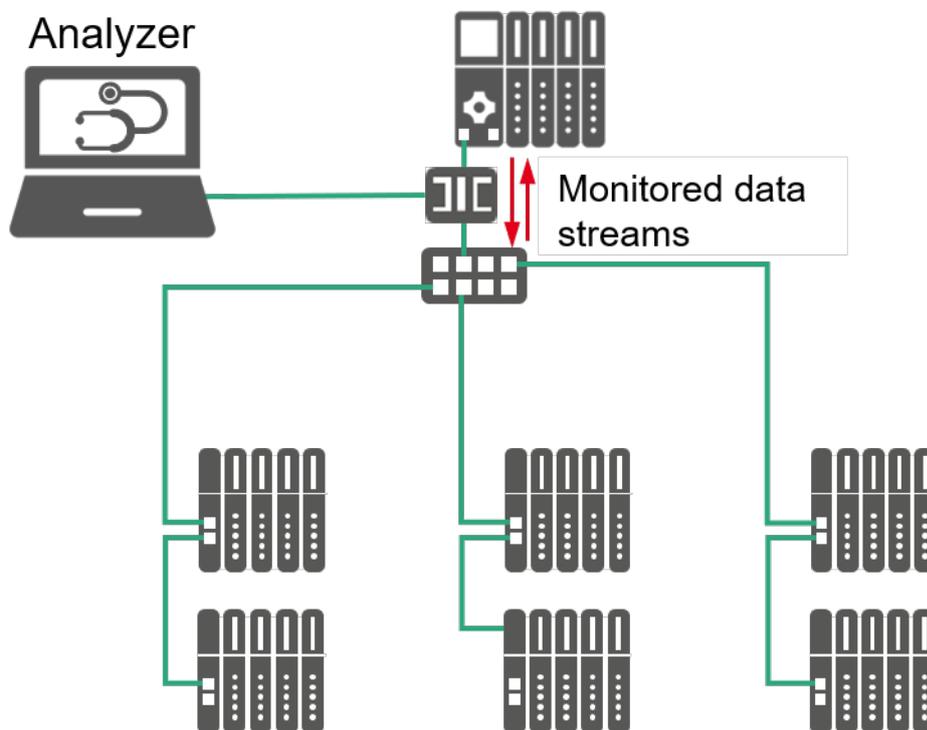


Figure 2-9: Reading data traffic through a TAP



A TAP allows reading out data streams without the limitations in terms of the data rate and change of packet contents implied by the port mirroring method.

It is, however, required to open the network link to be able to insert or remove the TAP.

Only the data stream passing through the TAP can be analyzed.

It is recommended to preferably use passive TAPs as the failure of a passive TAP does not result in the failure of the entire communication link.

If the TAP remains in the network, later diagnoses are possible without the need to open the network link again.



The physical layer for Ethernet-APL differs from the 100Base-TX physical layer used for PROFINET. Therefore, it is not possible to insert a TAP designed for a 100Base-TX signal to an Ethernet APL cable. The TAP needs to be connected to a 100Base-TX port in the connection between the APL field switch and the controller instead.

2.3.4.2 Active Diagnosis

The analysis of diagnostic data and statistics in the PROFINET devices require active polling of these components.

Examples are:

- Statistics in switches (see chapter 2.3.3)
- Neighborhood information for determining the topology
- Polling of status information (error memory, firmware revision level, etc.)

The active reading of component data, however, generates additional network traffic.

Active data reading is, thus, not suited for data stream analyses with high time resolution. In this case you should prefer the options for data stream analyses described in the previous chapter (data collection through a TAP).



The active diagnostic methods used by the engineering systems and tools allow for a comprehensive network analysis.

Actively polling the component will generate additional network load.



Please pay special attention, when using active polling in combination with Ethernet-APL. Due to the data rate of 10 Mbit/s data rate, the impact of the additionally generated network load is higher.

3 Installation acceptance

3.1 Performing the installation acceptance test

The installation acceptance test is performed upon completion of the installation. With the acceptance certificate the technician can document that the installation and planning were performed in compliance with the regulations. We therefore recommend recording the results of the installation acceptance. You can then pass the record to the commissioning staff.

This section describes how to proceed for installation acceptance and how to document the acceptance results. Separately perform an acceptance test and document the results for every PROFINET cable segment. You can find the appropriate templates for the documentation in the appendix.



It should also be observed that the PROFINET acceptance test should consider the ambient conditions specified in the planning phase.

3.2 Acceptance test of passive network components

This section deals with the acceptance of the passive network components. Passive network components are those elements that are basically involved in the network structure - here the PROFINET - but do not evaluate or process the data transmitted on the network.

Among other things, this chapter describes:

- Grounding and equipotential bonding
- Media like:
 - Fiber-optic cables
 - Copper cables
- Connectors
- Labeling of cables and connectors



It is essential to label the network components with a simple, but unambiguous designation.

Make sure that these requirements are met, as a good label will facilitate future work if the system should require troubleshooting.

The following pages give a description of how to verify the grounding and the definition of the PROFINET end to end link as well as of the measurement and verification of the PROFINET copper and FO cables.

3.2.1 Checking the PROFINET cabling

This section describes the first steps for checking the PROFINET cabling. First the description deals with the definition of the PROFINET end to end link then the visual inspection of the PROFINET cabling is detailed.



The planning, installation and commissioning process of Ethernet APL is described in the Ethernet-APL Engineering Guideline [APL2021]. Please check this document for further information on the APL commissioning

3.2.1.1 PROFINET end-to-end link

The end to end link defines a fixed transmission link between two devices (network components or automation units). This is a link between two active PROFINET components. The end to end link itself consists of purely passive components. Figure 3-1 shows the setup principle

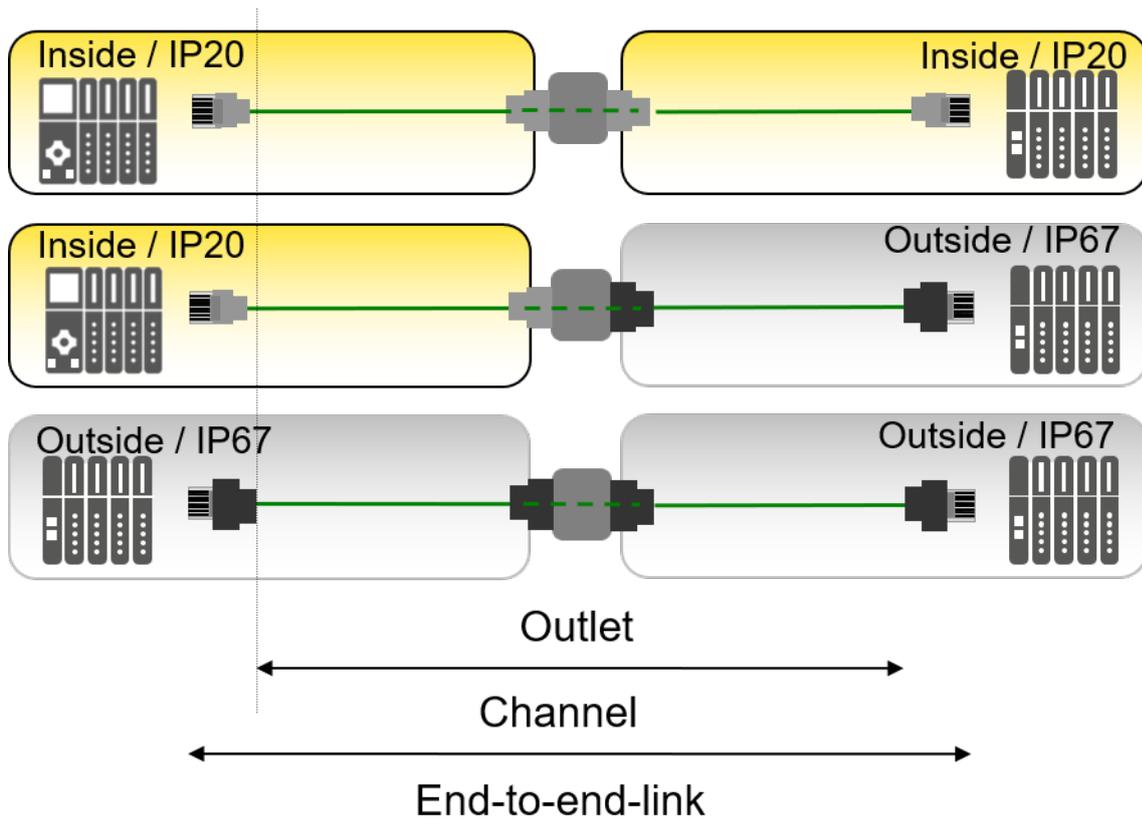


Figure 3-1: Channel / PROFINET end to end link

Using passive network components in accordance with the PROFINET component approach ensures that this transmission link meets the requirements of proper transmission. Passive PROFINET components have been designed specifically for PROFINET in such a way that their mechanical and transmission-relevant configurations satisfy the industrial demands in an optimal way. This fact is documented in the PROFINET component manufacturer declaration.



The PROFINET channel is part of the transmission line which is defined as an end-to-end link. Further the end to end link consists beside of the channel also of all connectors and junctions of the link.

At this the channel can consist of different transmission mediums like copper or fiber optical cables.

The PROFINET component approach considers all connector plug transitions in the transmission link (PROFINET end to end link).

The component approach includes the following rules for setting up a copper PROFINET cable (PROFINET end to end link):

- PROFINET network components are used exclusively.
- A maximum of 4 connector pairs is permitted per end to end link. This includes also the first and the last connector in a line.
- The end to end link length must not exceed 100 m.

Compliance with these rules ensures that the requirements on a PROFINET end to end link in terms of data transmission are met. An acceptance test of the end to end link or PROFINET cabling is not mandatory when using the PROFINET component approach. This is, however, only valid if PROFINET components were used exclusively.



Bulkhead connectors and couplings with two connections are always counted as 2 connector pairs. An exception is made for wall ducts and couplings for which the manufacturer has declared in the manufacturer declaration that they have the performance of a single connection.

An additional acceptance test is useful as part of the documentation for PROFINET cabling.

Note that the requirements of the PROFINET component approach must be met even if an acceptance test is made. An important reason for this is that the functionality and operational reliability of the entire plant must remain ensured even when individual PROFINET components need to be replaced during the product life cycle of the automation system.

If vibrations occur, use PROFINET cable **type B** as the cable type. Due to its low susceptibility to vibration, this cable is particularly suitable for flexible installations.

Acceptance tests to be performed

PROFINET does not use patch cables. As a result, the PROFINET end to end link can be adapted to the application in a flexible manner.

The measuring instruments for the acceptance test must comply with the following basic criteria:

- They must meet the common requirements of the cabling standards (Class D to IEC 11801). Additionally, the more rigid delay skew (20 ns per end to end link) must be measured between the wire pairs in accordance with PROFINET.
- They must be suitable for the measurement of a 2-pair cabling and provide the required measuring accuracy for a cable of 100 m of length.
- They must be suitable for connecting a PROFINET connector plug.

For this special measurement you require an acceptance tester (for certification) as described in chapter 2.1.3.

There are two measuring approaches in terms of the measurement procedures for checking the PROFINET end to end link.

1. The first approach describes the “end to end link” measurement in accordance with the standard. In this case the first and last connector of the end to end link are masked in the measuring instrument using special computing procedures and the performance of the first and last connector is separately evaluated, in parallel with the end to end link measurement. In this case the PROFINET cable is directly connected to the measuring device.
2. The second approach describes the measurement of the PROFINET end to end link using special measuring cables/adaptors to integrate the first and last connector into the functional test. In this case additional fibers are used to connect the measuring device to the fiber

Figure 3-2 gives an overview of the principle described above.

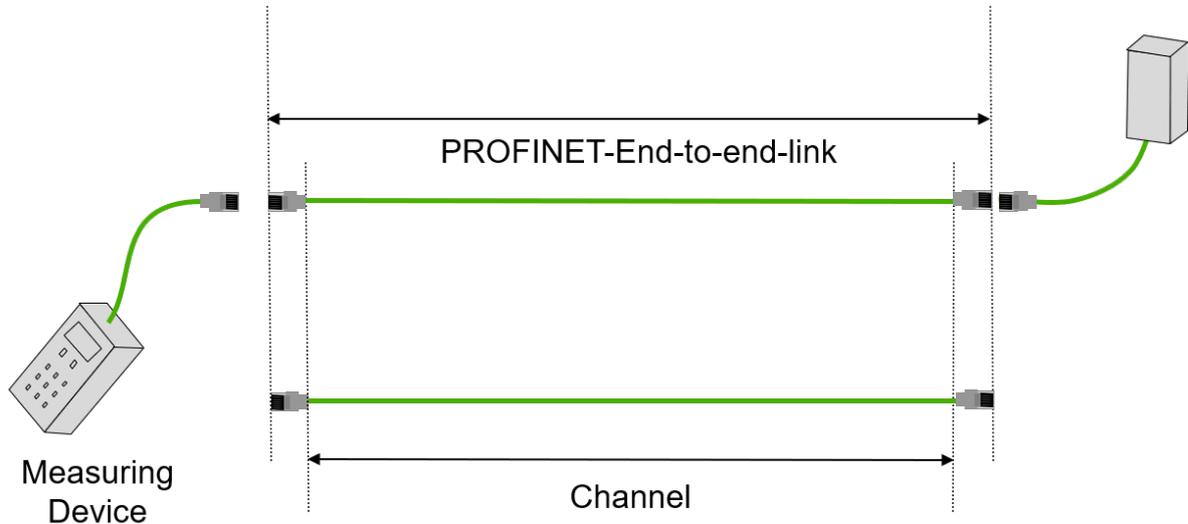


Figure 3-2: PROFINET end-to-end link

With this second method, a slightly higher requirement is willingly accepted for checking the PROFINET end to end link.



Note that not all measuring instruments support acceptance tests of the PROFINET end to end link.



As already mentioned earlier, it may be necessary to use special measuring adaptors or measuring cords, depending on the measuring instrument used. Please contact your measuring instrument manufacturer for details.



When installing your components, also observe the manufacturer declaration which ensures that the PROFINET component approach is complied with. You can find a list of these components on the PNO home page.

www.profinet.com



Please note that the generic end to end link definition also applies to FO cabling, even if the conditions are different in this case. Here, the end to end

link performance must be primarily ensured by the maximum permissible end to end link attenuation.

This is due to the electrical and mechanical properties of FO cables.

The following chapters will detail the differences regarding the measurement.

3.2.1.2 Visual inspection of the cabling

The visual inspection should always be performed prior to all other checks. The visual inspection allows you to provide evidence that the installation has been implemented in compliance with the corresponding installation guidelines. This helps to detect in this phase faults like:

- mechanically damaged PROFINET cables
- Cables that are bent tighter than the specified minimum bend radius
- disregarded minimum spacing
- defective connectors
- missing labels on connectors and cables
- and possible other faults.

Table 3-1 lists various items that should be checked visually. These check items are valid for:

- PROFINET twisted pair cables
- PROFINET optical fiber cables

Table 3-1: Check-list for the visual inspection of PROFINET installations

Step	Action
1.	Cable laid according to plan?
2.	Cable type according to planning?
3.	Maximum 100 m observed for copper cable? (Check, e.g., the length printed on the cable, else make an acceptance measurement)
4.	Maximum number of connector pairs in end to end link observed?
5.	Connector used according to planning (RJ45, M12...)?
6.	Minimum cable length observed or metallic separating strip inserted if necessary?
7.	PROFINET cable undamaged?
8.	Bending radii observed?
9.	Cable junctions right-angled?
10.	Sharp edges at the cableway removed or covered?
11.	No kinks in the cables?
12.	Precautions taken against mechanical damage at critical points? (e.g. bulkhead connectors)
13.	Strain relief built in and fixed?
14.	Cable parameters verified?
15.	Protective caps exist for connectors and links?
16.	Equipotential bonding implemented according to applicable regulations?
17.	Cable shield applied at the PROFINET stations and connected to equipotential bonding?
18.	Cable shield at cabinet entrance connected to equipotential bonding?
19.	Cableways connected to equipotential bonding?

20.	Topology observed?
21.	Links labeled and marked?
22.	Free Ethernet port available for diagnostics connection?
23.	Power distribution wired according to structure plan (Correct assignment of 24 V / 230 V)?
Additionally in case of PROFIsafe installations	
24	Only devices used in network which are IEC 61010-certified (in the EU: CE mark)?
25	Only PROFIsafe devices used in network which are PROFINET and PROFIsafe-certified?

The steps 3, 6, 9, 16 and 17 can be skipped when checking fiber-optic cable links.

The steps 24 and 25 must be performed in plants that have to meet the PROFIsafe requirements. Please refer to the appendix for a check-list that you can use for your visual inspection.

3.2.2 Checking the PROFINET copper cabling

This phase of the installation acceptance consists of checking the electrical functions of the PROFINET copper cable. Use a standardized cable tester for this purpose, preferably with an integrated function for the automatic documentation of the measuring results.

Document the measuring results in the same way as for the visual check, if the instrument does not provide an automatic documentation function. A template for an installation acceptance protocol is available in the appendix. You can then pass the installation acceptance protocol to the commissioning staff.



Please note that an acceptance test is not mandatory for ready-made PROFINET copper cables. It is, however, recommended to nevertheless include this measurement for the sake of completeness of the acceptance test and for documentation purposes, as these documents may be helpful for future troubleshooting and diagnosis of the network.

Some manufacturers of cable testers also offer special software for their instruments which allows you to automatically generate a protocol using a PC. If this option is available to you, this will aid your work considerably.

Table 3-2 provides a check-list in which the measurements to be performed are described.



Generally, the cable testers are not suitable for use in plants in hazardous area.

Table 3-2. Check-list for the test of the PROFINET copper cabling

1.	Visual inspection of cabling
	<ul style="list-style-type: none">- As described in chapter 3.2.1.2.- Maximum number of connectors observed?- etc.
2.	Cable testing for copper cabling
	<p>For this purpose you should use a simple line tester as described in chapter 2.1!</p> <p>The main criteria for evaluation of the cabling are:</p> <ul style="list-style-type: none">- Is there no short circuit between the wires?- Is there no short circuit between individual wires and the shield?- Is there is no wire break?- Is the shield is fully connected?- Has no pair has been separated?

3.	Acceptance test for copper cabling 100 Mbit/s Ethernet(optional)
	<p>Use an acceptance tester as specified in chapter 2.1!</p> <p>This measurement requires instruments with extended functionality which “simple” line testers usually do not provide. This can include the evaluation of :</p> <ul style="list-style-type: none">- cable length (is it below 100 m)- near-end and far-end crosstalk- permissible attenuation values?- potential reflections on the link
4.	Acceptance measurement for copper cabling 10 Mbit/s Ethernet APL (optional)
	<p>For this measurement, measuring devices for Ethernet APL cabling are required. The cable parameters can be found in the Ethernet Port Profile Specification [APS2021].</p> <ul style="list-style-type: none">- Cable length for spurs 200 m for cable category IV. For other cable categories less <p>The cable length for a powered trunk depends on the number of components on the APL segment and their power consumption as well as the cable cross-section See [APL2021].</p> <ul style="list-style-type: none">- Further measurements according to the cable parameters in [APS2021

Description of the steps:

1. Visual inspection of cabling

This primarily comprises the items described in chapter 3.2.1.2 which allow a first evaluation of an already performed installation of copper and FO cables. They are a first indicator for proper functioning of the PROFINET cabling structure.

2. Simple cable testing for copper cabling

These tests are limited to the measurement of the physical structure of the wires, sheath and shield.

Usually, these tests are performed using simple cable testers. The functional range of these instruments is limited to the test procedures already introduced in chapter 2.1. The advantage of this type of measurement is that potential error sources can be excluded using a low-cost tool.

3. Extended acceptance test for copper cabling

This measurement is considered as an extension of the simple testing for copper cabling of PROFINET. The tests performed in this case are usually quite complex measuring tasks that cannot be executed by simple cable testers. Among these tasks is, for example, the evaluation of reflections or attenuation.



Special features of the copper cabling like non-flammability or the adaptation for field mounted connectors could reduce the maximum cable distance of a copper cable.

Please check the manufacturer's information for further details.

3.2.3 Checking the PROFINET optical fibers

The signal transmitted in an optical fiber is attenuated by the connectors, the splices and the optical fiber itself. This is also called the “signal attenuation”. How much the signal is attenuated can be determined by a measurement after the completion of the signal transmission link. This measurement also allows you to check if the optical fiber has been damaged while being laid. The attenuation measurement methods described in chapter 2 can be used for this purpose.

Correct handling of the necessary instruments and the interpretation of the measurement results require special knowledge. If you should work with optical fibers from time to time we only recommend commissioning an external service company with the skills to perform these measurements. If you nevertheless decide to purchase the corresponding measuring instruments, please contact the measuring instrument manufacturer for details about the required equipment.

3.2.3.1 Measuring results of attenuation measurement

If you have commissioned an external service company with this measurement, you will receive a measurement reading from them. In this measurement reading you will find a measured value that will clearly indicate how much the signal of the transmission link is attenuated. The attenuation is specified in dB. The specified measured value must be smaller than the maximum permissible end to end link attenuation as described in chapter 2.2.1 Attenuation measurement of FO cables.

3.2.3.2 Measuring results of OTDR measurement

As already discussed in chapter 2.2.2, the OTDR measurement diagram allows besides the display of the overall attenuation of a line also an evaluation of the attenuation of the individual components like fiber, connectors and splices. This detailed information eases the error diagnostic. It is recommended to archive the OTDR diagrams acquired during the acceptance measurement. In case measurements are performed at a later point in time, the archived OTDR Diagrams allow a comparison and the detection of changes.



The measured attenuation shall not exceed the maximum permissible PROFINET FO end to end link attenuation according to Table 2-1.

3.2.3.3 How to proceed for measuring optical fibers

This chapter lists the most important criteria for evaluating the measuring results, similar to the relevant chapter for copper cable acceptance.

It is recommended to document the measured results, as they may be used as references for future troubleshooting. Again you can use the installation acceptance protocol template in the appendix. After having filled in this form, you should pass it to the commissioner.



As already mentioned earlier, an acceptance test is not mandatory for ready-made PROFINET FO cables. It is, however, advantageous for the documentation of the cabling structure, as it allows excluding in advance some of the potential error sources; additionally, you can use the values as references for later reference measurements.

Table 3-3 provides a check-list in which the measurements to be performed are described.

Table 3-3: Check-list for the acceptance of the PROFINET FO cabling

1.	Visual inspection of cabling
	<ul style="list-style-type: none">- As described in chapter 3.2.1.2.
2.	Attenuation measurement for optical fibers
	<p>For this measurement you should use a simple instrument to determine the insertion loss as described in chapter 2.2.1.</p> <p>The measured attenuation shall not exceed the maximum permissible PROFINET FO end to end link attenuation according to Table 2-1.</p>
3.	Extended functional test for FO cabling (optional)
	<p>Even if not mandatory, it makes sense to add some more parameters for the acceptance of the PROFINET optical fiber link:</p> <p>Data to be added may include:</p> <ul style="list-style-type: none">- Cable length- Distance between junctions (connectors/splices)- Fraction of the attenuation allocated to fiber, connectors, splices- etc.

Step 1 is the already described visual inspection. The main focus is on visible damages of the FO link.

Step 2 is the recommended simple attenuation measurement which can be executed using relatively low-priced decibel meters or the OTDR.

Step 3 is an extended test which requires an OTDR. Primarily, this step should be executed if a more detailed analysis of the link is needed. The attenuation introduced by the individual PROFINET fiber types depends on the fiber types used. For details see Table 2-1 which shows the permissible limit values and the wave length used for operation.



Please refer to the manufacturer specifications for the attenuation of the fiber you are using.



The attenuation of an optical fiber connection may vary, depending on the quality of its installation. Please bear in mind that every connector due to its unavoidable attenuation, reduces the maximum permissible length of an FO cable.



Please consider that the comparatively high attenuation of Plastic Optical Fibers (POF) in conjunction with multiple connectors will reduce the maximum distance of the fiber optical connection. Please consider this when conducting the acceptance test.

3.3 Checking active network components

This section deals with the acceptance of the active network components. Active network components are those components that are directly integrated into the network structure. They evaluate or process the data traffic that occurs. This applies primarily to devices like routers and switches, but also to the operator console or controller.

When making a visual inspection of the active network components, check the following items:

- Do the individual active network components (switch, router, media converter) provide the diagnostic functions?
- Do the devices feature the functionalities you have planned?
- Have the devices been installed in accordance with the guidelines?
- Active network components require a power supply unit. Make sure that power units that comply with the installation sites are available.
- Are all necessary protocols activated on the active component (e.g. LLDP (Link Layer Discovery Protocol) for vicinity communication in line topologies)?



Also make sure that only PROFI-safe devices are used which are certified for PROFINET and PROFI-safe.

4 Commissioning the PROFINET network

After the installation acceptance test has been performed as described in chapter 3, the PROFINET network can be commissioned.



Note that the installation acceptance tests in accordance with the specifications in chapter 3 is a prerequisite for commissioning the PROFINET network.

The corresponding documents and protocols should be available to you.



The planning, installation and commissioning process of Ethernet APL is described in the Ethernet-APL Engineering Guideline [APL2021]. Please check this document for further information on the APL commissioning

4.1 Visual inspection and acceptance test

After completion of the acceptance test the required documentation should be available. Before starting to commission the system, make sure that the installation has been performed in compliance with the PROFINET guidelines.



If you discover any installation faults or the acceptance test documents are incomplete the installer should be contacted. This helps to minimize the number of potential error sources in the PROFINET commissioning phase.

4.2 Planning / System configuration

An engineering tool is required for the configuration of PROFINET devices. The system configuration will not be described in more detail here because operation of the engineering tool varies from manufacturer to manufacturer. Only some basic issues are discussed here.

4.2.1 Device description files

PROFINET nodes are integrated into projects using device description files. This is a standardized type of file which describes the properties of the PROFINET I/O devices. The device description file for PROFINET is usually abbreviated “GSD file”. GSD stands for “General Station Description” while the extension ML indicates the use of XML).

A GSD file for a device contains standardized information on its properties.

It is important to use the correct GSD files in your PROFINET system. Each PROFINET device has an individual device ID. The device ID is allocated by the manufacturer and, in combination with the manufacturer ID allocated by the PROFIBUS user organization it is globally unique for each device type. The GSD file has to match the device ID of the configured device. The device ID consists of 16 bits. This information can be retrieved from the GSD file. The name scheme of a GSD file consists of several parts e.g. name of the device manufacturer, name of the device family and release date.

For example:

“GSD-V2.2-Siemens-ET200S-20040720.xml”

When using devices from different manufacturers, the relevant GSD files must be imported to the engineering tool.



Please observe the instructions for your engineering tool concerning the import of GSD files.

The GSD files of the used PROFINET nodes are available from the manufacturers.



When using the GSD files, make sure that the used GSD file matches the version of the PROFINET node. Otherwise some features may not be available to you.

4.2.2 Address settings

This section describes the required address settings and things to observe. The next section provides a detailed example for address and name settings.



The already considered address settings from the PROFINET design guideline is here additionally mentioned for a better understanding of the addressing.

4.2.2.1 Name and IP address allocation in an automation plant

This chapter describes an example for the allocation of the IP address for a PROFINET automation plant. The example described here is based on an automation plant with three PROFINET segments, as described in the PROFINET design guideline. The topology and the number of PROFINET devices have been determined for each island during planning. The result of this planning has been assumed to be as follows:

- **PROFINET segment A**
 - Number of PROFINET devices: 6; Tree topology; 3 plant parts
- **PROFINET segment B**
 - Number of PROFINET devices: 6; Line topology, application: Conveyor
- **PROFINET segment C**
 - Number of PROFINET devices: 6; Tree topology, 3 plant parts
- **Operator station**

- Number of PROFINET devices: 1 (PC); Star topology

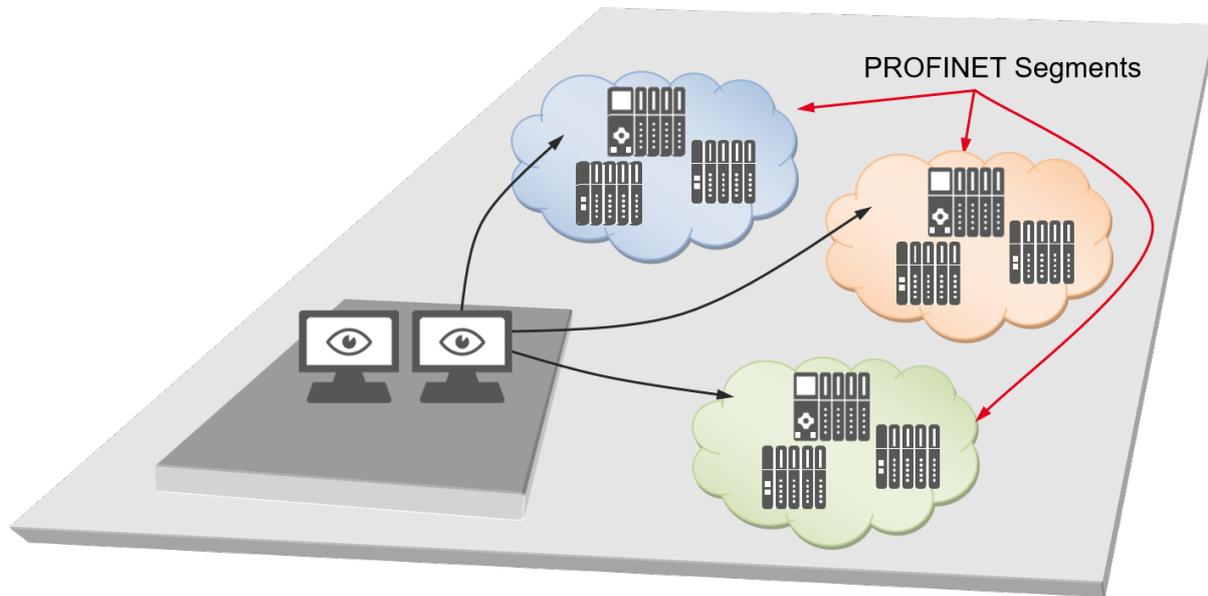


Figure 4-1: Map” of an automation plant

The summary of requests results in the following required number of IP addresses per PROFINET segments.

Table 4-1: Overview of number of devices (example plant)

Automation plant “Example”					
PROFINET segment A					
Number switches	4	Number devices	6	Controller	1
PROFINET segment B					
Number switches	0 (line structure)	Number devices	6	Controller	1
PROFINET segment C					
Number switches	4	Number devices	6	Controller	1
Operator station					
Number switches	1	Number devices	1	Controller	0

When commissioning a large plant, you should create an address table where the most important information about the PROFINET nodes can be entered. This will allow you at a later stage to easily retrieve faulty PROFINET nodes or PROFINET nodes to be replaced.

The notation of the IPv4 address used in PROFINET networks consists of four decimal numbers, each in the range between 0 and 255 and separated by a point, as e.g. 192.168.2.10.

Based on this address, the device name and the unchangeable MAC address, network nodes can be clearly identified. In addition to the IP addresses used in public networks such as the Internet, firmly defined private or non-public address ranges have been reserved.

The green figure of the address is determined by the number of available networks while the red figure is determined by the number of network nodes (see following table).

Table 4-2: Private IPv4 address ranges

No. of networks	Class	Address range	Network mask	Number of addresses
1	Class A	10.0.0.0 to 10.255.255.255	255.0.0.0	1 x 16.8 million
16	Class B	172.16.0.0 to 172.31.255.255	255.255.0.0	16 x 65534
256	Class C	192.168.0.0 to 192.168.255.255	255.255.255.0	256 x 254

In addition to the IP address, a PROFINET device requires a network mask in order to communicate in PROFINET. The notation of this so-called network mask is identical to the notation of IP addresses. Networks are subdivided into individual ranges using this network mask, also called subnet mask. The most common subnet masks correspond to the network masks as shown in Table 4-2.

Another way of subdividing networks into smaller logical segments is called “subnetting”, which means that the network mask is modified according to a special procedure. This makes sure that no direct communication between network nodes is possible within a network unless these nodes are members of the same “subnetwork”. As a consequence, the number of network nodes in a “subnetwork” is reduced. If required, the network size can be increased by changing the subnet mask.



In most cases, addressing using the private class C address range is sufficient. In cases requiring a wider address range than that provided in private class C you can increase the maximum number of network nodes by adapting the network subnet mask accordingly. This should be done in coordination with the person responsible for planning, only.



In order to provide a better overview, you can subdivide individual system parts into separate IP address ranges.



Please bear in mind that in larger companies, IP addresses are usually allocated by the department responsible for corporate networks.

Individual plant parts can be addressed using these addresses. Reserve addresses should be foreseen for future expansions. For the plant described above, the address structure could look like this.

1. Each individual automation island receives an address range

Operator station: 192.168.1.xxx

PROFINET segment A: 192.168.2.xxx

PROFINET segment B: 192.168.3.xxx etc.

2. The individual device types of a PROFINET segment are assigned to different address ranges:

PN controller / "segment A": 192.168.2.1 to 192.168.2.19

Switches: 192.168.2.20 to 192.168.2.49

PN devices: 192.168.2.50 to 192.168.2.199

Diagnosis: 192.168.2.200 to 192.168.2.254

The net mask here corresponds to the standard class C address range. Using this notation, the following address allocation can be used PROFINET segment A from the above example plant:

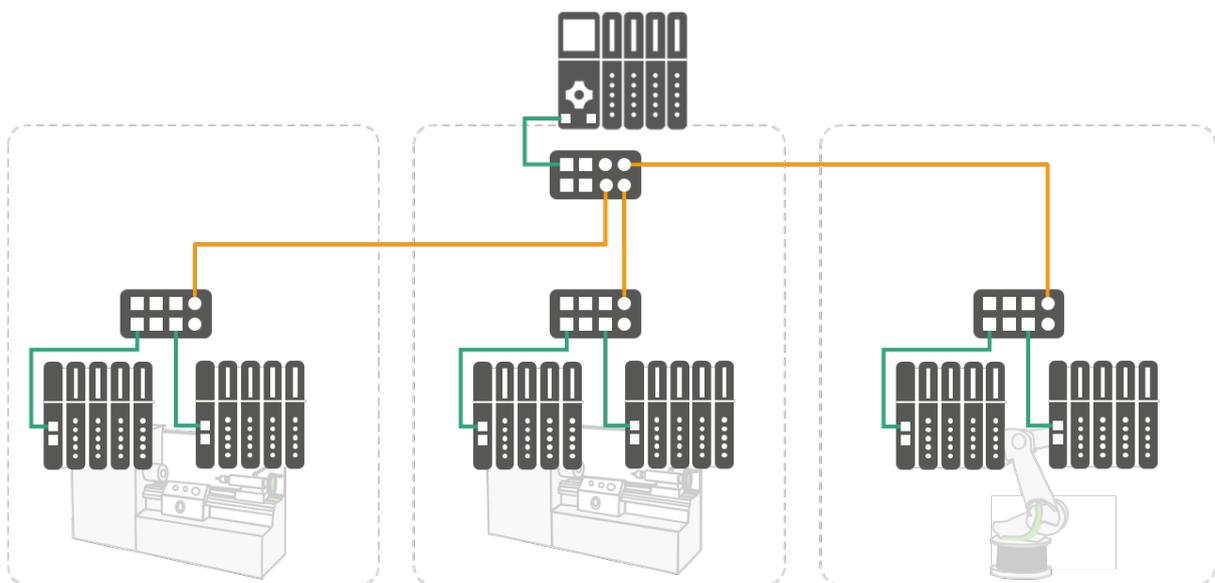


Figure 4-2: Cabling PROFINET segment A

Table 4-3: IP address allocation "example plant"

Type	Name	MAC address	Name	IP address:
PN controller	CPU.123.AB	08-B2-3C-D4-E5-6F	CONTROLLER1	192.168.2.1
Switch	Switch.AB1	08-13-AB-3D-A1-E7	SWITCH1	192.168.2.2 0
Switch	Switch.CD2	08-CC-AA-33-FF-D1	SWITCH2	192.168.2.2 1
Switch	Switch.EF3	08-57-AF-9C-A1-44	SWITCH3	192.168.2.2 2
Switch	Switch.GH3	08-28-EA-33-DF-21	SWITCH4	192.168.2.2 3
PN device	IO.device.V3	08-D7-66-6D-A6-4B	ISLAND1.DEV1	192.168.2.5 0
PN device	Eco.IO.V3	08-A1-F4-D4-E5-6F	ISLAND1.DEV2	192.168.2.5 1
PN device	K5.700.S	08-AA-33-3D-A6-A4	ISLAND1.DEV3	192.168.2.6 0
PN device	IO.device.V6	08-D7-69-6D-C2-4B	ISLAND1.DEV4	192.168.2.6 1
PN device	IO.device.98	08-A1-F5-A8-E5-56	ISLAND1.DEV5	192.168.2.7 0
PN device	K5.750.SE	08-AA-33-3D-A1-F4	ISLAND1.DEV6	192.168.2.7 1

A table provides better overview of the plant, reducing the required work and saving time. You are of course free whether or not to create a table.



In this example the switches, just as the PROFINET devices, are allocated an IP address and a PROFINET device name. This is the case if the switch is planned in the PROFINET structure, too.

There may be switches which do not get an IP address or a device name.

4.2.2.2 Device names

Before a PROFINET device can be contacted by a PROFINET controller, it must be allocated a device name.

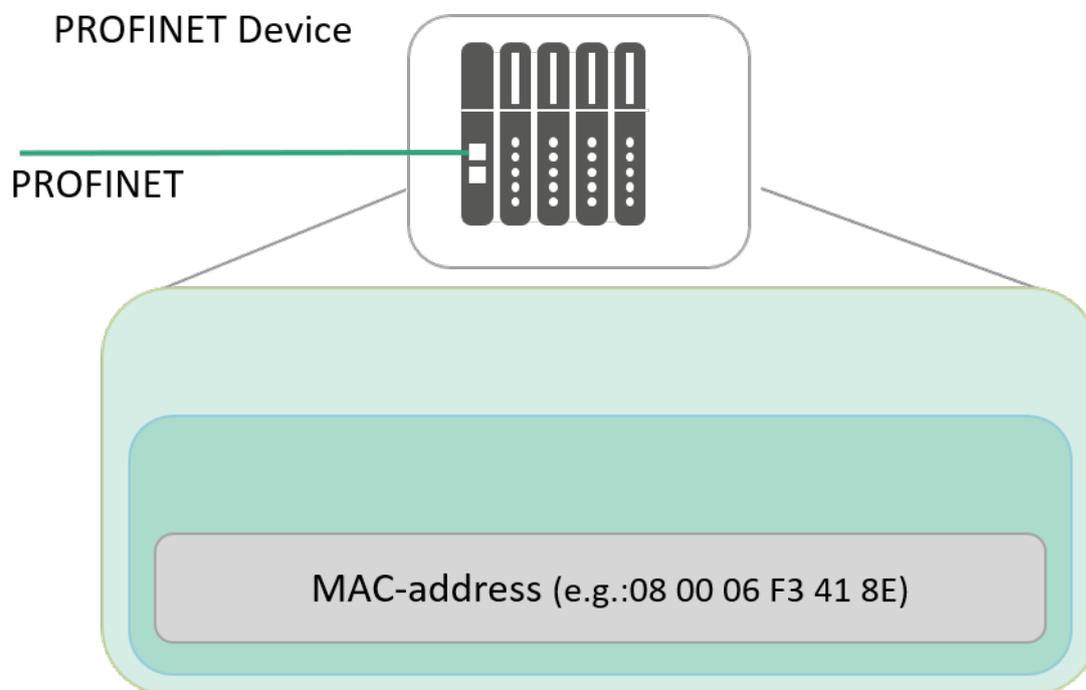


Figure 4-3: PROFINET device (delivery status)

For PROFINET, this procedure has been selected because names are easier to handle than more complex IP addresses. In their original delivery status, PROFINET devices do not have

a device name, but only a MAC address. This address is persistently stored in the device; it is globally unique and can usually not be changed. Some manufacturers have proprietary tools which allow for a MAC address to be changed in case a device has to be replaced. Many PROFINET devices have the MAC address printed on the housing or on the rating plate.

A PROFINET device can only be addressed by a PROFINET controller after having been allocated a device name, usually for the acyclic transfer of planning data (among others the IP address) or when starting the PROFINET device. Cyclical exchange of data is realized using the MAC address, if the PROFINET Controller and the PROFINET Device are placed in the same subnet.

The device name must be stored in non-volatile memory in the device. If supported by the PROFINET device, the device name can alternatively be directly written to a storage medium. The storage medium is then inserted into the PROFINET device. The device name is then copied from the storage medium to the PROFINET device.

Allocating names allows you to get a better overview of the plant to be commissioned. For the individual PROFINET devices you should therefore use names which make sense and provide an indication for the relevant plant part.

When commissioning the PROFINET devices, the device name is transferred to the PROFINET device.



Please bear in mind that PROFINET does not support the full character set for allocating device names. This holds in particular for special characters.

4.2.2.3 Allocation of IP addresses

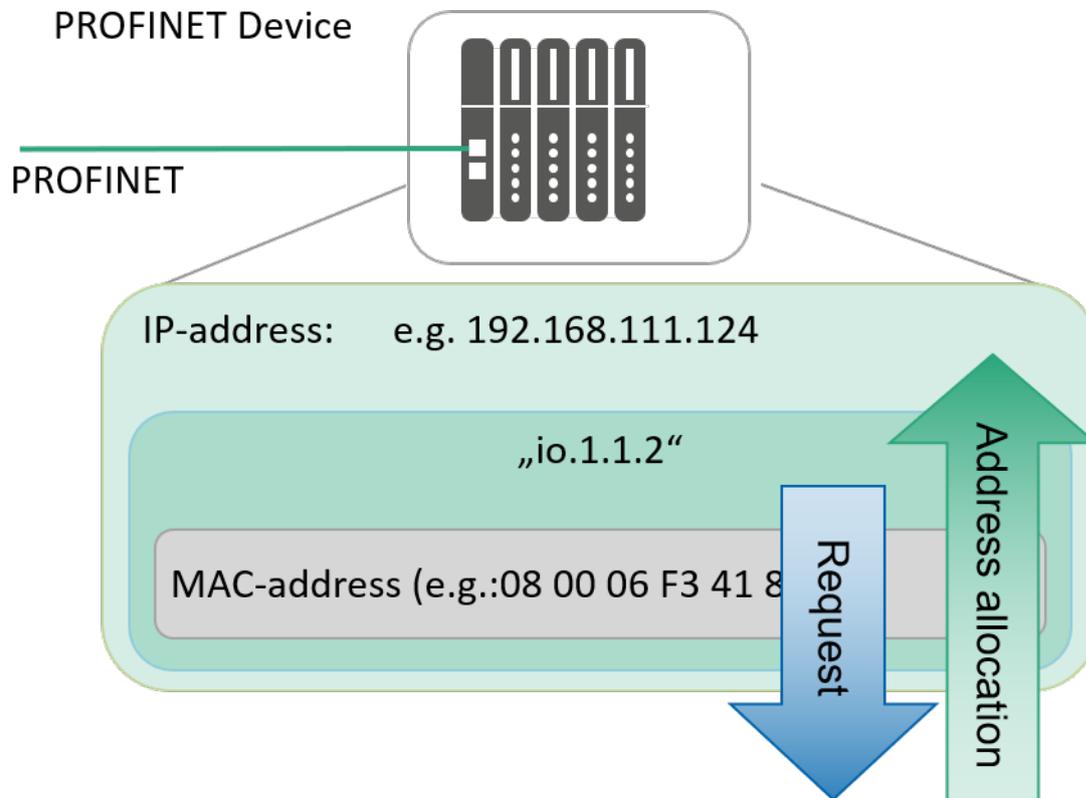


Figure 4-4: PROFINET device (address allocation)

The IP address is entered in the configuration of the PROFINET project. This is usually done automatically. IP addresses are allocated in a rising order, beginning from a start address, in the order in which the devices are inserted. It is usually also possible to firmly assign the IP address when planning the plant in the engineering tool. The address thus allocated will be transferred to the PROFINET device when starting PROFINET controller. This can be stored in non-volatile memory in the device.

Addressing of a PROFINET DEVICE therefore in total includes:

- **MAC address**, which is pre-defined in the device and can usually not be modified.
- **Device names** which can be freely selected, but which should reflect the relevant plant part for convenience reasons.
- **IP address**, which can also be freely selected, but which follows a firm scheme and which should be selected, similar to the device name, according to the assigned plant.



If the same address is assigned twice, this may cause malfunctions of PROFINET. Although diagnosis functions are usually still available, data communication is no longer possible. This error is usually indicated by online engineering user interfaces.



Some system approaches allow for the exchange of MAC addresses in PROFINET devices. The same approach applies in terms of IP addresses. You should ensure uniqueness of the addressing.

4.3 Commissioning PROFINET devices

4.3.1 Switching on the devices

After having configured the PROFINET controller with the PROFINET devices, you can commission the PROFINET network.



It is common practice to use separate voltage supplies for the PROFINET nodes and their signal outputs. This allows commissioning of the PROFINET network without activating the output devices. For safety reasons the output power supply should be isolated or switched off, so preventing actuators from operating when commissioning the PROFINET network.

Initially, the power supply to all PROFINET nodes should be checked. Please see the manufacturer documentation to find out which supply voltage is required for the relevant PROFINET nodes.



In this context you should also check any other available displays (e.g. LEDs). You will find more information on the function of these displays in the manufacturer documentation of the device. These indicators allow checking that the device is powered, operational and whether it is connected to the PROFINET network.

The next check is to use an engineering tool to check whether all PROFINET devices are accessible. The engineering tool must be connected PROFINET network via a spare port on a switch.

Usually, the engineering tool provides the appropriate option as a “live list” or topology diagram. These will display all PROFINET devices that are connected to the network.

Since no device name or IP address has been assigned to the PROFINET devices so far, only the MAC address and device type of the corresponding PROFINET device are indicated.



In this context you should also check that the required protocols have been activated. This includes for example the Link Layer Discovery Protocol (LLDP) required in line structures.

4.3.2 Allocating the device names

The next step is to allocate device names to PROFINET devices. Device names can be transferred in two different ways. The name can be allocated by using an engineering tool connected to the network. Use the MAC address of the PROFINET device to select the PROFINET device to be named and then transfer the device name from the PC to the PROFINET device. This is only possible in the same subnet.

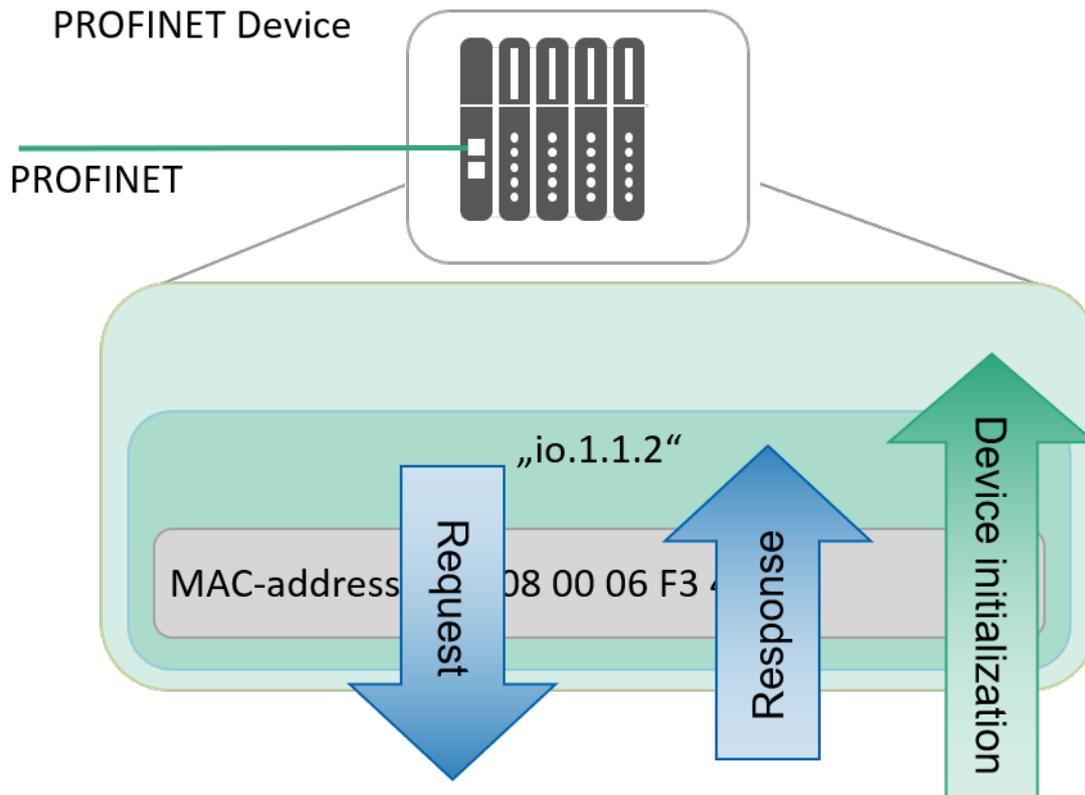


Figure 4-5: PROFINET Device ("device initialization")

The device name must be persistently stored in the device. When a defective device is replaced, you have to repeat the name allocation with the new device. To avoid this step, some manufacturers offer devices with a removable medium. Here the device parameters are stored on a replaceable storage medium. In case a component fails, the storage medium is inserted in the replacement component, thus being immediately operational.



There are different ways to update the address data of a PROFINET device in case a device is being replaced.

After names have been assigned to the PROFINET devices, please check once more, e.g. using the live list, whether all PROFINET devices are accessible. The live list should now also include the device name in addition to the MAC address.



The engineering tool can be used to update the “live list”. The "Live List" should now show all accessible PROFINET devices with their allocated device names.

It is usually not necessary to allocate the device name to the PROFINET controller. It usually gets his device name directly from the configuration.



Some automation systems also support topology-based name and address allocation. In this case no manual configuration is required. If a device is replaced, the name and address are automatically allocated to the replacement device.

4.3.3 Transmitting the planning data

You should now transfer the planning data from the engineering tool to the controller using the planning software. PROFINET controllers usually have different modes of operation, e.g. **STOP** and **RUN**.



There are some differences between the controllers from various manufacturers. Therefore, make sure to read the manufacturer instructions.

After initialization, the error free PROFINET devices are signaling operational readiness. You can read the operating condition by using the engineering tool. Some PROFINET nodes allow you to determine their status e.g. by means of LEDs. If the controller is in **RUN** mode, the PROFINET nodes should no longer indicate any communication problems.

In case any stations are indicating communication problems at this stage, additional checks should be undertaken, e.g.:

- Device type correctly configured?
- Device configuration OK / Device name correctly configured?



Please see the manufacturer documentation for the detailed functions of the PROFINET node displays.

4.3.4 Checking the firmware revision levels

In the planning phase, a firmware revision level has been defined for each device type. The used PROFINET devices should be checked for compliance with the defined firmware revision level.



Check the firmware revision levels of the PROFINET devices and document them.

If the firmware revisions installed in the plant deviate from the planning, contact the person responsible for the planning of the system.

4.4 Saving the project

Upon completion, the planning data should be saved and backed up onto suitable storage media (USB stick, CD-ROM, external hard disk, memory chip, etc.). A copy of this should be handed to the customer during acceptance. An additional backup copy should be kept in a safe place. This ensures that data will be available in the future, e.g. in case of outages or maintenance.

5 PROFINET acceptance test

5.1 Steps of PROFINET acceptance test

The acceptance test is subdivided into 4 steps, where steps 1 and 2 are parts of the installation acceptance procedure and step 3 is the commissioning phase. At this stage the steps 1 to 3 should already be completed.

1. Visual inspection

This has been done during the installation acceptance test according to chapter 3. Check to see that no system parts have been skipped.

2. Acceptance measurement of the cabling

If acceptance measurements were made in the installation acceptance phase (see chapter 3), the corresponding measurement protocols should be available to you. In this case check the protocols for completeness. If not acceptance measurement has been performed, document this fact.

3. Commissioning a PROFINET network

In the commissioning phase described in chapter 4 the PROFINET devices have been configured and commissioned. The following information should be available:

- Allocated device names
- Allocated IP addresses
- Firmware revision levels

4. Performing the network acceptance test

The devices have been commissioned. The network can now be checked for proper operation. An acceptance protocol should be created for this.



The planning, installation and commissioning process of Ethernet APL is described in the Ethernet-APL Engineering Guideline [APL2021]. Please check this document for further information on the APL commissioning

5.2 Checking the PROFINET communication monitoring

The PROFINET communication monitoring is intended for detecting communication errors. In the design phase a tripping threshold for communication monitoring has been specified. Usually the standard setting of three communication cycles without valid data should be kept as the tripping threshold. (This means a communication error is assumed in the third communication cycle **without** valid data.)



If not otherwise specified in your planning for PROFINET communication monitoring, assume the standard setting of three communication cycles without valid data as the tripping threshold.



The designation of the communication monitoring setting depends on the manufacturer. Examples:

- “Number of accepted update cycles with missing IO data”
- “Number of update cycles without IO data”
- “Number of faulty telegrams before communication is terminated”



Check the setting for PROFINET communication monitoring in the devices, e.g. using an engineering tool, and document the results.

In the event of deviations from the planning contact the person in charge of planning for an evaluation of the deviations.

5.3 Checking the system reserve with FO (POF)

When using polymer fibers (POF) you can determine the optical system reserve (power budget) of every single link. The system reserve is a measure of the light power reserve available on the link between the transmitter and the receiver intended to ensure trouble-free operation; this can normally be read out as a diagnostic value. The system reserve is a function of the cable length, the connectors and the transmit and receive power of the devices.



The system reserve has a valid measuring range of 0 to 6 dB.

For values below 2.0 dB the corresponding device outputs a “Maintenance required” alarm.

A “Maintenance demanded” alarm is output for 0 dB.

The cable length of a POF link between two devices can be determined by reading the diagnostic values. The maximum permissible length of a link cable between two devices (end to end link) is 50 meters. For this cable length a minimum system reserve of 2 dB must be provided.

If the system reserve has not been explicitly specified in your planning, assume the limit values listed in Table 5-1.

Table 5-1: Limit values for system reserve in optical fibers

System reserve	Evaluation
> 6 dB	The value is above the measuring range. No action required.
>2 dB to 6 dB	The value is in the valid measuring range. Trouble-free communication is ensured. Typical values for a cabling without additional connectors: <ul style="list-style-type: none">▪ 5 dB for cable lengths up to 30 m▪ 3.5 dB for cable lengths between 30 m and 40 m▪ 2.5 dB for cable lengths between 40 m and 50 m In the event of a deviation from the specified value ranges a check of the cables is recommended (check for additional connectors, check of attenuation).

5.4 Acceptance test of the PROFINET network

Once all devices have been commissioned, the PROFINET network should be checked for proper operation.



The acceptance of the PROFINET network requires that the installation acceptance has been performed as described in chapter 3 and the PROFINET devices have been commissioned as described in chapter 4.3.

The corresponding documents should be available to you.

The acceptance test is subdivided into the steps detailed below:

5.4.1 Checking the Topology

The topology specifications in the planning are to be checked for correct implementation.

This applies especially to the observance of the maximum line depth. The line depth is the number of forwarding devices (e.g. switches or Devices with integrated switches) between a PROFINET device and its controller. Figure 5-1 shows a line depth of 9 as an example.

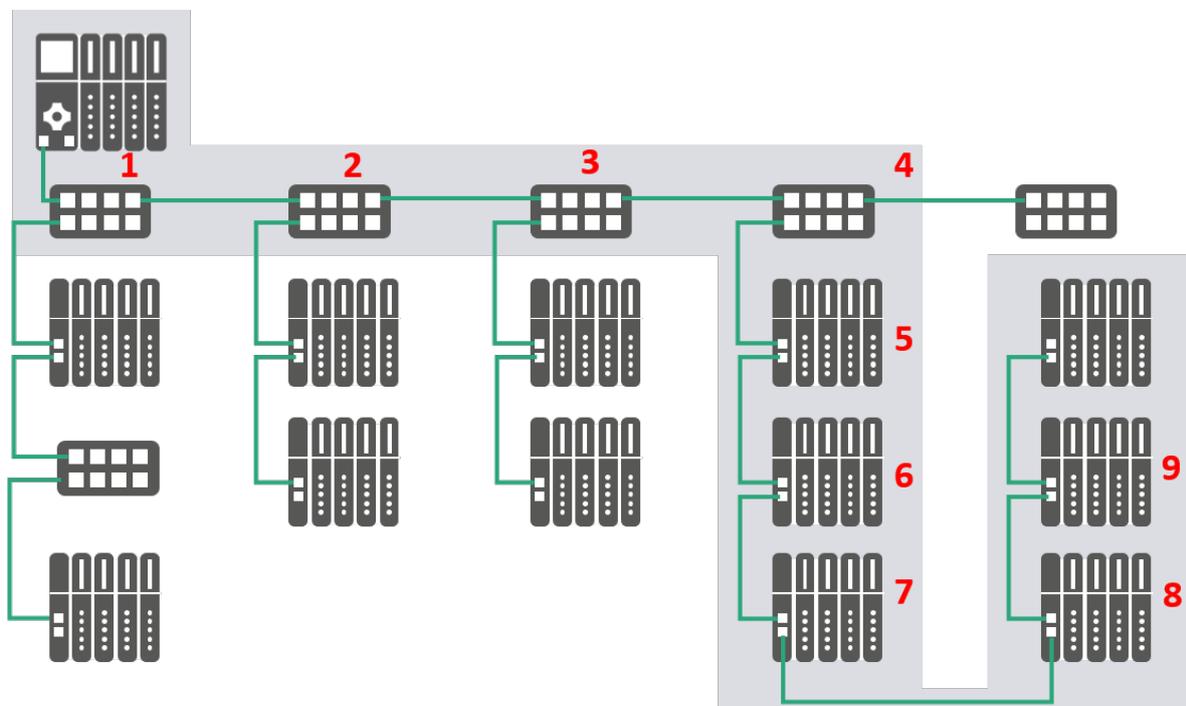


Figure 5-1: Example of a maximum line depth of 9

The maximum line depths listed in Table 5-2 are valid for “Store and Forward” switches.

Table 5-2: Maximum line depth with “Store and Forward” switches

Update rate	1 ms	2 ms	4 ms	8 ms
Maximum line depth	7	14	28	58

In a worst-case scenario, the processing time for these line depths in a line topology is as great as the update time.

The maximum line depths listed in Table 5-3 are valid for “Cut Through” switches.

Table 5-3: Maximum line depth with “Cut Through” switches

Update rate	1 ms	2 ms	4 ms	8 ms
Maximum line depth	64	100	100	100



It is recommended to plan a maximum line depth of 45, for the benefit of higher availability and easier diagnosis.

This also allows future extensions using media redundancy (MRP).



A mixed setup of “Store and Forward” and “Cut Through” switches can be used. In this case the limit values for “Store and Forward” should be used.



Compare the existing topology with the planned topology. Check for observance of the limit values for the maximum line depth according to Table 5-2 and Table 5-3.

If you should not know the switching technology of the used switches, assume they are Store and Forward Switches.

In the event of deviations from the planning or if limit values are exceeded, document these facts and contact the person in charge for planning for an evaluation of the deviations.

An additional calculation of the line depth has to be done for Ethernet-APL.

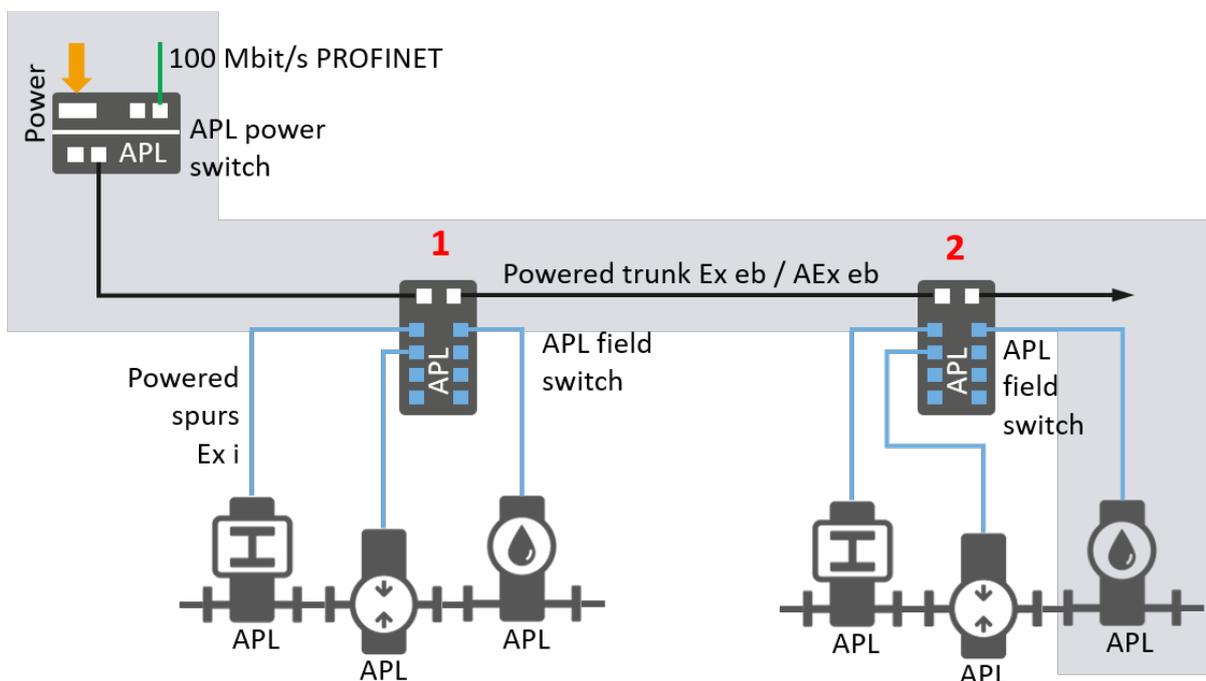


Figure 5-2: Line depth for Ethernet APL Trunk

Figure 5-2 shows a powered APL trunk. For APL trunks the line depth has to be calculated separately. For APL Trunks the line depth is calculated by counting the number of field switches between the most remote APL field device and the APL power switch. In this example the line depth is two.



For PROFINET Installations the maximum line depth for powered APL trunks is one. This is a preliminary specification. This value may change in future.

5.4.2 Discarded packets

A switch may discard packets, e.g. due to troubles, transmission errors or switch queue overflow.

Conclusions can be drawn from:

- The number of discarded packets in the period under consideration
- An accumulation of discarded packets in a specific section of the network, e.g. in individual PROFINET devices.

In a best case scenario, you should read out all switch components, including the switches integrated in PROFINET devices. At least you should check all devices with a presumably high network load. Figure 5-3 shows an example of such a communication link.

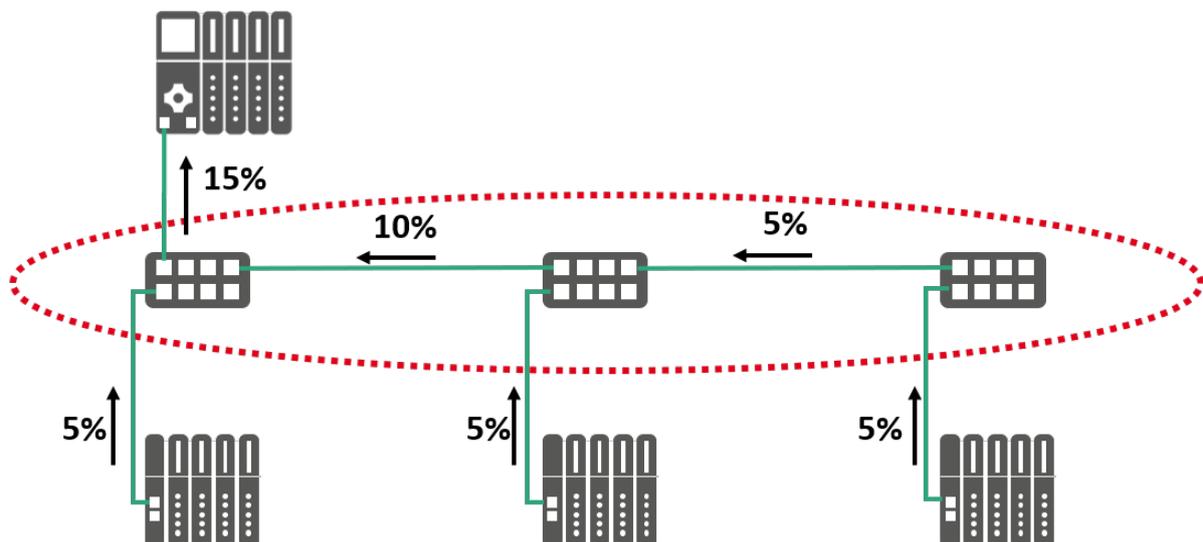


Figure 5-3: Example of a communication link with high load

In this example at least the three switches (red circle) should be checked.



The number of rejected packets can normally be read from managed switches or PROFINET devices. See chapter 2.3 for a description of the methods.



Determine the number of rejected packets in the network. The period under consideration should be **60 seconds**.

During this period **no lost packets** should occur. This applies to transmission links made up of copper or FO cables.

Document the results. If there should be any abnormalities consult the person in charge of planning for an evaluation.

5.4.3 Network load

Finally the network load during network operation should be determined.

This should be done at important locations in the network, e.g. the communication nodes where a concentration of the data streams is expected. This is usually the network link to the controller, as shown in the example in Figure 5-3.

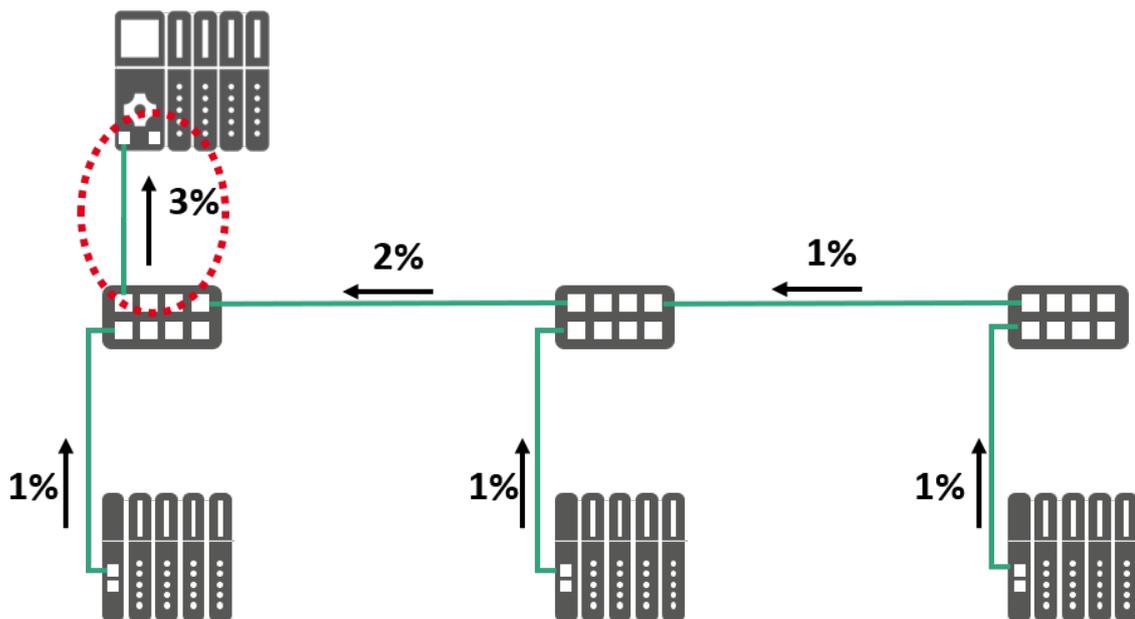


Figure 5-4: Important locations for determining the network load

For multi-controller applications the measurement should be made at every controller.

At least the maximum value of the network load should be documented.

Table 5-4: Limit values for the network load of cyclic real-time communication lists the limit values for cyclic real-time communication. The values correspond to the specifications in the PROFINET Design Guideline.

Table 5-4: Limit values for the network load of cyclic real-time communication

Network load	Recommendation
<20%:	No action required.
20...50%:	Check of planned network load recommended.
>50%:	Take the appropriate measures to reduce the network load.

In contrast to the maximum real-time (RT) network load specified in the Design Guideline, the combined network load can be considered with this approach. Non-real-time traffic (NRT) can be involved as well. For this purpose, you have to consider, the possible communication between standard Ethernet nodes and define other important issues. Figure 5-5 shows an example. For reasons of simplicity only one data direction is considered.

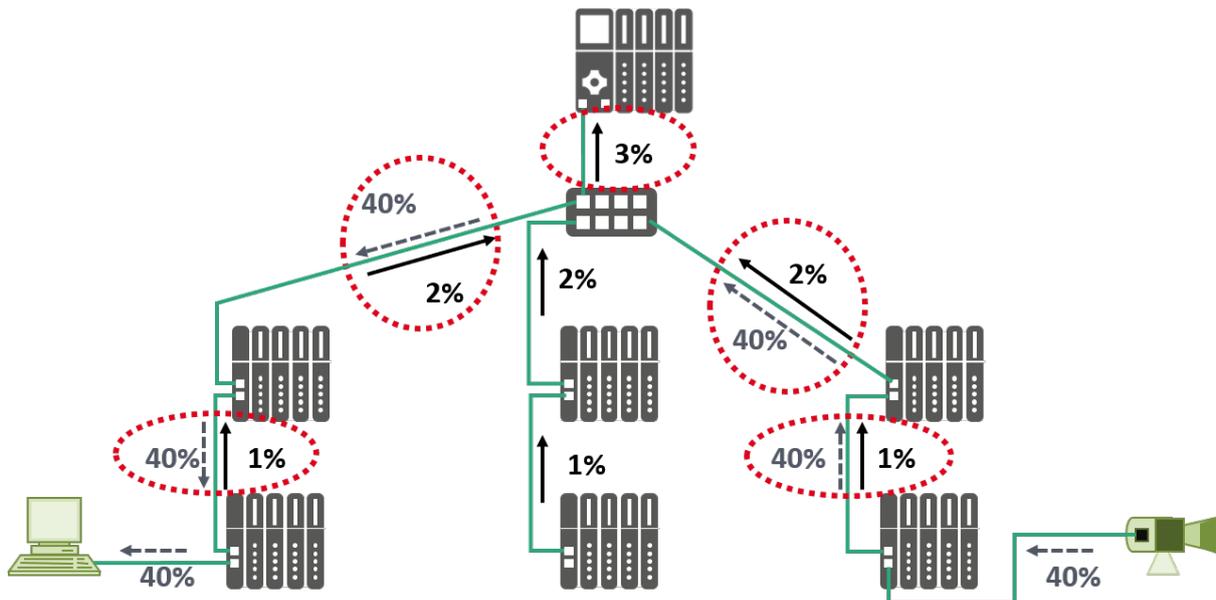


Figure 5-5: Important issues for determining the network load, topology with standard Ethernet nodes

The communication links with RT and additional NRT traffic are of special interest.

In order to ensure that the results are representative and to be able to detect rare peak loads, the time period selected for analysis should be sufficiently long and the analysis should be performed only while communication takes place. The measuring time should be sufficiently long to ensure that all results expected during a production cycle will be recorded.



If the combined network load should deviate considerably from the real-time network load, the reason has to be determined and evaluated.



The network load can be determined using the diagnostic methods described in chapter 2.3.4. It is also possible to read this information directly from many managed switches. Please note that this information is available for both, the transmit and the receive direction. These have to be evaluated separately.



Ethernet-APL networks require the same considerations with respect to network load, as described in this chapter, but adapted to the 10 Mbit/s data rate of the Ethernet-APL network. A detailed description of the network load calculation for Ethernet-APL networks can be found in the Ethernet-APL Engineering Guideline [APL2021].



Determine and document the maximum cyclic real-time network load at important locations of the network. Observe the limit values specified in Table 5-4.

If the limit values should be exceeded, contact the person in charge of the planning for further evaluation.

Also take into account the combined network load. In the event of a considerable deviation from the cyclic real-time network load contact the person in charge of the planning for evaluation.

5.4.4 Broadcasts and multicasts

Under certain circumstances, broadcast and multicast network loads can occur during commissioning and operation of a network. These network loads are Ethernet packets transmitted to all network nodes of a switched network (broadcast domain). Typical use cases are, for example, search requests for network nodes. Search requests can be executed for different reasons and by different nodes.

Typical examples include:

- ARP broadcast, e.g. an IP scan of entire AP address ranges for the purpose of determining the existing network nodes (performed, e.g. by engineering systems, service tools, diagnostic tools, IT systems).
- DCP multicast, performed e.g. at the startup of a PROFINET controller to search for the planned PROFINET devices.
- MRP multicast, test packets for verifying the 'data flow', e.g. with ring redundancy.

The above search requests have one thing in common: all devices in a broadcast domain first must receive and evaluate the corresponding Ethernet packets, irrespective of their location or the topology and regardless whether they are supposed to respond or not. For all devices in the network this results in an additional communication load which may be quite important, depending on the request frequency. Therefore, additional loads generated by broadcast or multicast requests should be minimized. See the following chapters for details.



As the network switches transmit the broadcast and multicast requests to be evaluated to all ports, the request can be recorded at any location within the network, including the free ports of a switch or device (no monitoring port or TAP required).



Broadcasts and multicasts are critical, when Ethernet APL with a 10 Mbit/s data rate is used. Special attention should be put in this case on the maximum number of broadcasts and multicasts. Please check the PROFINET Planning Guideline [PND2022] for more information on mixed link speeds in PROFINET networks

5.4.4.1 ARP broadcasts

The ARP request is a standard function of the IP network protocol and is used by the network nodes for preparing the IP communication in order to determine the MAC address of an IP node. An ARP request is transmitted to all network nodes as a broadcast. As a result, individual ARP broadcasts occasionally occur in a network. This is a normal operating condition.

The same mechanism can be used, however, to search for the accessible IP nodes in a network. In this case, the ARP requests are usually transmitted in quick succession to the IP addresses of the relevant network (IP scan). IP scans of this kind are used e.g. for search functions and by engineering systems, network management systems, service tools and diagnostic tools.

In the acceptance test you should therefore check if only the truly necessary functions and services are used.

The following table describes the recommended procedure.

Table 5-5: Procedure for ARP broadcasts (ARP requests)

Number of ARP requests	Comment
0	No action required.
>0	Check if individual nodes are searched or entire IP ranges are cyclically scanned. If only individual nodes are searched: <ul style="list-style-type: none"><li data-bbox="475 1487 1023 1520">• No action required, if reason is known. If entire IP ranges are scanned: <ul style="list-style-type: none"><li data-bbox="475 1644 1382 1722">• Contact the person in charge of planning and evaluate the possible reasons.

5.4.4.2 DCP multicasts

DCP requests are vital to the identification and parameterization of PROFINET devices. At the controller startup they are used for searching the planned PROFINET devices; they are repeated cyclically until the corresponding device responds. Once the controller startup has been completed, usually no more DCP multicasts occur in a PROFINET network. Possible exceptions are configurations with temporarily accessible devices, e.g. due to tool changes or wireless links. It should be decided on an individual basis which measures (e.g. temporary de-registration of nodes) could be taken to minimize the number of DCP multicasts.



The sender of a DCP multicast can be identified using the sender address of the packet.

The following table describes the recommended procedure.

Table 5-6: Limit values for DCP multicasts after system startup

Number of devices searched by the controller after system startup.	Comment
0	No action required.
1...10	No action required, if reason is known or cannot be changed (e.g. due to tool change, temporary nodes, etc.).
11...20	High multicast load. Contact the person in charge of planning for evaluation and possible reduction.
>20	The multicast load is too high. Trouble-free operation cannot be ensured.

5.4.4.3 MRP multicasts

In a network installation with ring topology operating on MRP basis the ring managers transmit test frames to check if the ring is closed.

These requests are multicasts which occur only at the device ports directly belonging to the ring, provided that the ring has been configured correctly.

If, however, the involved devices have not been configured correctly, the MRP multicast test packets may be transmitted to all devices. The MRP telegrams may then also occur outside the ring. As they are multicasts, they can be detected at all free ports of a switch or device. In these cases the configuration must be adapted accordingly.

Table 5-7: Limit values for MRP multicasts

Number of MRP packets outside the ring	Comment
0	No action required.
>0	Check the device configuration or contact the person in charge of the planning for an evaluation.

5.5 Additional parameters for evaluating the network

Besides the already described necessary acceptance criteria for a PROFINET network, there are some more parameters which allow you to draw conclusions regarding the behavior of the network and the connected devices.

Among these are:

- **Jitter**

In the context of PROFINET communication the jitter describes the variations in the time lag between PROFINET packets. If some packets are delayed more than others, the jitter increases.

A certain jitter is due to the system, especially with line topologies. It results from the different pass-through times of the packets through switch lines, depending on the current network load.

If, however, the jitter permanently increases, this may indicate e.g. a malfunction, a changed load situation, topology changes or a device change.

5.6 Creating the acceptance protocol

As a last step you should create an acceptance protocol. This can be used to document a successful acceptance.



For templates of the commissioning and acceptance test protocols please see the Annex.

6 Tips for troubleshooting

6.1 Introduction to troubleshooting

The Troubleshooting chapter will guide you in identifying problems with the PROFINET cabling or with the configuration. The first steps have already been described in chapter 3. This chapter will now explain additional possibilities required for the detailed analysis of the PROFINET network, exceeding the scope of simple networking analysis.



For additional information and training offers provided by PNO on the issue of troubleshooting, please visit:

www.profinet.com

The following procedures are recommended:

- Check the cabling structure (line tester)
- Measure the optical fiber performance
- Start Read Record Diagnosis at controller / live list
- Communication test using ICMP telegrams (e.g. ping)

A structured troubleshooting should be considered in addition to the PROFINET-inherent network diagnostic options. The exact type of network analysis and troubleshooting to a large extent depends on the manufacturer of your PROFINET solution. Many manufacturers are publishing free online tutorials and documentation on the analysis of automation plants.

In general, before you start your troubleshooting you should get an overview of the involved components and protocols. This will make it easier for you to locate any errors.

Make sure to always observe the following points:

- Never modify more than one thing at a time.
 - You will have problems to evaluate the combined effects of several modifications.
- Document of the effect of this modification
 - Retroactive troubleshooting is complicated by this and may cause outages at a later stage.

- It is therefore necessary to document any modification and to immediately reverse if it does not resolve a problem or does not have any immediate implication. This must also be documented.



Troubleshooting in networks is a matter of practice and may take some time. It is however the only way to ensure trouble-free and safe operation of the plant.

Troubleshooting requires in-depth, detailed know-how. Practical experience will always add the required detailed knowledge.

6.2 PI Competence and Training centers

PI Competence Centers (PICC) can provide expert help on troubleshooting PROFINET systems. PI Training Centers (PITC) can additionally provide accredited training on commissioning and troubleshooting. Such training is highly practical and involves hands-on exercises on real PROFINET systems. Certified PROFINET training is recommended for all persons that are involved in installation and commissioning of PROFINET.

6.3 Checking the cabling infrastructure

One of your first troubleshooting activities should be to check the cabling infrastructure. Errors may easily creep in here, in case the routing of the PROFINET copper cable has been changed during installation of the plant. In this context, the maximum segment length might be exceeded easily. It is **100 m** for PROFINET copper cables.



In case modifications or upgrades have been performed, the steps described in chapter 3, 4 and 5 must be executed.

This procedure is equivalent to a detailed troubleshooting.

Check the cabling structure. The following points provide a rough indication for checking upgrades and also for troubleshooting:

- Have the permissible cabling structures been observed during planning?
- Have the maximum permissible segment lengths (e.g. **maximum 100 m for copper cable**) been observed during planning?
- Has the PROFINET network been installed according to the planning?
- Have potential modifications of the installation, compared to the planning, been documented?

In case of modifications:

- Has the existing plant been modified?
- Has the cabling structure been complied with when carrying out the modifications?
- Has the maximum permissible segment length been observed for the modifications?
- Have the modifications been documented?

In addition to checking the network cabling, shielding, earthing and equipotential bonding should also be checked. Equipotential bonding and/or shielding problems may cause unreliable communications.



Since equipotential bonding problems are very hard to identify, you should check all connections of the equipotential bonding.



In this case you should also check the correct power supply of components recently added to the system since potential error sources cannot be excluded at this point, too, e.g. caused by overload.

6.4 Measurement of FO cables

Two technologies for optical fiber measurement have already been described in chapter 2. The insertion loss measurement indicates whether the overall attenuation of a FO link complies with the requirements of PROFINET. Furthermore, OTDR measurements (OTDR = Optical Time Domain Reflectometer) are of special interest for troubleshooting. Here, the measurement results can be used not only to point out the existence of a problem, but also the exact position and type of problem.

Here, the device sends a signal into the optical fiber. Parts of the signal are reflected or absorbed at junctions or discontinuities. The measurement instrument now detects the amount of reflection or absorption of the transmitted signal, but also the time difference between transmitting and receiving the signal. These measurement results can then be used to identify discontinuities and the fault position in the link. Splices, connectors or links show varying characteristics in the Diagram.



Compare the introductory chapter 2.2 which explains the different measurement principles for the evaluation of optical fibers.

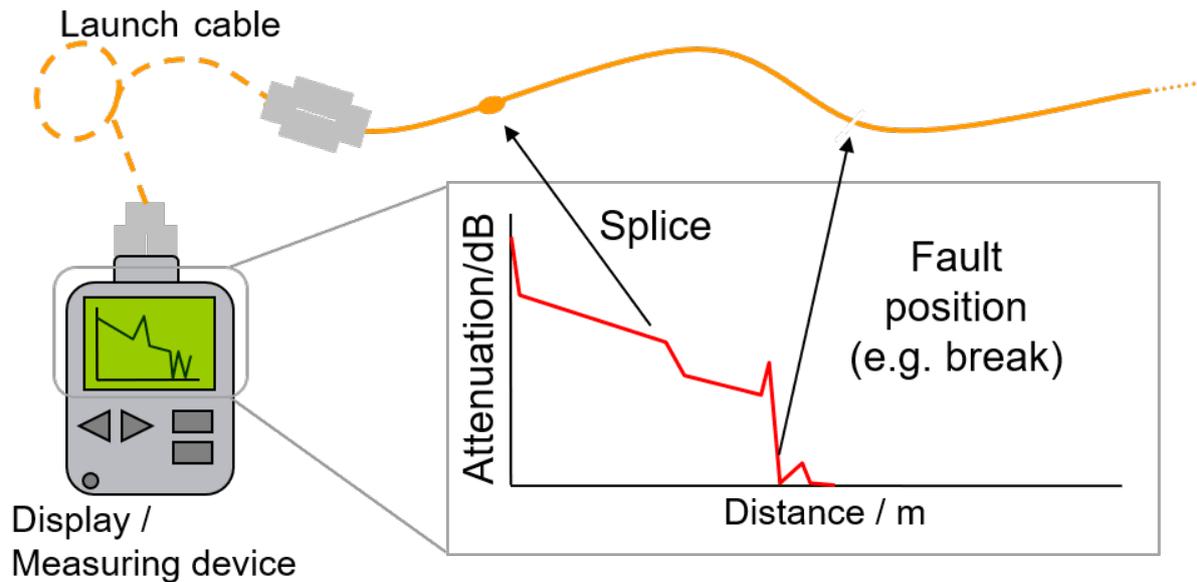


Figure 6-1: OTDR measurement

With OTDR measurement the results are shown in a graphic which has to be interpreted by the operator.

6.5 Checking connection

If you have so far not been able to identify the error source, you should now look at the activities of the PROFINET devices on the network. For this purpose, most manufacturers of PROFINET controllers offer an interface for monitoring the activities on the monitored network. See also chapter 2.3.

Another simple test to determine the establishment of a connection is the test using ICMP telegrams (Internet Control Message Protocol). The ICMP protocol is by default supported by all PROFINET devices. Depending on the operating system, a program is used for sending these telegrams (“ping”). A reply will be sent by the contacted device immediately upon receipt.



Based on this test, problems can be isolated in more detail, facilitating the search on protocol level. The ping should be executed in the local network.

6.6 Read Record (diagnostic data sets)

Potential problems are not limited just to the PROFINET network. Problems may also result from power supplies, IO cabling or sensors or actuators. PROFINET has extensive diagnostic functions in order to isolate potential problems. The PROFINET device diagnostics information is communicated to the PROFINET controller. The PROFINET controller thus has up-to-date diagnostics information from the individual PROFINET devices.

The diagnostic information of a PROFINET device consists of module- and end to end link-specific diagnostic data.

It is also possible to report PROFINET device-specific diagnostic information to the controller.

PROFINET also offers the possibility to read, via "Read Record", current diagnostics directly from the devices as data record. In many cases the engineering tools offer a possibility to read out diagnostics records (online diagnostics). These sometimes display the diagnostic information as plain text.

Data records can also be read using special tools or in some cases using controller functions. In such cases a manual analysis is required. You can find the coding of data records for example in IEC 61158-6-10. Some manufacturers offer the required information as handbooks.

7 Annex

7.1 Check-list for the visual inspection of PROFINET installations

Step	Action	
1.	Cable laid according to plan?	<input type="radio"/>
2.	Cable type according to planning?	<input type="radio"/>
3.	Maximum 100 m observed for copper cable (Check, e.g., the length printed on the cable, else make an acceptance measurement)?	<input type="radio"/>
4.	Maximum number of connectors in end to end link observed?	<input type="radio"/>
5.	Connector used according to planning (RJ45, M12...)?	<input type="radio"/>
6.	Minimum cable distance or metallic separating strip inserted if necessary?	<input type="radio"/>
7.	PROFINET cable undamaged?	<input type="radio"/>
8.	Bending radii observed?	<input type="radio"/>
9.	Cable junctions right-angled?	<input type="radio"/>
10.	Sharp edges at the cableway removed or covered?	<input type="radio"/>
11.	No kinks in the cables?	<input type="radio"/>
12.	Precautions taken against mechanical damage at critical points? (e.g. wall ducts)	<input type="radio"/>
13.	Strain relief built in?	<input type="radio"/>
14.	Cable parameters verified?	<input type="radio"/>
15.	Protective caps exist for connectors and links?	<input type="radio"/>
16.	Equipotential bonding implemented according to applicable regulations?	<input type="radio"/>
17.	Cable shield applied at the PROFINET stations and connected to equipotential bonding?	<input type="radio"/>
18.	Cable shield at cabinet entrance connected to equipotential bonding?	<input type="radio"/>

19.	Cableways connected to equipotential bonding?	<input type="radio"/>
20.	Topology observed?	<input type="radio"/>
21.	Links labeled and marked?	<input type="radio"/>
22.	Free Ethernet port available for diagnostics connection?	<input type="radio"/>
23.	Power distribution wired according to structure plan (Correct assignment of 24 V / 230 V or another mains voltage)?	<input type="radio"/>
Additionally, in case of PROFI-safe installations		
24.	Only devices used in network which are IEC 61010-certified (in the EU: CE mark)?	<input type="radio"/>
25.	Only PROFI-safe devices used in network which are PROFINET and PROFI-safe-certified?	<input type="radio"/>

7.2 Check-list for the acceptance of the PROFINET FO cabling

1.	Visual inspection of cabling
	<ul style="list-style-type: none"> - As described in chapter 3.2.1.2.
2.	Attenuation measurement for optical fibers
	<p>For this measurement you should use a simple instrument to determine the insertion loss as described in chapter 2.2.1.</p> <p>The measured attenuation shall not exceed the maximum permissible PROFINET FO end to end link attenuation according to Table 2-1.</p>
3.	Extended functional measurement for optical fibers
	<p>Even if not mandatory, it makes sense to add some more parameters for the acceptance of the PROFINET optical fiber link:</p> <p>Data to be added may include:</p> <ul style="list-style-type: none"> - Cable length - Distance between junctions (connectors/splices) - Fraction of the attenuation allocated to fiber, connectors, splices - etc.

7.3 Check-list for the acceptance of the PN copper cabling

1.	Visual inspection of cabling
	<ul style="list-style-type: none"> - As described in chapter 3.2.1.2. - Maximum number of connectors observed? - etc.
2.	Simple functional measurement for copper cabling
	<p>For this purpose you should use a simple line tester as described in chapter 2.1!</p> <p>The main criteria for evaluation of the cabling are :</p> <ul style="list-style-type: none"> - Is there is no short circuit between the wires? - Is there is no short circuit between individual wires and the shield? - Are the wires are intact? - Has the shield has been attached correctly? - Have the performance values been met? - etc.
3.	Extended functional test for copper cabling with 100 Mbit/s or above (optional)
	<p>This measurement requires instruments with extended functionality which “simple” line testers usually do not provide. This can include the evaluation of :</p> <ul style="list-style-type: none"> - cable length (is it below 100 m?), - near-end and far-end crosstalk, - permissible attenuation values, - potential reflections on the link. -

4.	Acceptance measurement for copper cabling 10 Mbit/s Ethernet APL (optional)
	<p>For this measurement, measuring devices for Ethernet APL cabling are required. The cable parameters can be found in the Ethernet Port Profile Specification [APS2021].</p> <ul style="list-style-type: none">- Cable length for spurs 200 m for cable category IV. For other cable categories less <p>The cable length for a powered trunk depends on the number of components on the APL segment and their power consumption as well as the cable cross-section See [APL2021].</p> <ul style="list-style-type: none">- Further measurements according to the cable parameters in [APS2021

7.4 Acceptance protocols

The following section provides some suggestions for the commissioning or acceptance protocols for PROFINET networks.

PROFINET acceptance protocol part 1: Visual inspection		
Description		Comment
Available documents up to date?	<input type="radio"/>	
Installation acceptance test complete?	<input type="radio"/>	
Installation acceptance protocol available?	<input type="radio"/>	
Power supply correct?	<input type="radio"/>	
Planning carried out?	<input type="radio"/>	
Planning stored on data carrier?	<input type="radio"/>	
All PROFINET controllers commissioned (<u>current</u> planning data transmitted)?	<input type="radio"/>	
All PN devices commissioned?	<input type="radio"/>	

All PROFINET nodes signaling readiness for operation?	<input type="radio"/>	
PROFINET acceptance protocol part 2: Diagnosis		
Description		Comment
Topology in accordance with requirements? (e.g. max. line depth observed)	<input type="radio"/>	
All PROFINET nodes accessible?	<input type="radio"/>	
IP addresses assigned according to planning?	<input type="radio"/>	
Device names according to planning?	<input type="radio"/>	
Firmware revision levels according to planning	<input type="radio"/>	
Update times according to planning?	<input type="radio"/>	
Communication monitoring according to planning?	<input type="radio"/>	Value: _____

Limit values for system reserve of optical fibers observed?	<input type="radio"/>	
Description		Comment
Limit values for rejected packets observed?	<input type="radio"/>	
Limit values for network load observed?	<input type="radio"/>	
Limit values for ARP broadcasts observed?	<input type="radio"/>	
Limit values for DCP multicasts observed?	<input type="radio"/>	
Limit values for MRP multicasts observed?	<input type="radio"/>	

7.5 PROFINET Documentation

This chapter makes a proposal for the documentation of PROFINET networks. The notes are to be regarded as recommendations. Depending on the conditions in the system or in the company, it is possible to deviate from the specifications.

7.5.1 PROFINET information relevant for documentation

Prior to starting the documentation, the following aspects should be clarified:

- Responsibilities
 - For the creation of the network documentation
 - For the management of the network documentation
 - Are there any persons responsible for the plant? Are there any responsibilities for individual plant sections?
- How and where will the documentation be distributed?

The cover page should contain all relevant information needed for identifying the document:

- ID of the documentation
 - Document type (here: Network documentation)
 - ID number / name
 - Date of issue
 - Revision index or version
 - Revision date
 - Document status (is it a draft or final version?)
 - Specific data (customer name, plant name)
- Information on the creator
 - Company name
 - Company address
 - Responsible author

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- Information on the creator
 - Company name
 - Company address

- Responsible author

The network documentation should range from a network overview for the entire plant over detailed views of the networks of plant section up to device-specific information. A topology overview is a visual representation and, hence, provides a good introduction.

- For example, an R&I diagram, plant structure or the architecture of the premises.
- Enter the assets into the drawing
 - Automation devices
 - Network infrastructure
 - Cabling including patch fields
 - The cabling order must be represented correctly.
 - Ring topologies must be marked.
 - The persons responsible of the plant must be noted.
- The identifiers/names of the devices must be included.
 - Device type (e.g. PLC, switch, repeater, etc.)
 - Make a clear allocation to the locality.
 - Specify the building (part).
 - Specify the room.
 - Make a note of the spot height to allow for easy device localization (e.g. in a high-bay storage).
 - Note the cabinet.
- The connection terminals (ports) of the devices must be designated.
- Segmentation plan
- Information on the cable
 - Cable length between two nodes
 - Used cable type (included in cable list?)
 - Note the medium (copper, FO).
 - Where are OLMs (Optical Link Modules) used?

For reasons of simplicity, further information should be documented in a separate Annex about topology.

- Information on the products
 - Manufacturer
 - Serial numbers of the devices
 - Model name / type designation
 - Spare parts
 - Serial number
 - Type number
 - Version number
 - Supplier (or alternative supplier)

- Reference picture
- Store data sheets.
- Describe the device functionality.
- Certificates
- Document the used software or firmware revision levels.
- Document the reference measurements of the network.
 - Measure and document the network load in normal operation.
 - Mark any points where EMC disturbances have to be expected.
 - Validation report of the physical layer (what are the physical variables during commissioning?)
 - Validation report of the communication layer (what does data modulation look like?)
 - Validation report of the hazardous area (which devices are used in the hazardous area?) Are these devices certified?
 - Are there any delays? How long is the delay?
- Information for cases of faults
 - List for fault localization
 - Description of integrated diagnostic systems
 - Drawings and diagrams
 - Contact information for further help (hotline/support)
 - Who is responsible of the plant (parts)?

Further information needs to be documented for PROFINET networks.

- Document the device name in the topology plan.
- Note the IP address on the device in the topology plan.
- Note the subnet mask on the device in the topology plan.
- List the MAC addresses of the devices.
- Are the GSD saved? Which GSD are used?
- Which protocols are used? Which services are supported?
- Ring topology and corresponding switch-over times

The following special documentation items must be listed for an IT security audit:

- When firewalls are used
 - Is the firewall password-protected?
 - Mark the (physical and logical) installation site.
 - Document the set of rules for the firewalls.
- Virus scanner
 - Does it exist?
 - How often is it updated?
 - How often is the segment scanned?

- Which ports/services are active?
- Does the current firmware revision levels feature any security gaps?
- Do VLANs exist?
- Passwords
 - Do they exist?
 - Was the default password, if any, changed?
 - Are access rights to the passwords defined?
- Are access rights to sensitive rooms defined? (R&D)
- Documentation of employee training
- Is an emergency manual available?
 - Which rules of conduct are to be followed in the event of a cyber attack?

7.5.2 Proposal for a PROFINET forwards documentation

This section is intended to further explain the information in section 7.5.1. The individual steps of forwards documentation are discussed and the difficulties are described.

A network documentation often addresses more than one target group (persons in charge of the installation, revision, operation, troubleshooting or audit). In a simplified approach, however, it is possible to identify two fields of interest (see Figure 7-1).

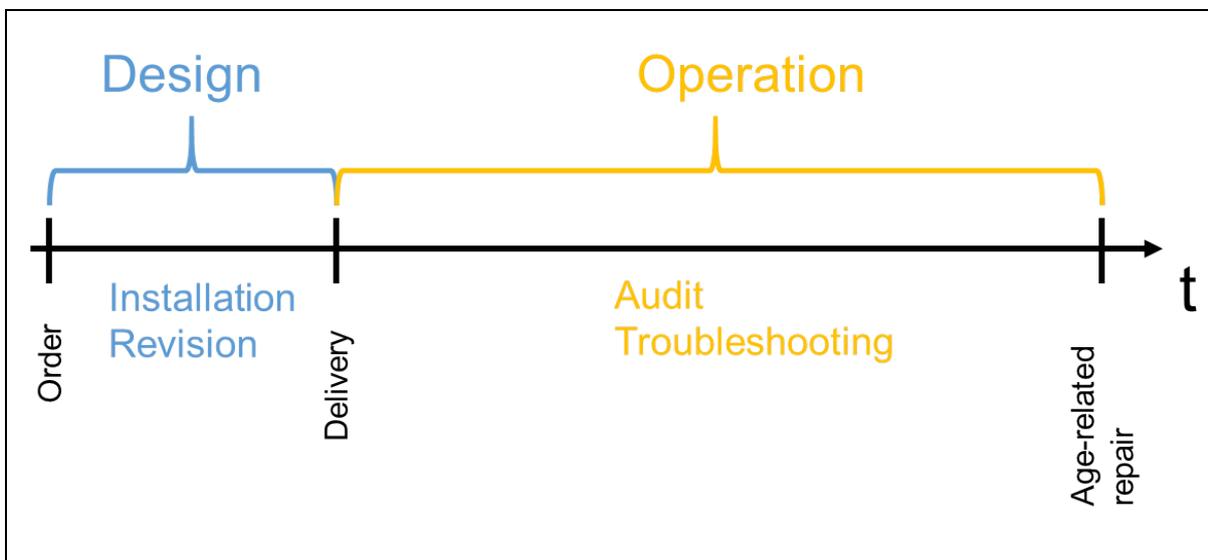


Figure 7-1: Fields of interest in a plant lifecycle

As the installation and revision departments normally use electrical wiring diagrams, the plant operators are the main target group of the network documentation.

The next step defines the format in which the network documentation is to be created. It must be clarified whether printed plans are to be published or digital documentation is to be used instead. Mind the fact that sensitive data must be access-protected. Digital plans must be saved in a file format which ensures (read and write) access and data readability and integrity. Also pay attention to the retention obligation. The documentation must be available for the retention period.

The persons responsible for the document creation and management during the operation phase must be defined. For large companies or plants the persons responsible for the corresponding plant or plant sections must be contacted.

Every forwards documentation begins with a cover page. The cover page should provide the information relevant for identification (plant, creator, responsibility). The document revision information (index, date) provides the revision level and allows you to clearly determine whether the document is up to date. It is also useful to indicate the status on the cover page. Moreover, it must be possible to clearly identify the creator for possible questions.

A table of contents must be included after the cover page. The more details the table of contents contains, the better, as you can directly access the information needed.

Begin with the topology plan. It is helpful to use the architecture or an R&I diagram as a template. All necessary network nodes must be integrated and numbered consecutively. Assign unique device names. The name should indicate the type or function of a node and also its location (building or building part, room). The spot height can also be provided. Add the IP address and subnet mask of each device to the topology. The plan must allow for easy identification of the responsibility for the segments or building parts.

Document all cables and connectors in the correct order. The port of each node must be noted in the plan to allow for unique identification of the device connectors. Special attention must be paid to patch field. Ring topologies must be marked expressly. Is it useful to assign a unique name to each connection (does a cable list exist?) and to note down the length of the laid cables. If different media (copper or FO cables, wireless) are to be used, these must be drawn differently.

Any further information and details should be moved to the Annex in order to keep the actual overview short and clear. It is recommended to list all further information in the Annex in a table and group the individual items by categories (product, cable).

Table 7-1 shows further information. Record the used protocols and services of the individual devices. All data sheets and certificates must also be stored. It is recommended to record in the documentation not only the information shown in Table 7-1, but also the type number, (alternative) suppliers and a picture of the node.

Add a network load calculation and measurement results of the network load in the individual segments to the documentation. Also record the data communication delays in the commissioning phase. Areas where EMC disturbances are likely to occur must also be marked. It is helpful to add a validation report for the physical layer and the communication layer. The reports should indicate whether and to which extent the physical (current, voltage) and communication-related (edge rise and fall times) PROFINET requirements were initially met by the plant.

Mark all integrated diagnostic systems and note the data of contact persons who may provide support (e.g. line manager, consultant engineer, hotline and support).

Table 7-1: Further information on the devices in the topology

No.	Device name	Manufacturer	Model/type	MAC address	HW revision level	Firmware revision level	Serial number
1	Sw.HA1.1	Manufacturer 1	Switch 12	12-34-56-78-9A-BC	1.3	1.3.1	ABC-12345
2	PLC.HA1.1	Manufacturer 2	PLC 5	13-24-56-11-90-01	2.0	2.2	1920-1812-8212-0

Additional information must be provided for an IT security audit. All places where firewalls are used must be marked in the topology to allow for the assessment of the IT security. Document the set of rules for each firewall. Also document whether default passwords were changed. In order to prevent any loss of knowledge or data in the event of illness, accident, death or job change of an employee, it is recommended to create and maintain a password list. Mind the access restriction and protection. Additionally, you should document all employee trainings related to IT security and have an emergency manual with rules of conduct to be followed in the event of a cyber attack. When using a virus scanner, document the update intervals and the frequency of virus scans. Also document all existing VLANs.

7.5.3 Example of a PROFINET forwards documentation

Table 7-2 shows the preliminary considerations.

Table 7-2: Example of PROFINET forwards documentation, preliminary considerations

Target group	Operator, special knowledge yes, special language yes	
Target country/language	Germany/German	
Type of publication	Printed documents, centrally managed plans, access only by counter-signature	
Number of copies	3 (1 design dpt, 1 operator, 1 external backup copy)	
Retention period	12 years, ensured by storage of printed plans in different locations	
Responsibilities	Creation	Company A, Mr. Sample
	Management	Company B, Ms. Example
	Plant	Ms. Meyer (administration) Mr. Smith (hall 1) Ms. Schulz (hall 2)

Figure 7-2 shows a cover page example.

<h1 style="margin: 0;">Network Documentation</h1> <h2 style="margin: 0;">PROFINET</h2>																							
Plant: ID No.: Issue date: Status:	Plant sections in hall 1 2508 25.08.2016 Released	Revision:	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%;">Index</th> <th style="width: 10%;">Date</th> <th style="width: 20%;">Created by</th> <th style="width: 20%;">Approved by</th> </tr> </thead> <tbody> <tr><td style="text-align: center;">1</td><td></td><td></td><td></td></tr> <tr><td style="text-align: center;">2</td><td></td><td></td><td></td></tr> <tr><td style="text-align: center;">3</td><td></td><td></td><td></td></tr> <tr><td style="text-align: center;">4</td><td></td><td></td><td></td></tr> </tbody> </table>	Index	Date	Created by	Approved by	1				2				3				4			
Index	Date	Created by	Approved by																				
1																							
2																							
3																							
4																							
Customer:		Customer Ltd. Customer Road 2 56723 Customer City																					
Created by:		Company Inc. Example Road 12 123456 Example Town	Responsible author: Mr. S. Sample																				

Figure 7-2: Cover page example for PROFINET forwards documentation

The information provided on the cover page should be repeated on all other pages. A title block on each page is a suitable means of achieving this. The title block must be placed in the bottom right corner of each page and contains all relevant information on the document. Table 7-3 lists the 15 most important items. Table 7-4 shows the structure of the title box in accordance with [ISO 7200] and Table 7-5; it also contains an example of the title box which will be represented on the following pages by a gray box for the purpose of simplification.

Table 7-3: Information in the title box in accordance with [ISO 7200]

Number	Data field
1	Legal owner of the document
2	Title
3	Supplementary title
4	Reference number
5	Change index
6	Date of issue of the initial version of the document
7	Language
8	Number of pages/sheets
9	Document type
10	Document status
11	Responsible department
12	Technical reference (contact person with required knowledge)
13	Name of the person who created the document
14	Name of the person who approved the document
15	Classification/key words

Table 7-4: Proposal for title box in accordance with [ISO 7200]

Responsible dept. (11)	Technical reference (12)	Created by (13)	Approved by (14)			(15)
(1)		Document type (9)		Document status (10)		
		Title, Supplementary title (3)		(4)		
				Rev. (5)	Date of Issue (6)	Lang. (7)

Table 7-5: Example of title box in accordance with [ISO 7200]

Responsible dept. Design 2	Technical reference Ms. N. Meyer	Created by Mr. S. Sample	Approved by Mr. K. Smith			
Company Inc.		Document type Network Documentation		Document status Released		
		Title, Supplementary title PROFINET Plant sections in hall 1		2508		
				Rev. A	Date of Issue 25.08.2016	Lang. En

Figure 7-3 shows the plant to be automated. It consists of three plant sections in hall 1 (responsible: Mr. Smith) of a company. A cabinet is already planned to be installed in the hall; therefore, it is represented by a dotted line.

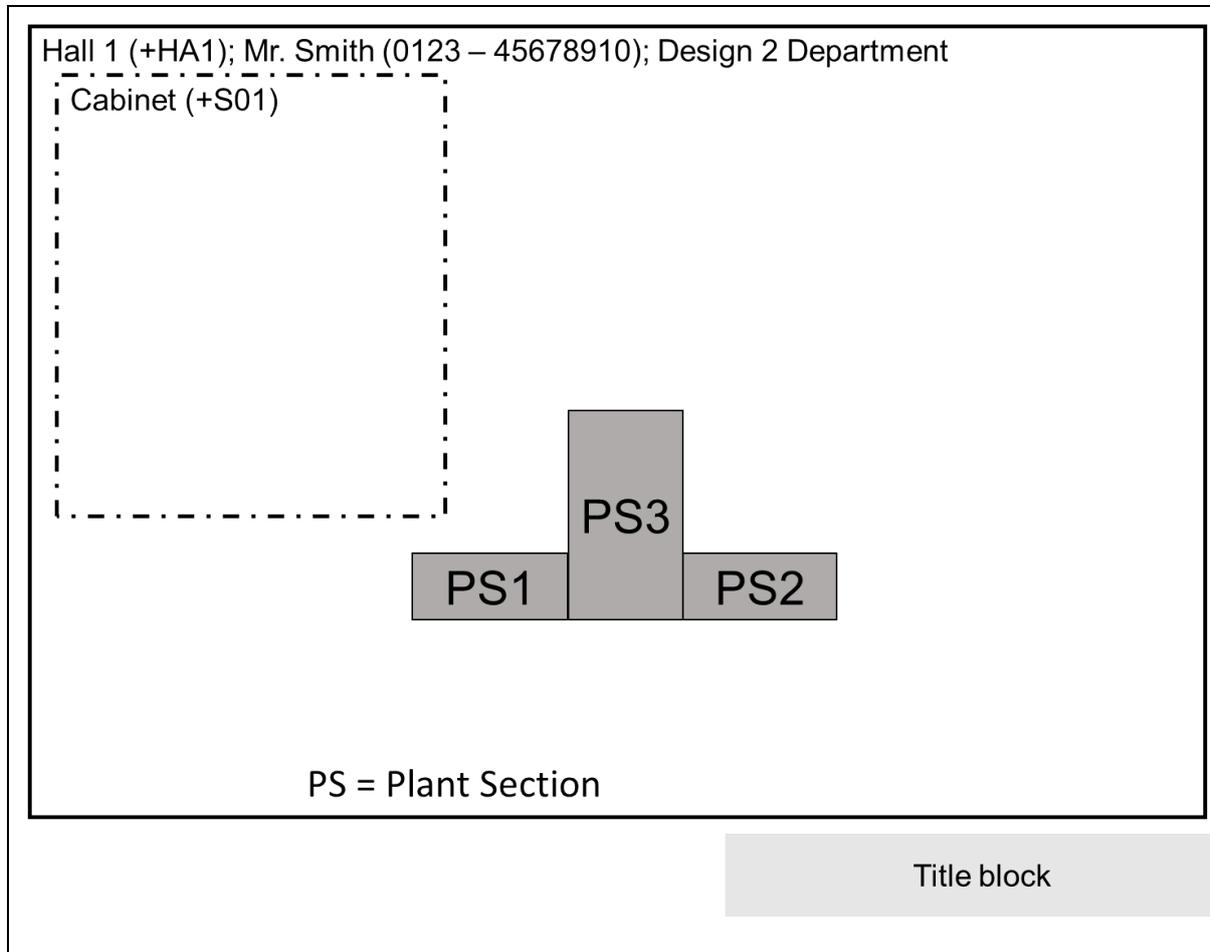


Figure 7-3: Example of forwards documentation for the automation of three plant sections

Figure 7-4 shows the configured automation devices and the required network infrastructure. In addition to a PLC and three remote IOs, there is a switch for connecting the network nodes and an HMI (Human Machine Interface) for visualizing the process. Figure 7-5 shows the logical topology plan.

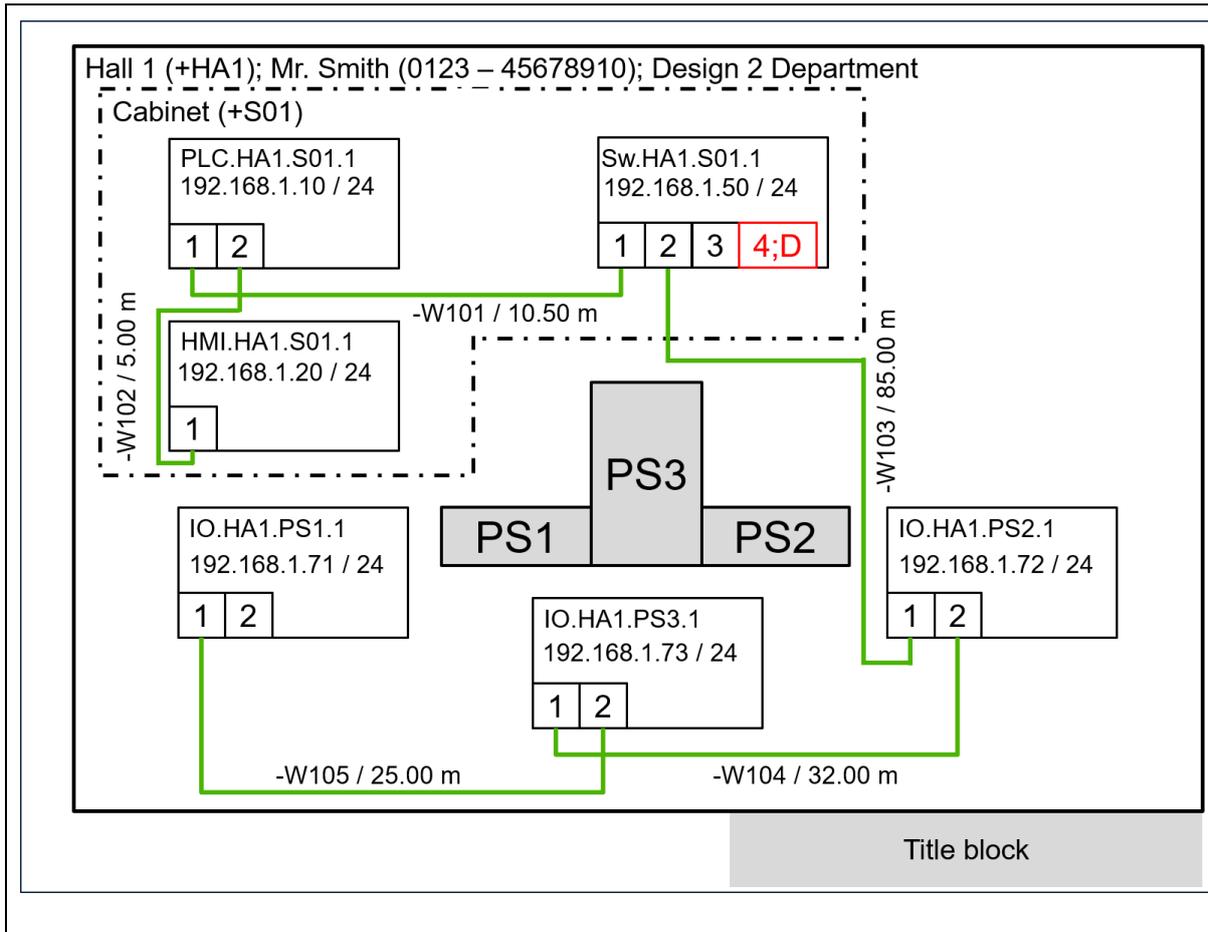


Figure 7-4: Example of PROFINET forwards documentation, physical topology plan

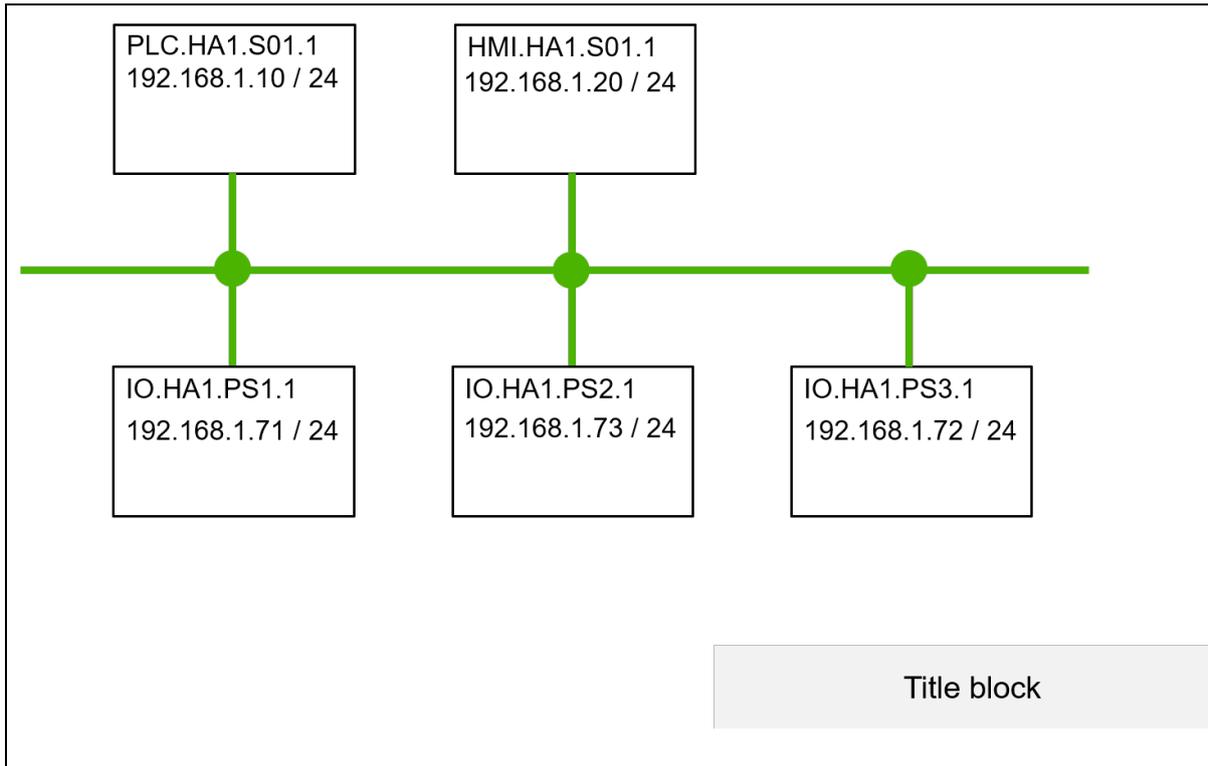


Figure 7-5: Example of PROFINET forwards documentation, logical topology plan

Figure 7-6 shows the topology plan of a ring topology. The switch (Sw+HA1+S01_1) is used to organize the ring. For this purpose, it is marked with a number (1) in a “ring”. The ring is drawn exactly between the two ports that spread it out.

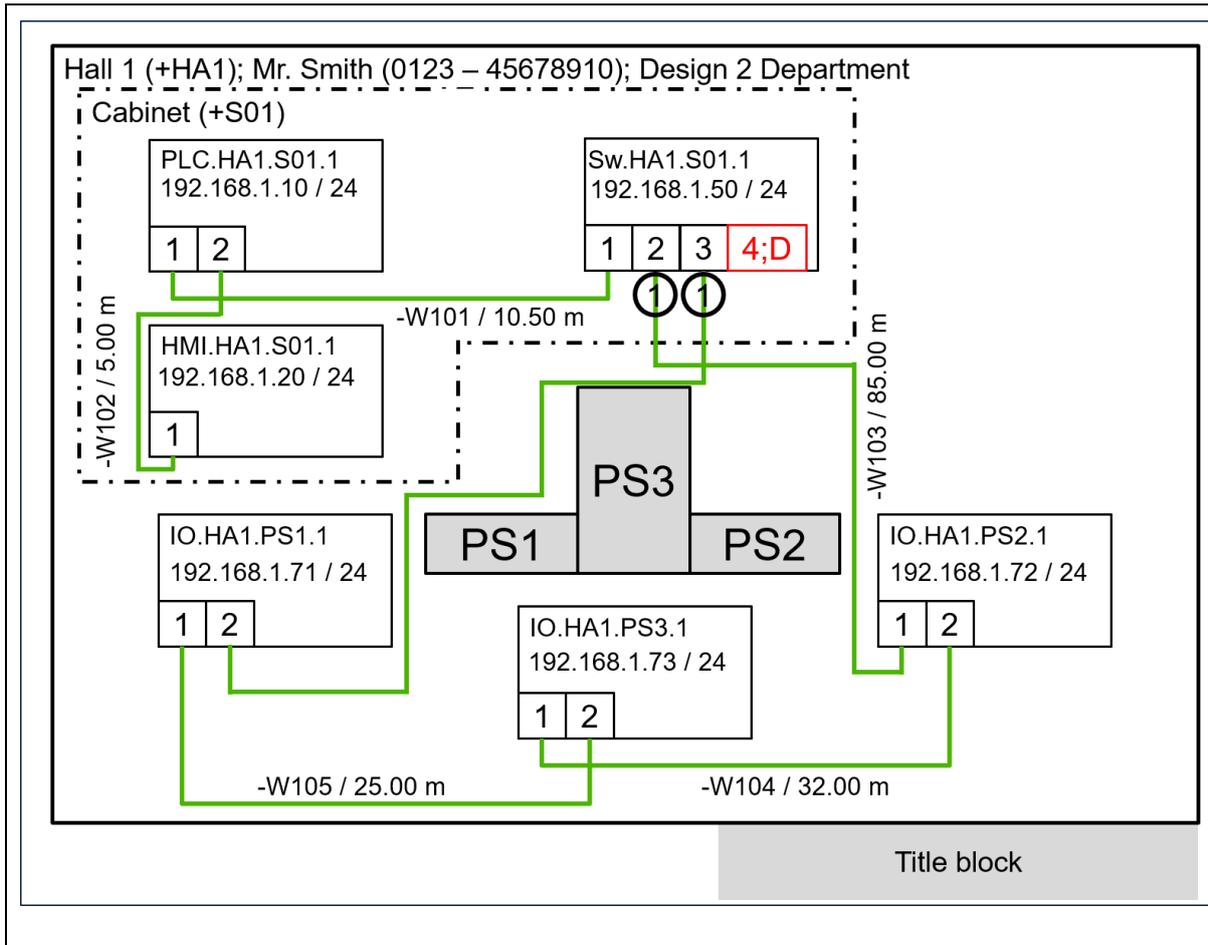


Figure 7-6: Example of PROFINET forwards documentation, ring topology

Table 7-6 enhances the topology plan (see Figure 7-6) with further information. The device in the first position manages the ring and, hence, has a different color.

Table 7-6: Example for PROFINET forwards documentation, information related to the ring topology

No.	Device name	Port	Next device		Port	Next device		Manager
			No.	Device name		No.	Device name	
1	Sw.HA1.S01.1	2	2	IO.HA1.PS2.1	3	4	IO.HA1.PS1.1	x
2	IO.HA.-PS2.1	1	1	Sw.HA1.S01.1	2	3	IO.HA1.PS3.1	
3	IO.HA1.PS3.1	1	2	IO.HA1.PS2.1	2	4	IO.HA1.PS1.1	
4	IO.HA1.PS1.1	1	3	IO.HA1.PS3.1	2	1	Sw.HA1.S01.1	

Table 7-7 contains further information on the automation devices and additional network nodes. Table 7-8 provides additional information for the replenishment. Table 7-8 summarizes the most important information on cables as an addition to the topology plan.

Table 7-7: Example for PROFINET forwards documentation, additional device information

No.	Device name	IP address	Subnet mask	Protocols	Port:Service	PW changed		MAC address	Firmware revision level	GSD saved? (version and storage place)
						Yes	No			
1	PLC.HA1.S01.1	192.168.1.10	255.255.255.0	PNIO + TCP/IP	80: HTTP	x		13-24-56-11-90-01	2.2	10.5 Server on 2016- 08-31
2	HMI.HA1.S01.1	192.168.1.20	255.255.255.0	PNIO + TCP/IP	80: HTTP		x	13-24-56-12-55-21	2.1	8.4 Server on 02.09.2016
3	Sw.HA1.S01.1	192.168.1.50	255.255.255.0	PNIO				12-34-56-78-9A-BC	1.3.1	1.1 Server on 02.09.2016

4	IO.HA1.PS1.1	192.168.1.71	255.255.255.0	PNIO				00-0E-8C-24-C5-51	2.5	1.3 Server on 02.09.2016
5	IO.HA1.PS2.1	192.168.1.72	255.255.255.0	PNIO				00-0E-8C-24-C5-4E	2.5	1.3 Server on 02.09.2016
6	IO.HA1.PS3.1	192.168.1.73	255.255.255.0	PNIO				00-0E-8C-24-C6-12	2.5	1.3 Server on 02.09.2016

Table 7-8: Example for PROFINET forwards documentation, enhanced device information

No.	Device name	Port	Cable	Device	Manufacturer	Model	HW/ FW revision level	Serial number	(Alternative) supplier Order number
1	PLC.HA1.S01.1	1	-W101	Sw.HA1.S01.1	Manufacturer 1	PLC 5	2.0 / 2.1.1	1920-1812-8212-0	Vendor X
		2	-W102	HMI.HA1.S01.1					7815182
2	HMI.HA1.S01.1	1	-W102	PLC.HA1.S01.1	Manufacturer 1	HMI 17	2.5 / 2.6	1231-3017-0111-5	Vendor X
		-	-	-					4825561
3	Sw.HA1.S01.1	1	-W101	PLC.HA1.S01.1	Manufacturer 2	Switch 12	1.3 / 1.3.2	ABC-12345	Vendor X
		2	-W103	IO.HA1.PS2.1					1541527
		3	-	-					
		4	-	-					
4	IO.HA1.PS1.1	1	-W105	IO.HA1.PS3.1	Manufacturer 3	IO S2	2.0 / 2.2	14-93-15	Vendor X
		2	-	-					4510965

Annex

5	IO,HA,-PS2.1	1	-W103	Sw-HA1-S01.1	Manufacturer 3	IO S2	2.0 / 2.2	14-93-15	Vendor X 4510965
		2	-W104	IO-HA1-PS3.1					
6	IO,HA1,PS3.1	1	-W104	IO-HA1-PS2.1	Manufacturer 3	IO S2	2.0 / 2.2	14-93-15	Vendor X 4510965
		2	-W105	IO-HA1-PS1.1					

Table 7-9: Example of PROFINET forwards documentation, cable list

Name	Connector 1			Connector 2			Actual length in meters (m)	Medium	Type / Nature
	Device	Port	Connection	Device	Port	Connection			
-W101	PLC.HA1.S01.1	1	RJ45	Sw.HA1.S01.1	1	RJ45	10.50	Cu	A
-W102	PLC.HA1.S01.1	2	RJ45	HMI.HA1.S01.1	1	RJ45	5.00	Cu	A
-W103	Sw.HA1.S01.1	2	RJ45	IO.HA1.PS2.1	1	M12	85.00	Cu	A
-W104	IO.HA1.PS2.1	2	M12	IO.HA1.PS3.1	1	M12	32.00	Cu	A
-W105	IO.HA1.PS3.1	2	M12	IO.HA1.PS1.1	1	M12	25.00	Cu	A

Describe normal plant operation in a clear manner (see Figure 7-7).

Figure 7-8 shows how the diagnostic port can be marked.

Segment: 192.168.1.0 – 192.168.1.255 / 24	
Tag	_____
Network load	_____ % (< 20 % all right; 20 .. 50 % review recommended; > 50 % need for action!)
No. of ARP broadcasts	_____ (0 all right; > 0 review recommended)
No. of DCP multicasts	_____ (0 all right; 1 .. 10 if cause is known and inevitable; 11 .. 20 consult design dept.; > 20 review recommended)
No. of MRP multicasts	_____ (0 all right; > 0 review recommended)
EMC disturbances expected?	<input type="checkbox"/> No <input type="checkbox"/> Yes, where: _____
FO available?	<input type="checkbox"/> No <input type="checkbox"/> Yes, attenuation: _____ dB
Delay in communication?	<input type="checkbox"/> No <input type="checkbox"/> Yes:
Title block	

Figure 7-7: Example of PROFINET forwards documentation, information in cases of faults

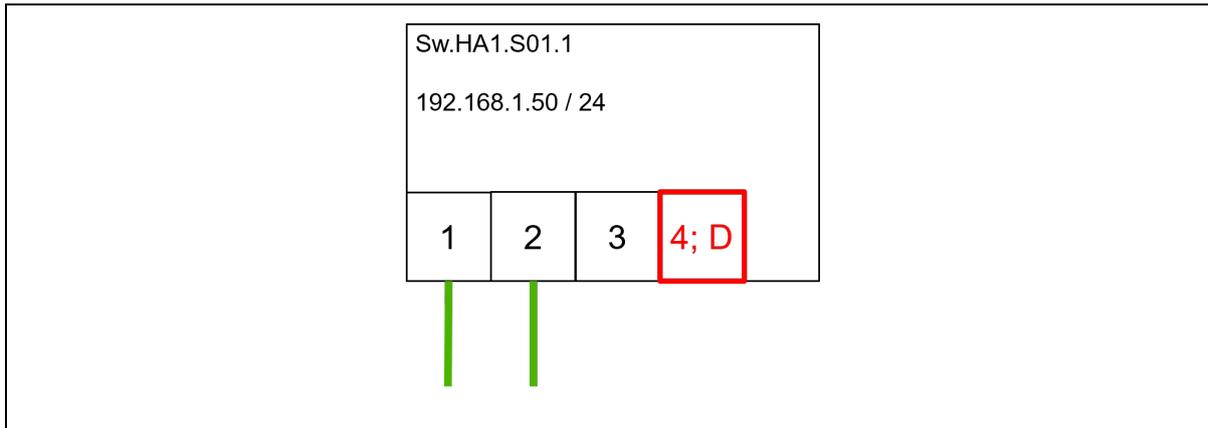


Figure 7-8: Example of PROFINET forwards documentation, diagnostic port example

The use of firewalls should be shown clearly in the topology. Further information related to the access and the default settings must be recorded in a separate list. Figure 7-9 shows an IT security assessment.

IT Security Assessment for Plant: Plant sections in hall 1 (ID No. 2508)

Security officer: Mr. Sam Sample

IT Security employee training
 First execution: 16.09.2016 Execution interval: Annually (every 12 months)

Next IT Security audit: 16.03.2017

Connection to other networks?: No Yes, where:

Virus scanner used? No Yes, where:
 Scan interval: _____ Update interval: _____

Emergency manual available? No Yes, where:

Access control to sensitive data? No Yes, how: Access through person transponder

Free device ports:

Device name	Port	Free?
Sw+HA1+S01_1	1	No
	2	No
	3	Yes
	4	Yes, diagnostics

Are there WLAN access points? No Yes, where:

Title block

Figure 7-9: Example of PROFINET forwards documentation, IT security assessment

Keep all data sheets and the manuals of the used devices. Add a functional description of the plant to your documentation.

7.5.4 Problems of forwards documentation in the product lifecycle

Deviations frequently occur in the installation or commissioning phase already. They should be eliminated in a revision. However, the large number of manual user interactions by different employees results in a high risk of faults. Once the system has been delivered to the plant operator, the designers are no longer responsible, and the knowledge recorded in a good network documentation is no longer available. In cases of faults, the employees of the plant operator normally attempt to eliminate the faults themselves. Minor changes of the plant are often not recorded as they have to be made under some time pressure.

A forwards documentation often contains many items throughout the entire lifecycle of the plant. These reduce the quality of the network documentation. The network documentation becomes unclear, difficult to understand or faulty. Often the network documentation is not up-to-date, the access is denied or the documents are missing.

Due to these detriments it is not recommended to use the forwards documentation in the operational phase of the lifecycle. Writing an up-to-date network documentation on site is more suitable for troubleshooting. A standardized backwards documentation helps reduce the time required for documentation.

7.5.5 Proposal for a PROFINET backwards documentation

The requirements on the backwards documentation must be reduced to a minimum as the documentation is generated automatically. The backwards documentation should also begin with an overview and then provide details. The cover page contains all relevant information needed for identification:

- ID of the documentation
 - Document type (here: Network documentation)
 - ID number / name
 - Date of Issue
 - Revision index or version
 - Revision date
 - Document status (is it a draft or final version?)
 - Specific data (customer name, plant name)
- Information on the creator
 - Company name
 - Company address

- Responsible author

The topology must be clearly designed and contain all additional information (device name, IP address, subnet mask, port assignment, cable length). Further information (cable type, cable medium) can be provided in tables. From the ports assignment you can derive free access ports of the plant. Additionally, the firewalls should be shown. Information about an existing password-protection can be written in the topology on the firewall or can be color-coded (green = password-protected, red = no password-protection)

Reading out the used network nodes is supposed to provide information on possible spare parts. This information includes:

- Manufacturer
- Model name/type designation
- MAC address
- Used protocols
 - Used ports and services
- Serial number
- Version number
- Reference picture
- Used software or firmware revision levels
- Contact information of the hotline or technical support
- Password security: Are standardized passwords used?

Any information that cannot be determined through backwards documentation must be provided by the employees.

Tools for analyzing PROFINET networks are already available. Various vendors offer tools for backwards documentation. Nearly all criteria can be met.

However, the information determined by commercial tools does not comply with the requirements of an IT security audit.

7.5.6 Difficulties of backwards documentation

A topology can only be read and visualized by the tools if all nodes are capable of handling the LLDP (Link Layer Discovery Protocol). This is an obstacle to using backwards documentation, as low-cost alternatives that do not support LLDP are often used in networks.

Moreover, passive network nodes require different measurement mechanisms and often result in incomplete network documentations, since passive network nodes cannot be recognized correctly.

7.5.7 Requirements on future backwards documentations

A backwards documentation should begin with a topology plan. Additional information must be visualized on the devices. This information includes the device, name, IP address, subnet mask, port assignment, device function (if not clearly indicated by the device name) and a reference picture of the device. Further information should be listed in tables. You can find an overview of all information in section 7.5.1.

The general network documentation can be used as the basis for information on IT security. All services must be disclosed for this. As a result, the device vendors should reveal the standard ports/services of their devices.

In order to allow for a successful backwards documentation, the plant manufacturers and operators must select the appropriate components. Additionally, the product manufacturers must provide more data for their products. The conversions process is ongoing.

7.6 Definitions

10Base-T

Standard Ethernet using two pairs of twisted wires, where the lower transmission rate causes less complex requirements to the transmission lines.

100Base-TX

Just as 10Base-T, uses two pairs of twisted wires, but requires Cat 5 cable. With 100 Mbps, 100Base-TX today is the standard implementation of Ethernet.

Absorption / Reflection

Process in communication technology which involves the absorption or reflection of parts of the signal by the medium.

Access Point

Usual name for a network device which provides the transition from wire-based technology to wireless technology.

Advanced Physical Layer (APL)

The Advanced Physical Layer (APL, Ethernet-APL) is based on 10BASE-T1L physical layer, specified in [IEEE 802.3cg]. Additional specifications for use in process industries are provided within the APL documentation such as the Ethernet APL port profile specification [APS2021].

Attenuation

An effect which causes degradations of the signal/data quality when transmitting data by means of lines.

Commissioning

The systematic process used to put a PROFINET network into operation, including the connected devices and the associated parts of a machine or of a plant. The steps include the configuration, parameterization, programming, troubleshooting at various system levels, such as PROFINET diagnoses, system diagnoses, program monitoring etc. The planning systems guide to these steps. The commissioning is complete once the system operates according to plan and according to the customer's requirements and once the system documentation has been completed.

Communication

In case of PROFINET, the electronic transfer of digital data between two network devices.

Crosstalk

Effect that may occur when data which are electrically transferred via communication or data cable cause an unplanned effect on the transmission taking place on parallel lines.

Data

IEC vocabulary: Re-interpretable presentation of information in a formal way, suitable for communication, interpretation or automated processes.

Diagnosis

Detection and determination of the cause of an incorrect or unexpected reaction by a PROFINET device. PROFINET provides tools which help to convert digital information into information that can be utilized by people, using helpful text directives or graphics.

DIN

Deutsches Institut für Normung, German Institute for Standardization (www.din.de)

EMI

Electromagnetic interferences which are usually caused by strong power lines or strong wireless systems. Such interferences can also be caused by strong engines or transformers.

EN (European Norm)

European standard/norm that is acknowledged and applied by all European countries. Many of the IEC standards have been accepted as EN standard

Ethernet APL

See Advanced Physical Layer

Glass fiber / optical fiber

Transmission line made of glass or plastic, used for the transmission of light waves. Other than electrical lines, optical fiber is unsusceptible to electromagnetic interference, thus allowing for higher cable lengths

Hazard

IEC 61508-4: Potential sources of danger. This term includes hazards for people that emerge within a short time (e. g. fire and explosions) plus such hazards that have a long-term effect on the health of people (e. g. waste of a toxic substance).

ICMP

(Internet Control Message Protocol) A protocol used to check connections. This is often used in combination with the term or the program "Ping". This program cyclically sends packets to a network device which immediately sends a defined reply, the "Pong".

IEC

International Electrotechnical Commission (headquartered in Geneva, CH)

Interface

General term for each connection and interaction between hardware, software and the user, but also between hardware and software themselves.

IO

Abbreviation for Input Output

IP address

An IP address (Internet protocol address) is a number that is used to address computers and other devices connected to an IP network. Technically, this number is a 32-digit binary figure when using the current standard IPv4. With the release of standard version IPv6, the length of the IP address has been extended to 128 bit.

ISO

International Organization for Standardization.

LAN

Abbreviation for a local area network which is used to transfer data between PCs, but also between Ethernet-based field buses.

MAC address

The MAC address (Medium Access Control address) is the hardware address of each individual network card which is used to clearly identify the device within the network. The MAC address is assigned to the layer 2 (data link layer) of the OSI model.

MAC addresses are six byte long, represented by means of a 12-digit hexadecimal figure. They consist of two parts. The first six characters indicate the manufacturer of the network card. The remaining characters represent a consecutive serial number. The network card

manufacturers each have reserved certain ranges. This makes sure that MAC addresses are globally unique.

Manufacturer ID

The PNO offers a reference list via the Internet which includes the manufacturer ID, the relevant company name and other useful information. This list has been partially coordinated with the reference list of the Hart Association.

Operator console

Operating panel of a PROFINET network.

PROFIBUS/PROFINET Nutzerorganisation e.V. (PNO, user organization)

PROFIBUS & PROFINET International has authorized the PROFIBUS Nutzerorganisation e.V. (PNO Germany) to install committees (C), working groups (WG) and project groups (PG) in order to define and maintain the open, manufacturer-independent PROFIBUS/PROFINET standard. The PNO was founded in 1989. The PNO is a non-profit organization headquartered in Karlsruhe, Germany. Members of PROFIBUS & PROFINET International are entitled to join the technical committees and the workgroups of PNO. Members can take an active role in the maintenance and development of PROFIBUS/PROFINET. This ensures the openness and manufacturer-independence of the PROFIBUS/PROFINET technology. For further information please visit <http://www.profibus.com/pi-organization>.

PROFINET

(Abbr. PN). This is a standard for industrial Ethernet in automation technology.

PROFINET cable

Medium for the digital transmission of data, available as copper cable and as fiber optic cable.

PROFINET components

Refers to all components of a PROFINET network (e. g. cable, connector, PN controller / device, switches etc.)

PROFINET end to end link

The PROFINET end to end link defines a connection between two active PROFINET network nodes and includes all connector junctions. The channel may be based either on copper or on optical fiber technology.

PROFINET controller

PROFINET controllers take care of the defined start-up of subnetworks as well as for the cyclic and acyclic exchange of data. The PROFINET controller exchanges signals between assigned devices and ensures that the signals are accessible for the engineering tool. Controllers are directly connected to the Ethernet.

PROFINET Device

A device is a field instrument which is controlled by means of a PROFINET controller. A device consists of several modules and sub-modules.

PROFINET supervisor

Name of the planning workplace (programming device).

PROFINET node

A device that communicates with other devices via the PROFINET cable (PROFINET controller, PROFINET device, PROFINET supervisor)

Programming device / supervisor / engineering workstation

Adapted to the size of the programmable logic controller (PLC) there is a multitude of programming devices and / or software which is distributed by the manufacturer.

Single-command programming devices: This programming device is useful for small modifications in an existing program.

Specific computer hardware and software from the manufacturer of special programming languages, such as “Ladder Logic”, contains special functions for automation applications or for the industrial environment. These programming devices are extended for planning purposes and therefore allow all commissioning steps.

PC-compatible software, required to be able to use a standard PC or a notebook as programming device. You need special hardware, e.g. a PROFINET interface, in order to complement this system to a planning tool.

Proprietary software

Manufacturer-specific software which is usually tailored to a certain product of this manufacturer.

Protocol analyzer

Software for the analysis of individual data packets on a network.

SNMP

(Simple Network Management Protocol) Protocol used for simple monitoring and control of IP-based networks.

Splice

Procedure for establishing a connection between optical fibers (FO cables) by means of a direct connection between single fibers without using connectors.

Switch

Active network component acting as an exchange in a network.

Subnet mask

A subnet mask, in combination with the IP address, serves as an attribute of an IP network which defines the number of hosts and subnets of a network.

System bus

A network which is superordinated to the field bus (in this case PROFINET) and which is responsible for the networking of automation plants.

TAP

A TAP is used to eavesdrop on data traffic without affecting the data traffic. This is done by “separating” a direct feed line and routing the data via a special hardware which records the data traffic. Finally the data are routed back to the normal line via the other connection of this hardware.

Twisted Pair

In computer technology, the term twisted-pair cable is used for cables where the two wires of a wire couple are twisted. The twisting each of one forward conductor and one backward conductor of a current loop (the wire couple) leads to data transmission being less susceptible to interference.

Web interface

User interface of a network component which is accessible via a browser.

Wavelength

Light has various different types which can be indicated in its wavelength. Starting from infrared light via the visible light to the ultraviolet light.

WiFi (WLAN)

Wireless communication to build up or to extend a Local Area Network (LAN). This network can be spread over a certain area (see Access Point) or can be pointed to cover certain distances (radio communication).

Measure for the receive quality in a wireless transmission system is the signal strength which is indicated either in dBm or in %.

7.7 Addresses

PROFINET Competence Center

The PI Competence Centers (PICC) can be contacted in case of problems related to PROFINET. The PROFINET Competence Centers are staffed with specialists who will help you in case of problems with PROFINET. The PROFINET Competence Centers also offer training and develop new components for PROFINET. PROFINET Competence Centers are available in many countries all over the world.



You can find the current addresses of PI Competence Center on the Internet at www.profinet.com

in the area Institutions & Support.

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