PROFINET

Design Guideline

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1.14	30.12.2014	Review Comments after Advisory Board review integrated

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1 Introduction

1.1 Preface

The goal of this PROFINET Design Guideline is to support engineers who have to design PROFINET automation systems, to facilitate the professional design of plants and to serve as a helpful guide for the step-by-step design of a plant.

The information is presented in a way which tries to be as brief and easy to understand as possible. It is nevertheless assumed that users have basic knowledge of PROFINET technology, electrical engineering and network technology.

This guideline is not intended as a PROFINET compendium. If you need more detailed information about PROFINET, please use the appropriate documents published by PROFIBUS Nutzerorganisation e.V. or comparable technical literature. This guideline does not cover the installation and commissioning of PROFINET. Please refer to the PROFINET Installation Guideline (Order No.: 8.072) and the PROFINET Commissioning Guideline (Order No.: 8.082) for more details.

This Design 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 Liability exclusion

The PROFIBUS User Organization has taken utmost care in the preparation of this document and compiled all information to the best of their knowledge. This document is nevertheless based on present knowledge, is of an informative character and is provided on the basis of a liability exclusion. Therefore, this document may be subject to change, enhancement or correction in the future without any reference. PROFIBUS Nutzerorganisation e.V. expressively refuses all types of contractual or legal liability for this document, including the warranty for defects and the assurance of certain usage properties. Under no circumstances shall PROFIBUS Nutzerorganisation e.V. accept liability for any loss or damage caused by or resulting from any defect, error or omission in this document.

1.3 PNO documents

PROFINET Installation Guideline

Order No.: 8.072, Version 1.0, January 2009

PROFINET Commissioning Guideline

Order No.: 8.082, Version 1.35, November 2014

PROFINET Security Guideline

Order No.: 7.002, Version 2.0, November 2013

PROFINET System Description

Order No.: 4.132, Version June 2011

PROFIBUS and PROFINET Glossary

Order No.: 4.300, Version 0.92, January 2007

Conformance Class A Cabling Guideline

Order No.: 7.072, Version 1.0, July 2008

PROFINET Cabling and Interconnection Technology

Order No.: 2.252, Version 3.1, March 2014

Physical Layer Medium Dependent Sublayer on 650 nm Fiber Optics

Technical Specification for PROFINET

Order No.: 2.432, Version 1.0, January 2008

1.4 Referenced standards

IEC 11801 (2013)

Information technology - Generic cabling for customer premises

IEC 24702 (2006)

Information technology - Generic cabling - Industrial premises

IEC 60364-4-41(2005)

Electrical installations of buildings - Part 4-41: Protection for safety - Protection against electric shock

IEC 60364-5-54 (2011) / VDE 0100-540

Selection and erection of electrical equipment - Earthing arrangements, protective conductors and protective bonding conductors

IEC 60529 (2010)

Degrees of protection provided by enclosures (IP Code)

EN 50174-3 (2013)

Installation technology – Cabling installation - Part 3: Installation planning and practices outside buildings

IEC 61140 (2014)

Protection against electric shock - Common aspects for installation and equipment

IEC 61300-3-4 (2001)

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

IEC 61158-2 (2013)

Industrial communication networks – Fieldbus specification – Part 2: Physical layer specification and service definition

IEC 61918 (2010)

Industrial communication networks – Installation of communication networks in industrial premises.

IEC 61784-5-3 (2013)

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

EN 50310 (2011)

Application of equipotential bonding in buildings with information technology equipment

EN 50174-2 (2011)

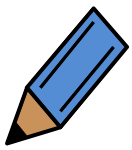
Information technology - Cabling installation - Part 2: Installation planning and practices inside buildings

1.5 Symbols and their meaning

The figures used in this guideline will help you better understand the text. In addition, symbols for text structuring will be used. These symbols highlight important text passages or summarize certain sections.

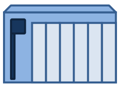
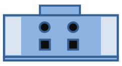
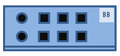
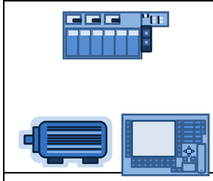
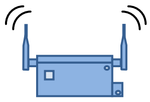
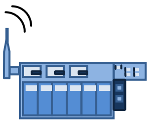
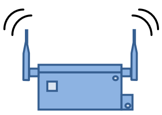
1.5.1 Symbols for structuring the text

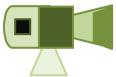
Table 1-1: Symbols for structuring the text

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!

1.5.2 Symbols for components

Table 1-2: Symbols for components

Symbol	Name	Meaning
	**Operator con-sole**	Command and control station
	**IO Supervisor**	An engineering station or PC with commissioning and diagnostic functions for PROFINET IO
	**IO Controller**	A device (typically a control unit) that initiates the IO data traffic.
	**Router**	Network component for interconnecting data traffic between different sub-networks.
	**Switch**	Device for the interconnection of several PROFINET devices.
	**IO Device**	A locally assigned field device that is allocated to a PROFINET IO controller.
	**WLAN access point**	A device that allows changing over from wired to wire-less communication.
	**IO device with WLAN**	Local field device with WLAN.
	**Wireless access point**	Device which provides a transition from wired trans-mission to wireless transmission.

	**Media converter**	Converter from one physical medium to another.
	**TAP**	Abbreviation of “Test Access Point”. Device for reading the network traffic without causing any impact
	**Video camera**	Device for image-based monitoring
	**Control station**	Standard PC with control functions
	**Server**	Server computer, e.g. for backup tasks.

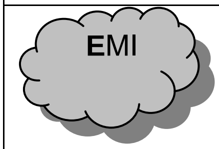
1.5.3 Symbols for PROFINET cables

Table 1-3: Symbols for PROFINET cables

Symbol	Name	Meaning
	Standard Ethernet	Standard Ethernet connection which does not involve the PROFINET protocol
	PROFINET copper cable	PROFINET Industrial Ethernet cable with copper wires Sheath color: green The dotted line indicates a connection with increased determinism requirements.
	FO	Fiber-optic cable Sheath color: green Note: for easier differentiation between copper and FO, the FO are highlighted orange in this guideline although the cable sheath is usually green. Once again, the dotted line indicates a connection with increased determinism requirements.
●	**Conductive link**	Electrically conductive link

1.5.4 Symbols for areas

Table 1-4: Symbols for areas

Symbol	Name	Meaning
	**EMI**	Area where the occurrence of electromagnetic interference (EMI) must be expected.

1.6 Template for documentation of design process

In general, the design process should be documented throughout the entire process. For this purpose you can use internal documentation tools based on your internal standards.

In addition, a number of engineering or planning tools offer additional functions for the documentation of automation plant design.

! Automation plant documentation supports the correct installation and commissioning. During the design process you should document all modifications in order to ensure correct operation in the future.

1.7 About the structure of this guideline

The structure of this guideline corresponds to the design process. This process will be followed step by step, while each modification in a later process shows a possible implication on the previous steps. Figure 1-1 shows the structure of the design process.

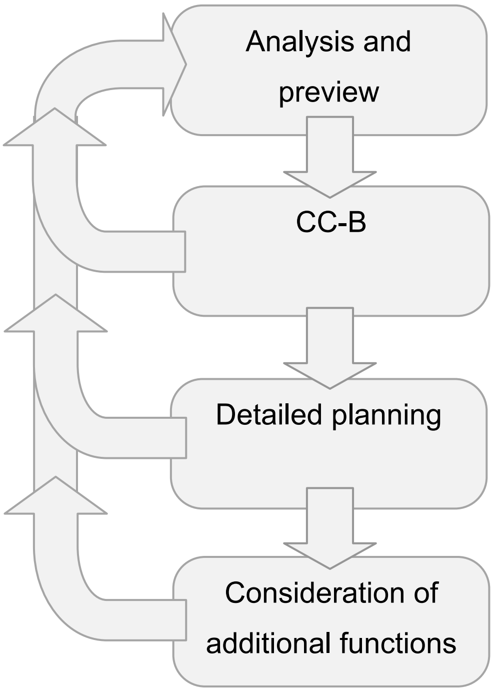


Figure 1-1: Design structure

The chapters of this design document follow this procedure. While chapter 1 contains an introduction, the following chapters go from general issues to the details of the design process. The chapters highlight the following issues:

Chapter 2: This chapter starts with a preview and analysis of the process to be automated. The properties and the placement of the automation components are described.

Chapter 3: This chapter includes the topology definition of the automation plant based on the findings gathered in chapter 2.

Chapter 4: The existing basic design is extended by such cases which are typically not part of PROFINET.

Chapter 5: In order to ensure the performance in a PROFINET network, based on the previous chapters, the PROFINET design aspects relevant for the performance are considered.

Chapter 6: PROFINET offers a multitude of possible applications for additional functions which require a special consideration. The chapter provides an overview of these functions.

Chapter 7: This chapter describes a careful planning of name and address assignment

Chapter 8: This provides a short summary of design results.

The annex (chapter 9) of this document also provides additional information about different components and their properties which are used in a PROFINET network. This includes information such as cable parameters or application examples for cable design and many more.

An index is provided in chapter 10 to facilitate the search for topic-related information in the guideline.

1.8 Goal of the guideline

The main goal of this guideline is to help you to select devices and networking components for a PROFINET system, and to design and layout the system to give reliable performance and allow easy installation, commissioning and maintenance.

After completion of the design process, the following information should be available or be generated.

- Plant design
- Topology
- Selection of components
- Selection of transmission medium
- Selection of connectors
- Communication relations
- Estimate of data volumes to be transmitted

In case any of this information should be missing, the design process has to be restarted at the relevant position.

2 Analysis and preliminary considerations

Before planning can start …

…you need an overview of your project. For example this may include the physical layout, a plan of the plant or the plant schematics.

This information provides a first idea of the extent of the PROFINET network to be designed.

The goal of the next section is to analyze and to describe the process to be automated.

The properties and the placement of the individual automation components will be defined. In addition, information will be provided about the points to be considered when selecting the components.

As a rule, bear in mind that PROFINET design is an iterative process followed step by step. If required, the process has to be repeated several times.

2.1 Determination of automation concepts

In the following step, the designer has to determine the components for plant automation. First, each component needs to be appropriately placed based on the plant design information or the building floor plan.

For example:

Controller placement in a separate switch cabinet away from the process or together with other PROFINET devices close to the process, remote I/O placed close to the process or in a remote cabinet, display panels for control close to the process or geographically remote for monitoring, etc.

The required components should then be added to the layout plan of the automation plant. After this, the components should be grouped to allow for geographical and functional component assignment.

The geographical assignment is usually created by considering the geographical proximity in the layout plan. The functional assignment is determined via common control tasks which can be determined from the mutual data exchange between control and periphery. It also makes sense to create a functional grouping according to the conformance classes (see next chapter).

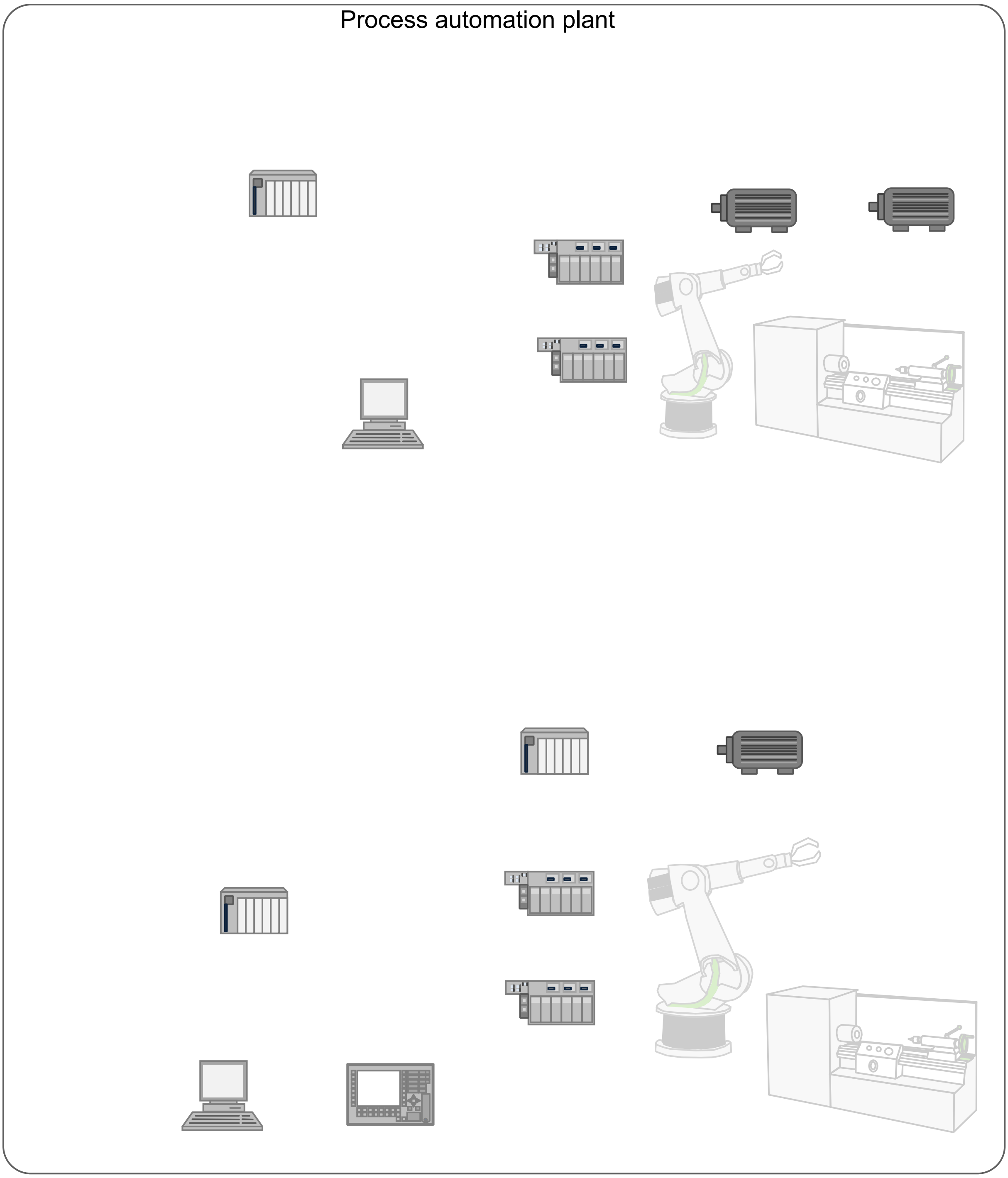


Figure 2-1: Floor plan of a plant with pre-placed components

In Figure 2-1, the initial placement of the automation components has been completed with the PROFINET devices positioned according to the task in the automation plant.

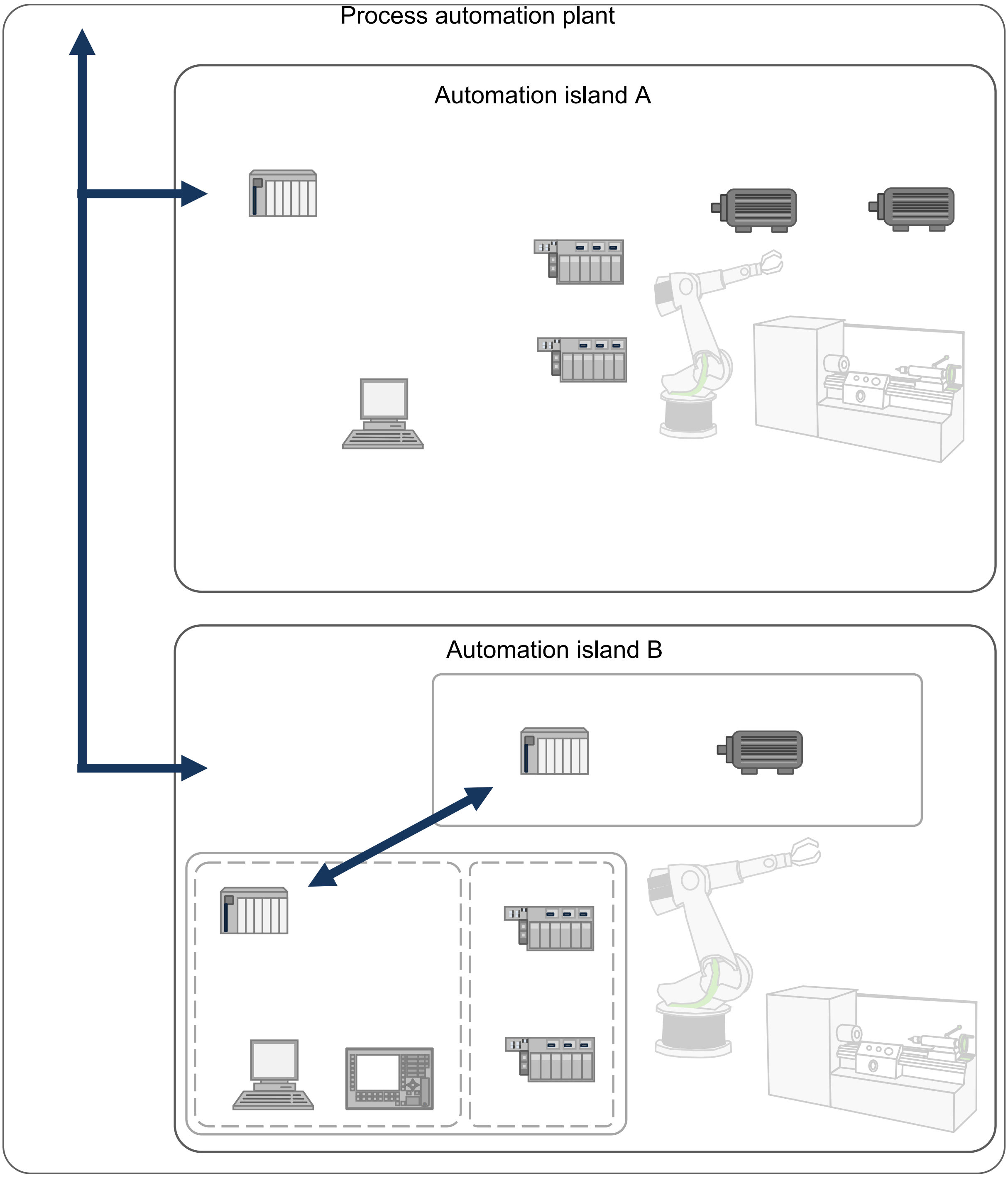


Figure 2-2: Sample layout plan of a plant with special assignment

Figure 2-2 shows the geographical and functional assignment of components. In this example the automation plant is sub-divided into two islands. The chosen arrangement depends upon local conditions which may occur, in this case, different plant areas.

The relationship between the controllers in automation island B does not only require a geographical differentiation, but also a functional differentiation - a fact that is indicated by the additional gray frames in automation island B. Another example might be a common task within the plant part but where each individual part has to meet different requirements.

There is also an additional geographical separation within the second plant part in automation island B since the PROFINET IO devices must be positioned separately from the rest.

It is furthermore necessary to identify any communication relations that are required between the control systems. These relations are shown as arrows in the example. At a later stage of design you have to check whether the required communication relation can be realized for the selected devices. If this is not the case, you have to foresee additional hardware components.

Direct communication between the control systems is required within island B, it is also necessary for these controllers to communicate with the control system within island A.

At this point, the components are not interconnected, but only positioned in the automation plant and combined to groups with different functionalities.

Mark the areas with increased requirements, e.g. determinism, to ensure they can be considered separately during the design.

2.2 Device selection

Depending on the required positions of the automation components within the plant, the PROFINET devices can now be selected. This chapter describes the preselection of PROFINET network nodes and their properties.

In general, the following criteria should be observed:

- Conformance Class
- Time request
- Consideration of device function
- Feasibility of the required communication relations
- Type of connection of PROFINET device (copper cable or FO with appropriate connection technology)
- Protection class of device
- other specifications

The preselection of devices according to the following criteria makes sure that your components are able to fulfill the automation task. You should also check the manufacturer data of the selected devices for possible restrictions and requirements.

2.2.1 The PROFINET Conformance Classes

The functionality of the PROFINET components has been categorized into application classes or so-called *Conformance Classes (CC)*. The target of these categories is to define reasonable functionalities in order to narrow down the decision criteria for plant operators when using PROFINET components.

For detailed information on the individual conformance classes, please use the document “PROFINET Conformance Classes” (Order No.: 7.041) provided by the PROFIBUS User Organization.

After assigning an application to a CC, the user can select a number of components which definitely meet the defined minimum requirements. All CCs already have a certain basic functionality. This may e.g. include:

- Cyclic data traffic
- Acyclic data traffic
- Identification and maintenance functions
- Prioritization of data traffic
- Basic mechanism for neighborhood screening and device swapping

Another grading has been added to these basic functions. So each conformance class (CC-A, CC-B, CC-C) defined different functionalities.

In general, these classes cover content such as

- the type of communication (TCP/IP and real-time communication),
- the **transmission medium** (copper, FO, wireless) used,
- synchronized communication and
- the **redundancy** behavior.

Figure 2-3 shows the structure of the conformance classes as well as an extract of their functionality.

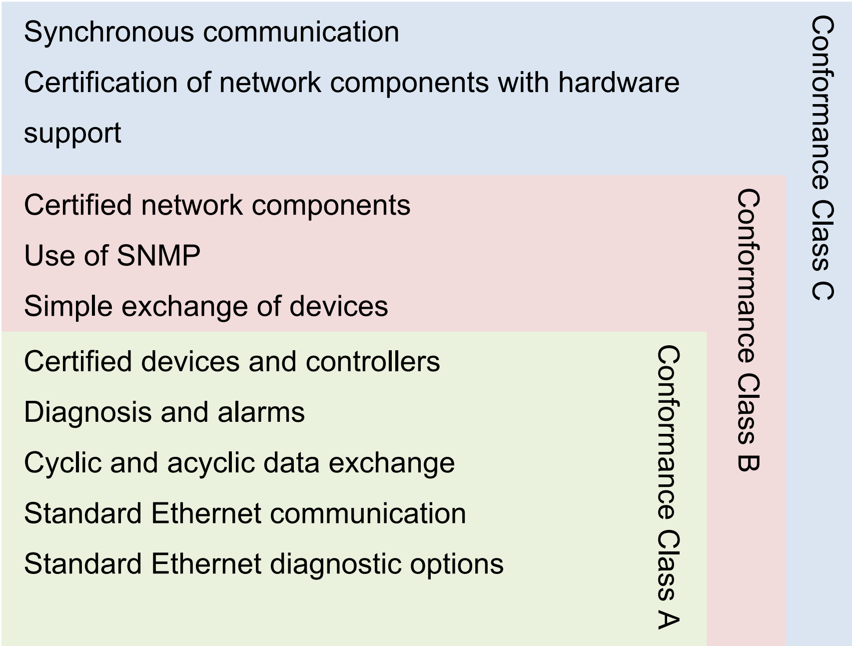
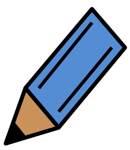


Figure 2-3: Classification and content of the individual conformance classes

As you can see from the figure, CC-B includes the functionality of CC-A. The same is true for the functionality of CC-C which in turn includes the functionality of CC-B and thus also CC-A.

You should define the conformance class of each device in the design phase. To ensure that the required functionality will be available in a certain PROFINET device.



Mark the plant parts that are subject to special requirements. You should check whether the conformance class you have defined really covers this requirement profile, and adjust the selection of PROFINET devices accordingly.

2.2.2 Special timing requirements

General information on communication

While a real-time channel is used for cyclic transmission of process data, PROFINET offers an additional channel based on standard Ethernet communication (standard channel) for acyclic services such as parameterization and diagnosis. Table 2-1 shows the basic differences between these two communication channels.

Table 2-1: PROFINET data channels

Standard channel	Real-time channel
Reading of diagnostic data	Cyclic data exchange
Acyclic data exchange	Synchronous data exchange
Device parameterization	Alarms

PROFINET also enables unrestricted open TCP/IP data traffic (non real-time data traffic), with real-time communication getting higher priority compared to non real-time communication.

In addition to the terms mentioned above, the following terms have been established for PROFINET transmission technologies:

IRT: Isochronous real-time, for a cyclic data transmission which is the basis of a synchronous application.

RT: Real-time for a cyclic data transmission.

NRT: Non real-time for an acyclic data transmission (e.g. TCP / IP, UDP / IP).

For more detailed information about the structure of communication and the properties of data channels, please use appropriate literature.

Definition of the timing requirements

Depending on the target group, PROFINET devices face different requirements in terms of timing. In general we distinguish between the timing of the application on the automation plant and the communication on PROFINET.

Table 2-2: Differentiation between application and communication

Communication	Application
Real-time (RT)	Non-synchronous application
Isochronous real-time (IRT)	Non-synchronous or synchronous application

The communication and the application have to be fit to each other.

A synchronous application can be only be realized via an isochronous communication.

To facilitate the selection of PROFINET devices, the various conformance classes include appropriate communication request profiles, starting from CC-A with a simple standard Ethernet transmission, up to CC-C for synchronous transmission.

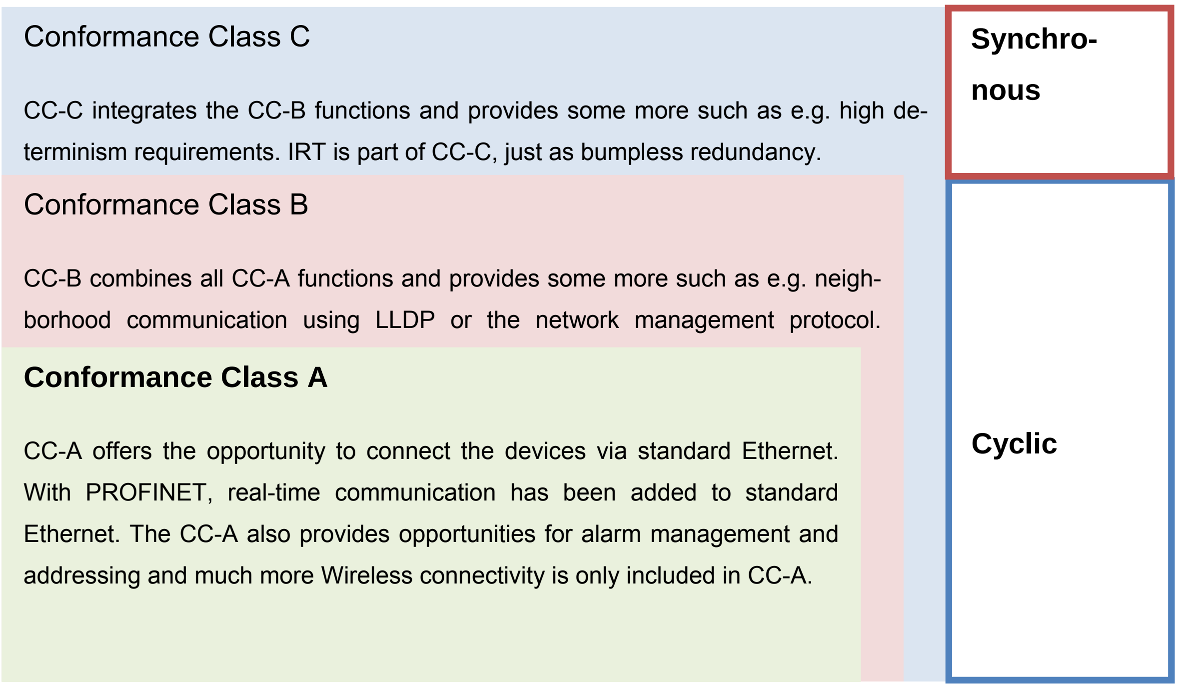


Figure 2-4: Coverage of communication timing requirements

Since every higher level CC includes the functionality of the lower level CC, any higher level CC provides enhanced communication functionality (e.g. LLDP, SNMP). To make sure that the PROFINET devices meet these requirements profiles, the device manufacturer has to carry out a certification test.

Always use certified PROFINET devices with the appropriate requirement profile. You can thus make sure that these devices have been configured for the relevant automation task. You should determine which requirement profile your PROFINET devices have to meet.

2.2.3 Further criteria for device selection

Further important criteria for the selection of devices will be explained in more detail on the following pages. This includes points such as:

- End user specifications,
- Environmental requirements,
- Connection to PROFINET device,
- PROFIsafe and
- PROFINET devices with integrated switch.

End user specifications concerning device selection

In many cases, the requirement profile of an automation plant has been predetermined. In such cases it is common practice for the design or the selection of devices to use so-called approval lists which are provided by the end user. These lists include the components approved by the end user. The goal of such an approval list is:

- to reduce the selection process time and effort,
- to use homogeneous components in the entire plant and
- to always have the same requirement profile available.

Device selection specifications provided by the end user must always be observed. It is also important that the approval lists correspond to the specifications of the conformance classes.

You should check whether the latest version of approval lists is available to you.

Environmental requirements for the PROFINET device

Environmental aspects must also be considered for the selection of PROFINET devices when planning an automation plant. With reference to the location of the devices, we basically differentiate between the installation in a cabinet and the unprotected installation in the plant environment.

Both environments imply certain requirements for the nodes of the PROFINET network.

- Penetration of foreign objects and liquids (IP protection class).
- Mechanical requirements, e.g. vibration, shock
- Temperature influences
- Electromagnetic influences

In order to optimize your device selection, mark those areas of the plant that generate special requirements for the PROFINET device to be installed.

For the device selection, consider potential external influences. Adjust your device selection according to the manufacturer information.

Type of connection at the PROFINET device

PROFINET supports many different types of connection to the network. Copper cabling is normally used for the connection of PROFINET devices. Optical fiber and wireless communication can also be used.

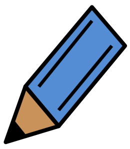
Several connection technologies are available when using wired transmission media. These connection technologies can be categorized according to their transmission medium, as shown in Table 2-3.

Table 2-3: Connection technologies for PROFINET devices

Copper cable connections	Optical fiber connections
M12 RJ45 (IP20) Push-Pull-RJ45 (IP65)	M12 SCRJ (IP20) SCRJ Push-Pull (IP65)

The connection technology is determined by the selected PROFINET device. In a later design step, additional media converters may be necessary due to certain topology or environmental requirements.

All connectors and cables are PROFINET components that require a manufacturer declaration concerning the compliance with PROFINET standards.



Take a note of the connection technology of the selected device since this may require adaptation at a later stage.

PROFIsafe via PROFINET

PROFIsafe is a standard for safety-relevant communication. It ensures that people and machinery will not suffer any damage during the operation of an automation plant. PROFIsafe equipment can be mixed with non PROFIsafe equipment within your PROFINET network. Figure 2-5 shows an example of the use of PROFIsafe devices in a PROFINET network.

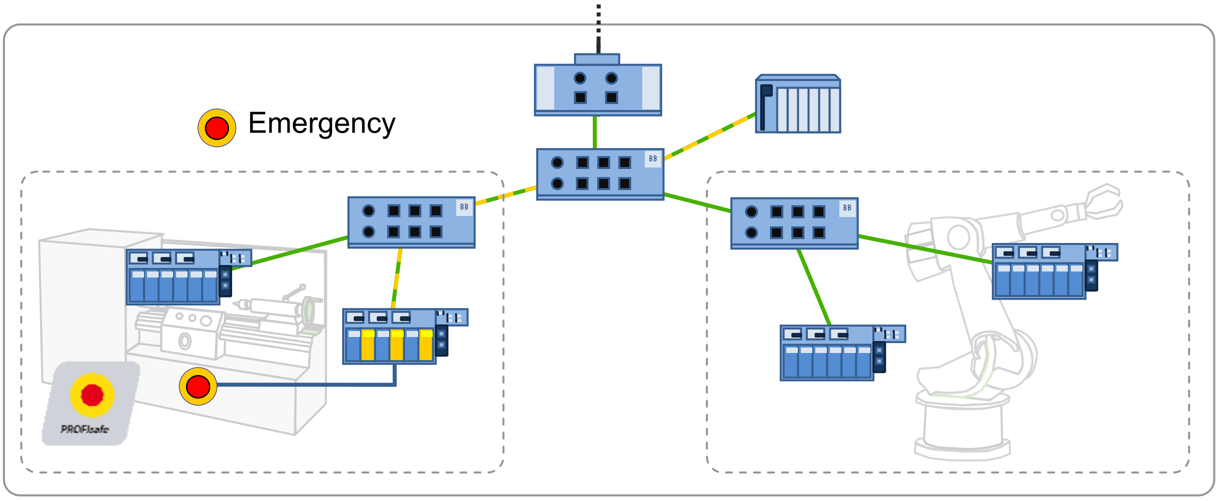


Figure 2-5: Use of PROFIsafe via PROFINET

The safety-relevant PROFIsafe communication (yellow) is transmitted over the same network as the standard PROFINET communication. All nodes of the safety-relevant communication must be certified according to IEC 61010 (the equipment CE label).

For the device selection you should consider safety-relevant aspects to ensure that damage to people and machinery has to be averted during operation. PROFIsafe devices must be both PROFINET and PROFIsafe certified.

You will find more information about PROFIsafe in the IEC 61784-3-3 as well as under www.PROFIsafe.net.

Use of switches or integrated switches

PROFINET devices are connected to the network via switches. Switches route the PROFINET data traffic through the network. Many devices offer the functionality of an integrated switch. Figure 2-6 shows the difference between the connection via an integrated switch or via a separate switch.

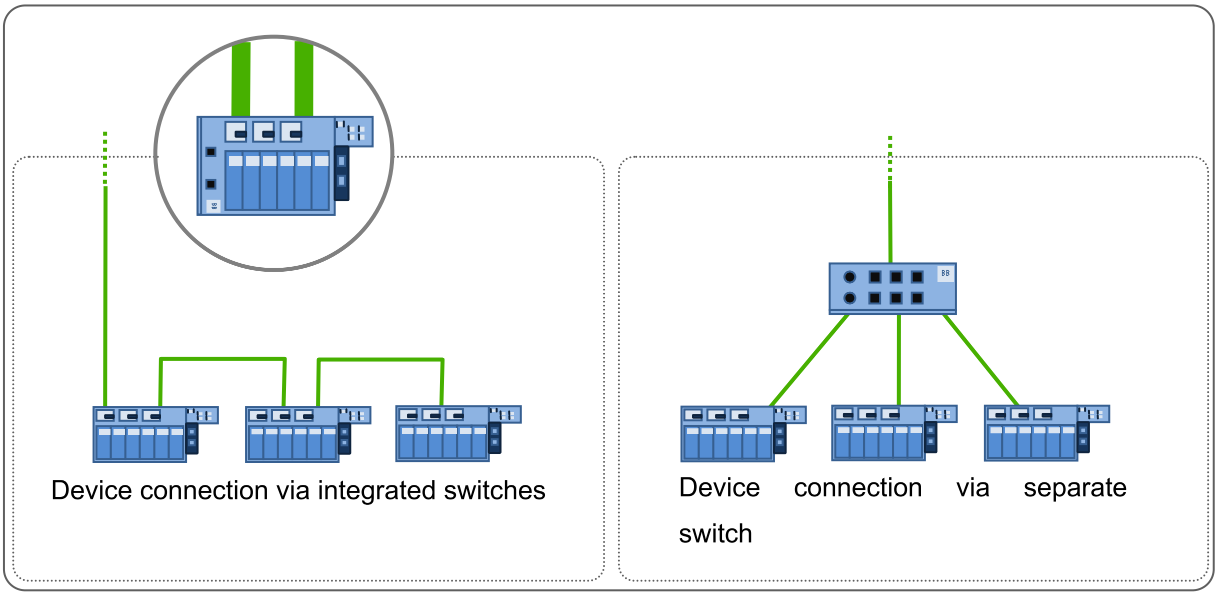


Figure 2-6: Difference integrated switch and separate switch

While a system based on integrated switches does not require any additional component for routing, a device without integrated switch may require an additional separate switch.

Note that when using integrated switches in a line structure, device failure or replacement can cause all devices downstream from the failure to also fail. Generally a star or tree structure using separate switches gives improved availability in the event of device failure and replacement.

PROFINET devices equipped with an integrated switch can provide different numbers of ports.

Use the plan to check whether additional switches may be required.

Check whether your plant consists of independent plant parts. Plant parts should be linked in a star or tree topology.

Table 2-4 lists the benefits of switch connection options.

Table 2-4: Benefits of both switch connection options

Benefits of separate switches	Benefits of integrated switches
Replacement of defective network nodes is possible without interruption of the remaining communication for star and tree topologies.	Cost reduction since no additional switch is required. Replacement of defective network nodes without interruption of the remaining communication is possible for line topology with ring redundancy.

Separate switches are required if your PROFINET devices are not equipped with integrated switches or if it is necessary due to the distribution of network nodes within the plant.

The requirements for system availability during device failure and replacement will often dictate when you should use integrated or separate switches.

The selection criteria of the PROFINET network nodes with respect to device properties and environmental requirements must also be determined for separate switches.

You should define a suitable number of additional separate switches for the future definition of the network topology.

Conformance class B requirements, where applied, means that switches have IO device properties. That is they have a PROFINET device name and are capable of providing diagnostic data. If separate switches need to comply with conformance class B, additional information is provided in the Annex of this document.

2.3 Definition of device types

Devices can now be selected based on the information available concerning the plant as well as the environmental conditions and the requirements to the automation task.

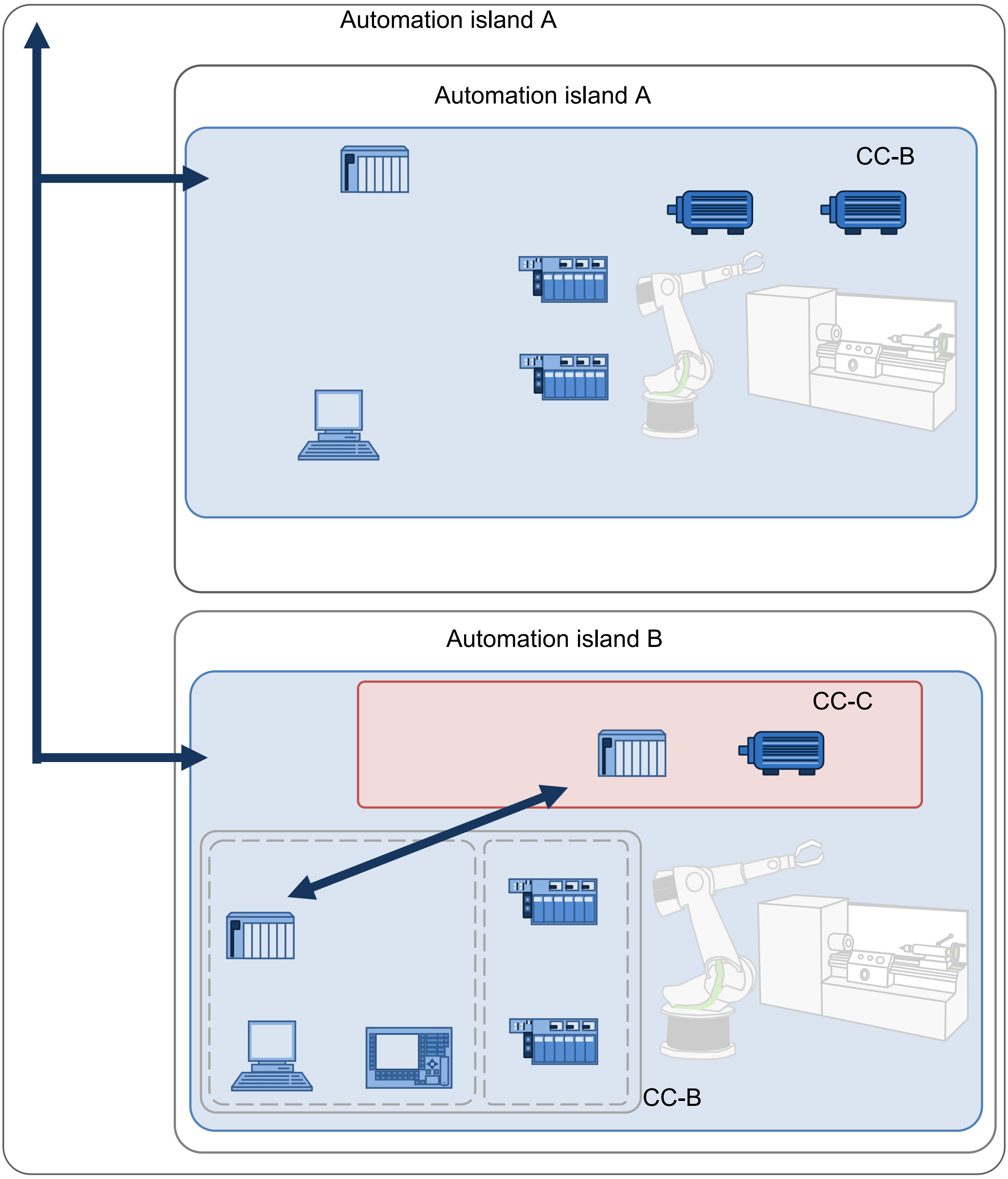


Figure 2-7: Sample layout of a plant with device preselection

Figure 2-7 shows the example plant with devices preselected. It also shows the assignment to different conformance classes and their timing requirements. Further analysis shows that some devices are equipped with integrated switches.

In this example the automation island A is assigned to the requirements of CC-B. Island B is also subject to these requirements. However, in this case a plant area is subject to more deterministic timing requirements. The area is therefore categorized as conformance class C.

The preselected devices may have to be modified at a later stage in order to adjust the connection technology and the transmission medium to the requirements.

You should make a further check that all the positioning and device requirements have been met.

During the design you should take into account the grounding as well as an equipotential bonding for the network nodes. In the Annex of this document you will find information about power supply and grounding of network nodes in PROFINET systems.

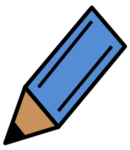
2.4 Documentation of results

After completion of the analysis and preview of the automation task, all information concerning device selection should be available. This includes device information such as

- Device connection or transmission medium (copper, POF, HCS, optical fiber (monomode, single mode) or wireless),
- Number of integrated switch ports at the PROFINET device and
- the conformance class requirements.

In the automation task, mark the PROFINET devices and the related applications that are subject to high real-time requirements. These devices must be considered separately during the design process.

Detailed planning of device characteristics, options and parameters are not required at this point. These will be covered later.



All relevant information on the selected PROFINET devices and network components should be collected and documented at this stage. A list of selected devices and their properties should be generated.

3 Network topology

The previous chapter covered the analysis of the automation task and selection of components to be used in the plant.

The next step is to create the network topology. First some general topology examples will be described, followed by a short overview of the possible transmission media and their most important properties.

Later on, specific examples are provided for typical network topologies in automation plants.

After the topology and required transmission media have been defined, we must check that the selected devices suite for the connection of the selected transmission media.

Finally the topology design will be documented.

The information concerning transmission media and connectors considered here is only a short overview of the most important data.

Please use suitable sources (e.g. the manufacturer) for more detailed information.

3.1 PROFINET Topology

Flexibility in network design and layout is a key feature of PROFINET. Since all standard Ethernet topologies are used, PROFINET supports an almost unlimited number combination options.

The network topology mainly results from criteria such as:

- The location of the components,
- the distances to be covered,
- the EMC requirements,
- electrical isolation requirements,
- conformance class requirements,
- requirements for increased availability and
- consideration of network loads.

The selection of the correct topology is important for the future design of the PROFINET automation plant. The topology may have to be adjusted in a later design step.

!

Additional switches may be required to create the topology.

The following pages of this section will introduce the different basic PROFINET topologies.

Star topology

The star topology is suitable for areas with limited geographical extension. A star-topology is automatically created if several communication nodes are connected to a common switch.

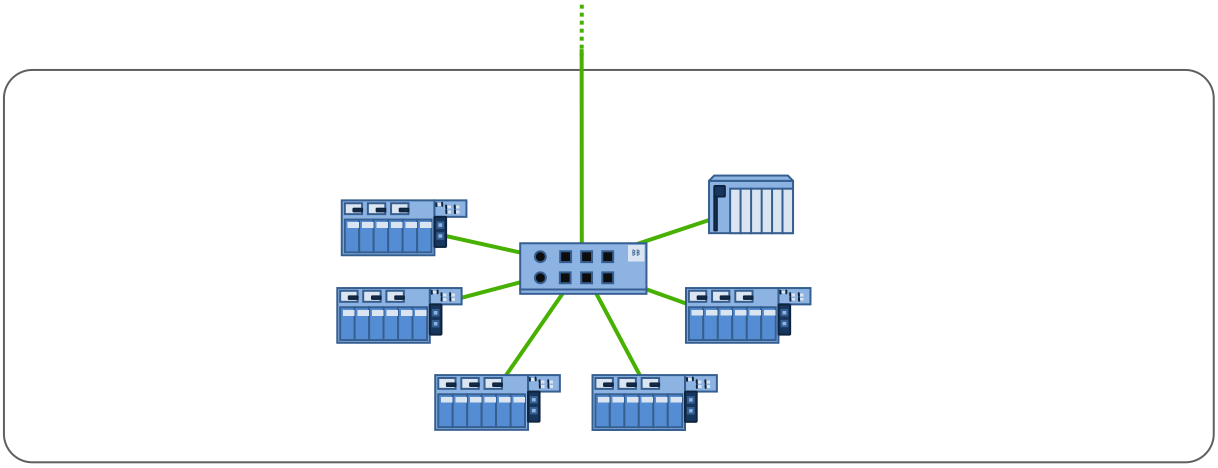


Figure 3-1: Star topology

If a single PROFINET node fails or is removed, the other PROFINET nodes will continue to operate. However, if the central switch fails, the communication to all the connected nodes will be interrupted.

Tree topology

A tree topology is created by combining several star-shaped networks to one network. Plant parts forming a functional unit are combined to star points. These are inter-networked via neighboring switches.

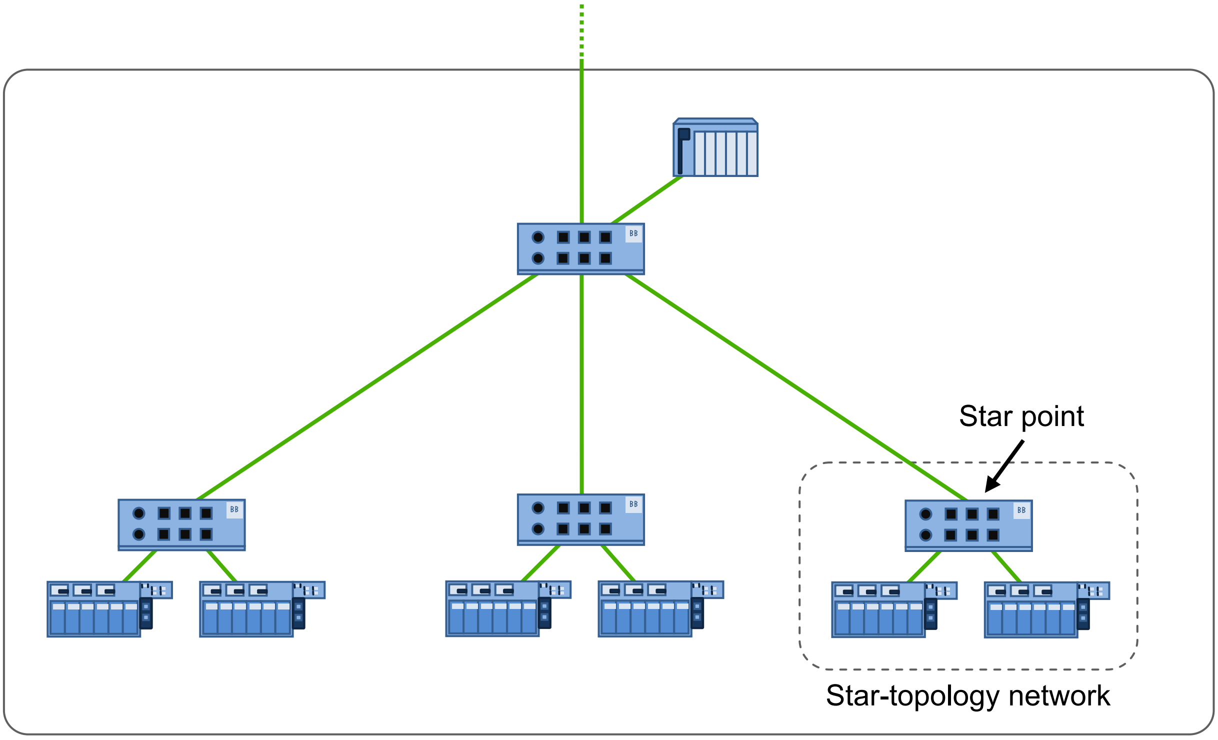


Figure 3-2: Tree topology

One switch operates as a signal distributor in the star point. Since the switch routes messages based on an address, only those messages will get to a neighboring distributor which are really required at this distributor.

The tree topology is a typical example for an automation plant being grouped into different manufacturing islands.

Line topology

The line is a well-known topology used in automation. It is used for applications in extensive automation plants such as conveyor belts, but also for small machine applications. PROFINET devices equipped with an integrated switch facilitate the realization of line topologies.

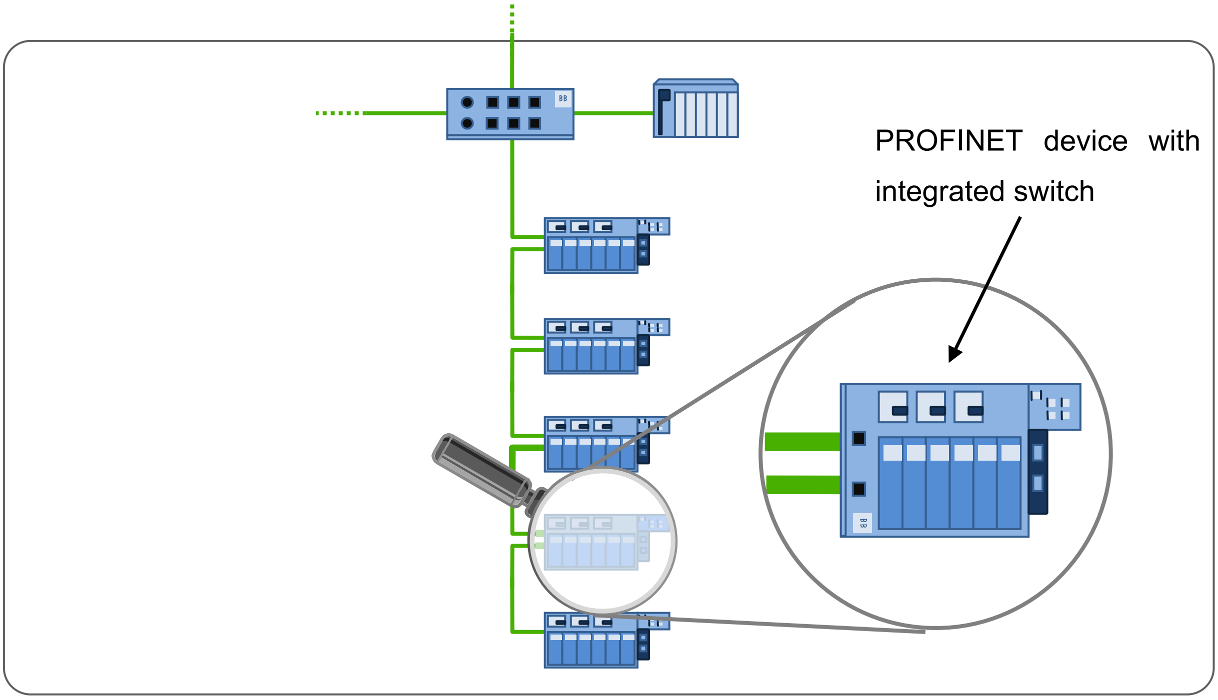


Figure 3-3: Line topologies with internal switches

The cabling of PROFINET devices is thus possible without using additional switches.

! When using line topologies, bear in mind that in case of a line interruption (e.g. outage of a device), the devices located behind the failed device can no longer be contacted. This can be prevented by extending the line to a ring structure using a redundancy protocol.

3.2 Applicable transmission media

Copper cables and optical fibers are available for a wired connection of network nodes. The cable used must meet the requirements of the planned automation project. For this purpose, the cable manufacturers offer a range of PROFINET cables that are differentiated by their applications and special properties.

The following section describes the main considerations when selecting the PROFINET copper and optical fiber cabling. Compared to copper cabling, the optical fiber cabling has additional typical parameters such as attenuation and used wavelength which primarily restrict the length of the transmission link.

In the Annex to this document, in addition to an overview of typical cable properties you will find a description of the transmission media as well as their application ranges and versions.

! When selecting the transmission medium you should bear in mind the possible influences in the application area (e.g. chemical, electrical or mechanical).

Some examples are provided in the annex to illustrate the selection of cabling components. Pre-assembled and field-assembled cables are also described.

The correct installation of the PROFINET cabling must be considered in the design. Make sure the allowed distance between power cables and data cables will note be exceeded. For more information, please see the PROFINET Installation Guideline Order No.: 8.071.

A PROFINET connection between two devices is named “end-to-end link” if the two connectors at the end of the cable are considered. A channel is a connection that excludes the two connectors at the end of the cable. .

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

3.2.1 PROFINET copper cabling

A typical PROFINET copper cable is a 4-core, shielded copper cable (star quad). For high transmission rates (1000 Mbit/s) an 8-core cable is specified. The different types of cables vary in

- the structure of the wires (solid core / stranded for fixed / flexible applications)
- and / or the jacket material and construction.

The cores are color-coded. In a 4-core cable, wire pair 1 is yellow and orange, wire pair 2 is white and blue. The cores in each pair are arranged to be diametrically opposite within the cable. 8-core PROFINET copper cables consist of 4 wire pairs, with green, blue, orange and brown wires and the corresponding white wire.

As in standard Ethernet applications, the maximum distance between the end points of communication is limited to 100 m when using copper cabling. This transmission link has been defined as PROFINET end-to-end link.

For automation plants you may only use PROFINET cables.

The corresponding manufacturer's declaration is available for PROFINET cables.

Application-neutral cabling (e.g. based on existing building cables) may only be used in network areas that correspond to conformance class A (e. g. to interconnect automation islands).

However it is recommended to use PROFINET cabling for this application (e.g. in order to cover higher conformance class requirements).

!

The common installation of power cables and copper cables for communication is subject to regulations in order to minimize the electromagnetic influence of power cables on the communication lines. Optical fibers however are not subject to these electromagnetic influences (see chapter 3.2.2).

Regulations for the common installation of power cables and PROFINET copper cables must be observed for the design of cable routing.

Follow the instructions provided in the PROFINET Installation Guideline Order No.: 8.072.

Cable types

PROFINET copper cables are categorized in different types which are mainly differentiated by the relevant applications:

Type A cables are designed for fixed installations. This cable type is not subject to any motion after being installed.

Type B cables are designed for flexible installations. This cable type allows for occasional motion or vibrations.

Type C cables are designed for special applications (e.g. for continuous movement of the cable after being installed). This includes e.g. applications such as trailing chains or festoons.

!

Special properties of some copper cables, such as flexibility for use in trailing chains or construction using flame retardant materials, can reduce the maximum length of a copper cable to less than 100 m.

Observe the manufacturer data for cables and connectors.

In addition to the special properties of PROFINET copper cables, the Annex of this document provides detailed data concerning the individual cable types.

Types of PROFINET copper cables

A number of special cable types are available for PROFINET. The most commonly used PROFINET cable types as well as their applications are listed below:

- **PE cables:** PE cables are suitable for installation in areas where constant humidity must be expected.
- **Buried cables**
- **Flame retardant non corrosive cables (FRNC cables):** Suitable for installation in areas where special fire protection regulations must be observed, e.g. halls with public access.
- **Trailing cable** for installation on moving machine parts.
- **Festoon cable**
- **Ship wiring cable (with approval for shipbuilding):** For installation on board ships and offshore units.

You should only use cables that have been specified as PROFINET cables by the manufacturer. Only such cables will ensure trouble-free operation of the network.

Observe the information material provided by the cable manufacturer.

You will find further information about the installation and grounding of copper cabling in the PROFINET Installation Guideline Order No.: 8.072.

Separation distances between cables

When laying PROFINET cables, observe the minimum required separation distances specified in Table 3-1. The values have been taken from the EN 50174-2 standard.

Table 3-1: Minimum required separation distances for PROFINET cables

	Conduits used for information technology cables and mains power cables		
Separation without electromagnetic barriers	**Open metallic conduits a**	**Perforated metallic conduits b, c**	**Solid metallic conduits d**
10 mm	8 mm	5 mm	0 mm

[a] Shielding effect (0 MHz to 100 MHz) equivalent to welded meshed steel basket with mesh size 50 mm × 100 mm. The same shielding effect can be achieved using steel cable trays (cable bundles, without cover) with a wall thickness of less than 1.0 mm and/or an evenly perforated surface of more than 20%.

[b] Shielding effect (0 MHz to 100 MHz) equivalent to a steel cable tray (cable bundles, without cover) with a minimum wall thickness of 1.0 mm and an evenly perforated surface of not more than 20%. This shielding effect can also be achieved with shielded power cables which do not provide the features specified in footnote d.

[c] The top surface of the installed cables must be at least 10 mm below the top surface of the barrier.

[d] Shielding effect (0 MHz to 100 MHz) equivalent to a steel installation pipe with a wall thickness of 1.5 mm. The specified separation distance must be taken into account in addition to the separation distance required by dividers/barriers.

For more details about minimum separation distances please refer to the IEC 61784-5-3 or EN 50174-2 standard, respectively.

Grounding and equipotential bonding of copper cabling

When installing PROFINET copper cables correct grounding of the cabling as well as equipotential bonding must be provided. This does not apply to optical fibers.

The cable shield must be properly grounded at **both ends** of every cable, i.e. **at each connected network node**. Usually, the connector collar in the PROFINET device is grounded accordingly. If no large-area grounding of the cable shield is visible on the device, you should ground the cable shield near the device. In addition, equipotential bonding should be used to prevent large ground currents flowing along the screen of the cable. The equipotential bonding cable carries the earth currents which would otherwise be discharged through the copper PROFINET cable shield.

Grounding of the cable shield at each end is normally achieved via the connectors which provide a low resistance path from the cable shield to the local device earth. However, it is also very important that every device is properly earthed.

You will find information about the assembly and the grounding construction as well as about the equipotential bonding in a PROFINET network in Annex of this document as well as in the PROFINET Installation Guideline Order No.: 8.072.

Device manufacturers' guidelines will generally show the recommended way to connect the device to the local ground. These instructions should be followed when given. Otherwise you should always ensure a low-impedance route from the device earth to the local earth. Note that coiling the grounding wiring can introduce significant impedance in the earth cable. Grounding cables should not be coiled.

Proper grounding together with equipotential bonding reduces the susceptibility of the PROFINET network to electrical interference.

The grounding of the PROFINET shield and of the network nodes can be designed in a way where equipotential bonding and a common system grounding are realized by the same grounding system.

!

Poor grounding is a common cause of problems in PROFINET systems. Incorrect grounding as well as the risk of electrical hazard, can also cause errors in the automation system that can damage to people and machinery.

3.2.2 PROFINET optical fiber cabling

In areas where electromagnetic interference may be present or significant earth potential differences are expected it is recommended that fiber optic (FO) connection is used. Fiber optic connection can completely remove problems caused by electromagnetic interference (EMI) and/or ground equalization currents flowing in copper cable screens.

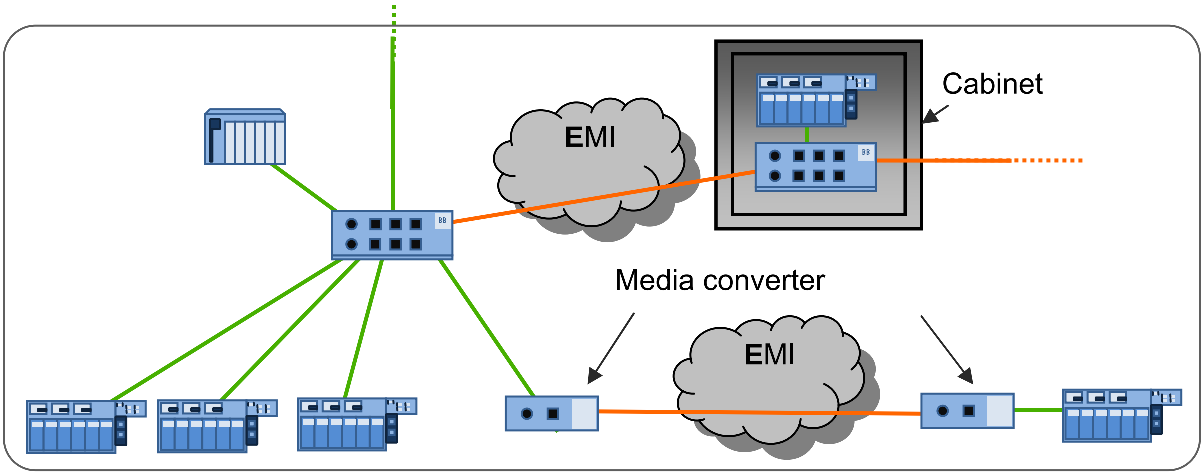


Figure 3-4: Application of optical fiber technology for EMI

Figure 3-4 shows the application of optical fiber technology for the connection of network nodes and / or switch cabinets in areas subject to electromagnetic interference. The benefits of optical fibers over copper cables are:

- Optical fiber cables usually cover longer distances as compared to copper cables.
- FO cables provide total electrical isolation between plant areas.
- FO cables are totally immune to electromagnetic interference (EMI).

A description of the different fiber types that can be used for the design of the PROFINET network is provided below

Optical Fiber types

Four different fiber types can be employed when using optical fibers (FO) for PROFINET. The fiber types must be selected according to requirements given by the planned automation project.

The following fiber types are available:

- Plastic optical fiber (POF)
- Glass fiber (multi-mode)
- Glass fiber (single-mode)
- Glass fiber with plastic jacket (hard-cladded silica fiber (HCF) or plastic-cladded fiber (PCF))

The key parameters of optical fibers are listed below.

Specific attenuation of the fiber

The specific attenuation of the fiber depends on the operating wavelength and is indicated in dB/km. The maximum values for the different fiber types, based on IEC 61784-5-3, are shown in Table 3-2.

Table 3-2: Specific attenuation of fiber types

Fiber type	Maximum attenuation	Wavelength
POF	≤ 230 dB/km	650 nm (LED excitation)
Multi-mode	≤ 1.5 dB/km	1300 nm
Single-mode	≤ 0.5 dB/km	1310 nm
HCF / PCF	≤ 10 dB/km	650 nm

Maximum FO transmission path

The maximum FO cable length is limited due to the attenuation of the optical signal within the fiber. The optical wavelength that is used will also have an effect.

Table 3-3: Attainable transmission links of optical fiber types

Fiber type	**Core diameter**	**Sheath diameter**	**Transmission path (typ. values)**
POF	980 µm	1 000 µm	up to 50 m
HCF / PCF	200 µm	230 µm	up to 100 m
Multi-mode	50 or 62.5 µm	125 µm	up to 2 000 m
Single-mode	9 to 10 µm	125 µm	up to 14 000 m

The maximum transmission link is a criterion for the design of the optical fiber link. The maximum PROFINET end-to-end link attenuation of optical fiber links however is decisive.

Maximum permissible PROFINET end-to-end link attenuation

Table 3-4 summarizes the maximum admissible attenuation values, based on the IEC 61784-5-3 and IEC 61300-3-4 standard for optical transmission links.

Table 3-4: Maximum permissible PROFINET end-to-end link attenuation

Fiber type	Maximum PROFINET end-to-end link attenuation	Wavelength
POF	12.5 dB	650 nm (LED excitation)
Multi-mode optical fiber	62.5/125 µm : 11.3 dB 50/125 µm : 6.3 dB	1 300 nm
Single-mode optical fiber	10.3 dB	1 310 nm
HCF / PCF	4.75 dB	650 nm

When using optical fiber links, make sure that the maximum permissible PROFINET end-to-end link attenuation are observed as taken from IEC 61300-3-4.

These limit values already include attenuation reserves.

Additional junctions in optical cables

Additional junctions in the link (splices or plug connections) cause an additional attenuation of the transmitted optical signal. Plastic optical fiber (POF) and hard-cladded silica are often assembled in the field using simple tools. This practice has been accounted for by means of a higher attenuation for the junction. Typical values are shown in Table 3-5.

Table 3-5: Attenuation of splices and connector pairs

Fiber type / Connection	Optical fiber	Plastic optical fiber / Hard-cladded silica / PCF
Per thermal splice connection	0.3 dB	Not possible
Per pair of connectors	0.75 dB	1.5 dB

Use of different fiber types

The use of different fiber types in one plant often produces costs due to additional materials or tools being required. Although it is possible to use various types of fiber in the same plant, this should only be done in exceptional cases.

Table 3-6: Use of different fiber types

The use of different types of fiber can be justified:	The use of different types of fiber should be avoided:
If, within one plant, numerous links can be realized using plastic fiber and only one link, due to its length, requires the use of glass fiber. In this case the overall costs would be higher if all links were realized using glass fiber.	If most of the links have to be configured as glass fiber and only a few links can be realized using plastic fiber. This could cause higher costs due to the additional treatment of the plastic fiber required (tools, material).

Attenuation of an optical fiber link

The secure operation of an optical fiber transmission system requires that optical signals reaching the receiver have sufficient signal strength. The PROFINET end-to-end link attenuation must not exceed the maximum permissible attenuation value.

The following parameters could have an influence:

- Specific attenuation of the fiber
- Additional junctions in optical cables

In order to achieve reliable communication over optical fibers, the following condition should be checked.

Transmit power - total attenuation ≥ receiver sensitivity

For short transmission links it may be necessary to check the max. permissible receiver sensitivity. If required, reduce the transmit power of the transmitter.

For the design of an optical fiber link, the specified limit values indicate the maximum transmission link length. You should also use a simple attenuation calculation to check the link.

You will find examples for the selection of cabling components for optical fiber links in the Annex of this document. In addition you will find an example for the determination of the attenuation balance.

However bear in mind that this is only a verification which by no means replaces potential acceptance measurements.

3.2.3 Selection of required connectors

PROFINET cables are equipped with connectors at both ends. The combination of connectors at the cable and at the socket is considered as a connector pair.

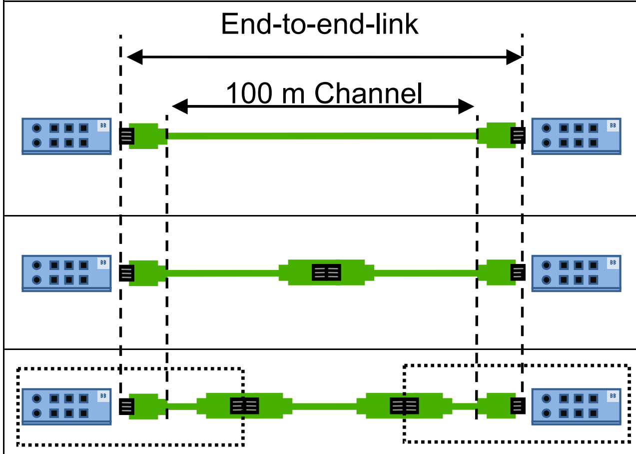
The connectors at both ends of the cable must also be included. Each of them forms a pair with the socket of the terminal device.

Detachable connections including bulkhead connectors and transition points are also part of the cable/connector system. The Annex provides a short description of such items.

Connectors for copper cabling

For the design of your PROFINET network you should bear in mind that the number of detachable links within an end-to-end link is limited.

Table 3-7: Transmission link length and connector pairs (copper)

Cabling example of two network components	**Number of Connector pairs**	**Maximum distance**
	2	100 m
	3	100 m
	4	100 m
IP20 environment	 Connector	 Coupler

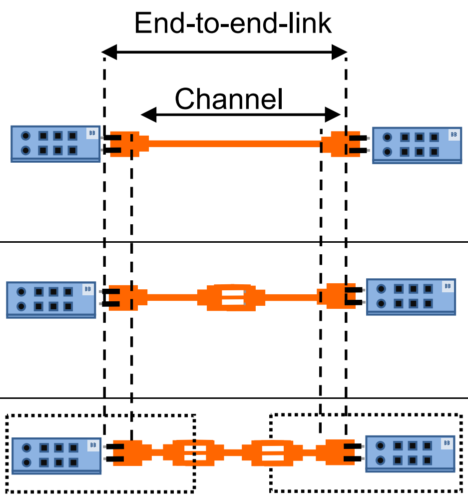
If the specified cables are used in combination with the specified connectors, a maximum cable length of 100 m can be achieved when using up to four connector pairs. You should try to use as few plug connections are possible since each plug connection represents a potential disturbance source.

In case more than four connector pairs are required for an application, you have to make sure that the attenuation values for the entire link are observed. (channel class-D values)

Connectors for optical fiber links

The maximum number of detachable connections for a channel based on optical fiber is limited, similar to a channel based on copper cabling.

Table 3-8: Transmission link length and connector pairs (FO)

Cabling example of two network components	Number of Connector pairs	Maximum distance		
		POF	HCF /PCF	Optical fiber MM / SM
	2	50 m	100 m	2,000 m / 14,000 m
	3	42.5 m	100 m	2,000 m / 14,000 m
	4	37 m	100 m	2,000 m / 14,000 m
IP20 environment	 Connector		 Coupler	

The comparably high attenuation of POF fibers, combined with the simultaneous use of several connectors, has a large impact on the maximum length of a POF connection. This should be considered in case you use POF fibers in a network.

3.3 Preferred devices for primary infrastructure

Compared to cyclic real-time communication, data exchange in a PROFINET network mainly occurs between the controllers and the devices. As a result, PROFINET-certified switches should be used for the communication link with the major load.

Generally, a link can be established by using a line structure with arbitrary PROFINET devices and integrated switches. However, depending on the application, it is recommended to define a primary communication link to which sub networks or line topologies can be connected. This will also simplify later plant extensions.

Conformance Class B requirements mean that managed switches are mandatory. These switches also provide various benefits such as improved diagnostic features for plants according to Conformance Class A; thus it is recommended to use managed switches in all cases.

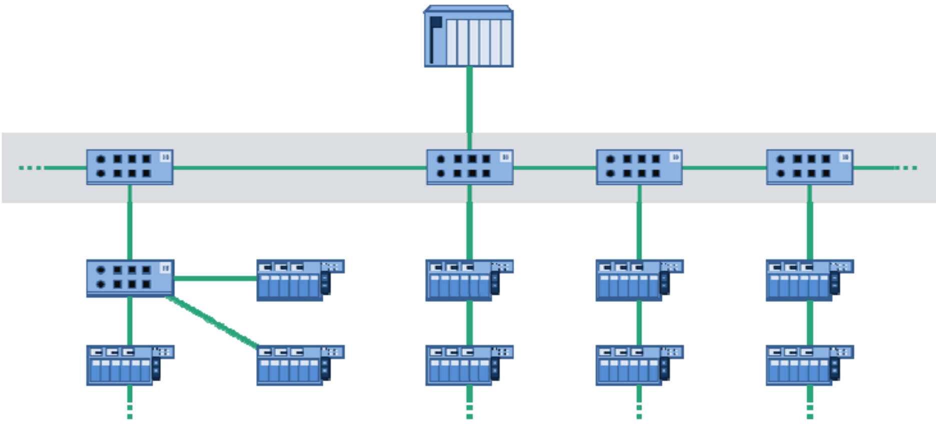


Figure 3-5: Topology example

Figure 3-5 shows an example of a primary communication link (gray box). This link can also be implemented as a redundant configuration, to increase the availability.

If possible, you should design a primary communication link using PROFINET-certified, managed switches.

3.4 Definition of network topology

Based on the information available the topology of the planned automation project can now be defined.

A systematic approach is recommended as follows:

Step 1: Define the required position of all network nodes in the automation plant. Determine which network nodes must be installed together in one location. Based on this positioning, define your topology.

Furthermore, connect the individual components, bearing in mind to check whether the PROFINET devices are already equipped with switches.

Step 2: This step considers PROFINET devices with special requirements in terms of deterministic timing or synchronization. Deterministic timing requires specific considerations in the topology definition.

All PROFINET devices supporting IRT must be connected to switches supporting IRT. Devices and switches not supporting IRT can still be connected to the network, but the topology must be laid out so that these do not degrade IRT communication.

Bear in mind that any replacement of devices in live operation will interrupt an existing line structure. In order to ensure the availability, you should consider using additional switches or extending the line to a ring structure.

Step 3: Next the transmission medium must be selected. Determine which links shall be designed as optical fiber or as copper connection.

Check whether the network node supports this transmission medium. If necessary, you should install additional media converters in the transmission link (see chapter 3.5).

Make sure here that the cabling is compatible with the environmental conditions.

Also make sure not to exceed the maximum permissible number of connector pairs within a link.

The Annex provides a description of the connectors currently available for PROFINET. The following pages provide some example plants and their topology. These examples can only show a brief overview of possible PROFINET topologies.

Example 1: Factory automation

The topology for an automation plant, designed for factory automation, could have following structure.

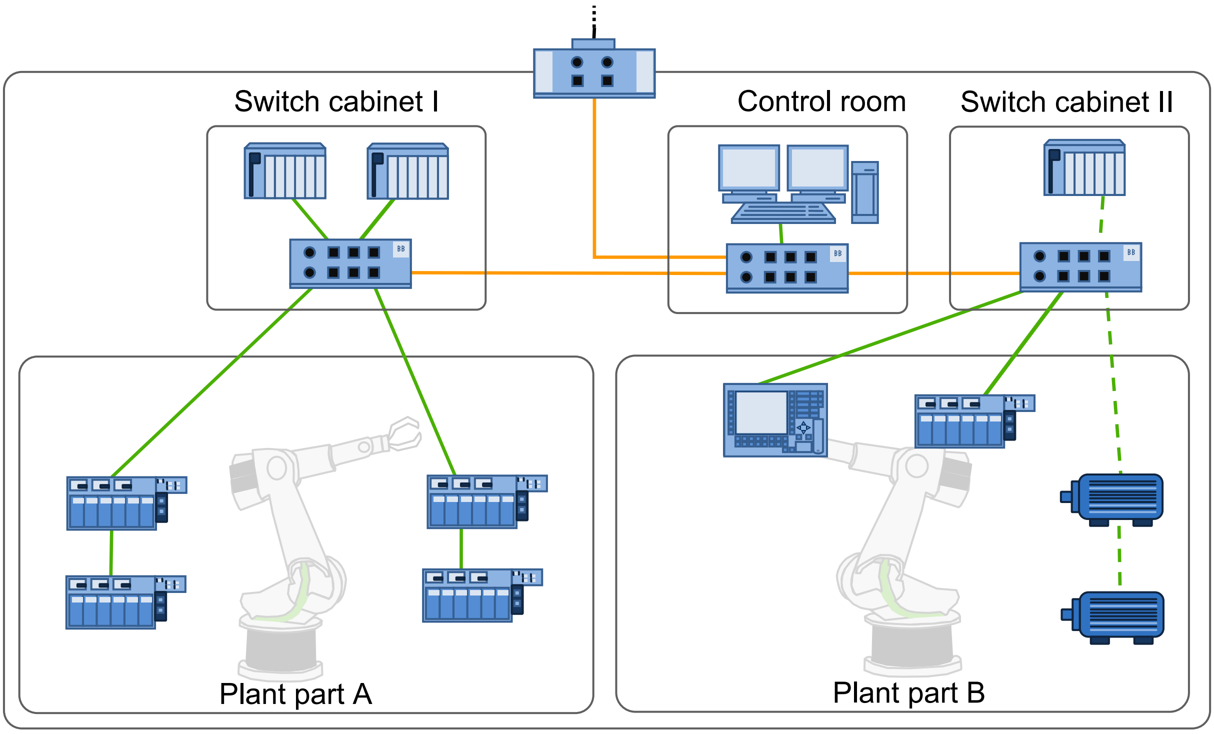


Figure 3-6: Example of a factory automation

In this example, the controllers and switches are installed in separate switch cabinets next to the production line. All controllers are able to communicate with each other without limitation. Due to the large distance between the plant areas, the links between the switches are implemented by means of optical fiber.

In plant area A, the IO devices are located near the manufacturing process and are connected via a line structure while plant area B, in addition to a synchronous connection of drives, foresees additional PROFINET devices with cyclic communication such as IO devices and IO panels.

This example clearly shows the combination of different topologies.

Example 2: Automation of a machine

The following example shows the automation of a machine. Here, the plant is subdivided into several areas which assume different functions. The response times of the plant typically are very short.

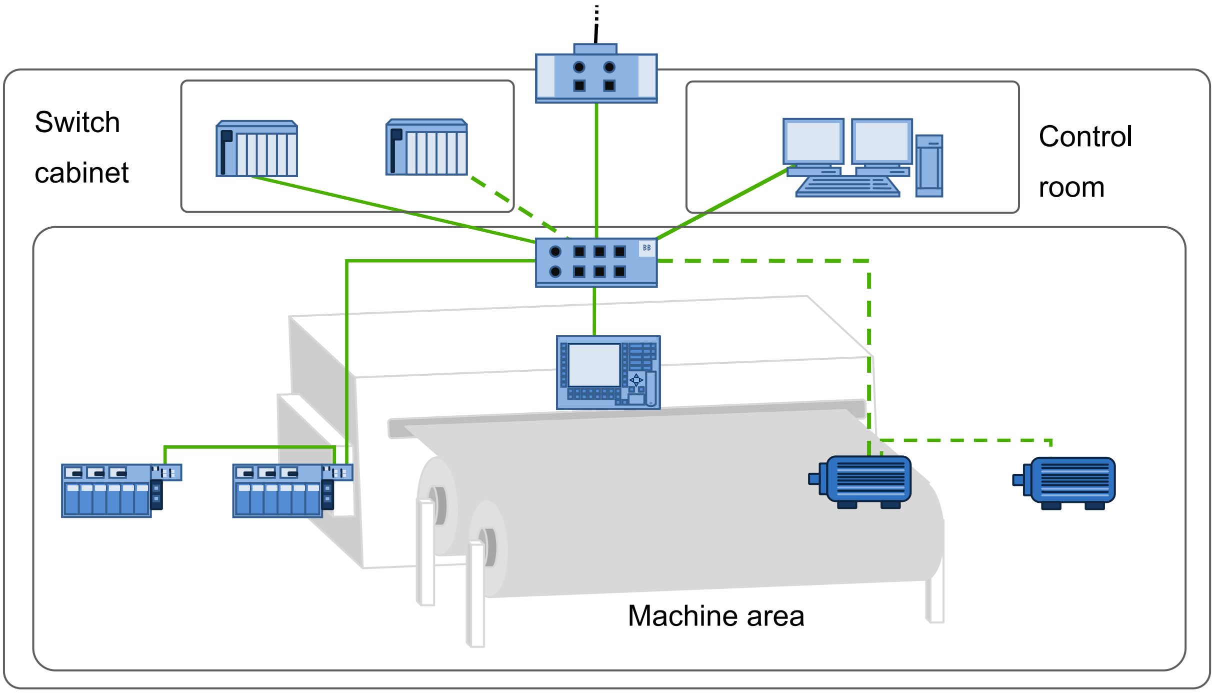


Figure 3-7: Example of a machine automation

While the operator panel is installed in the control room and the IO controllers outside the machine area are in a switch cabinet, the IO devices and an IO panel are located in the machine area.

The PROFINET devices which do not require a synchronous connection are positioned first and connected to the switch. The special requirement in terms of determinism (e.g. position-controlled axes) also implies the drives to be synchronously connected to a switch supporting IRT. Non-IRT PROFINET devices can also be routed via the IRT switches jointly with the IRT traffic.

Example 3: Process automation

Process automation amongst others covers chemical industry applications. Here, the network structure is typically used to link:

- chemical reactors,
- power plants or
- chemical plants.

The requirements in terms of response times are typically lower in process automation than they are in manufacturing or machine automation.

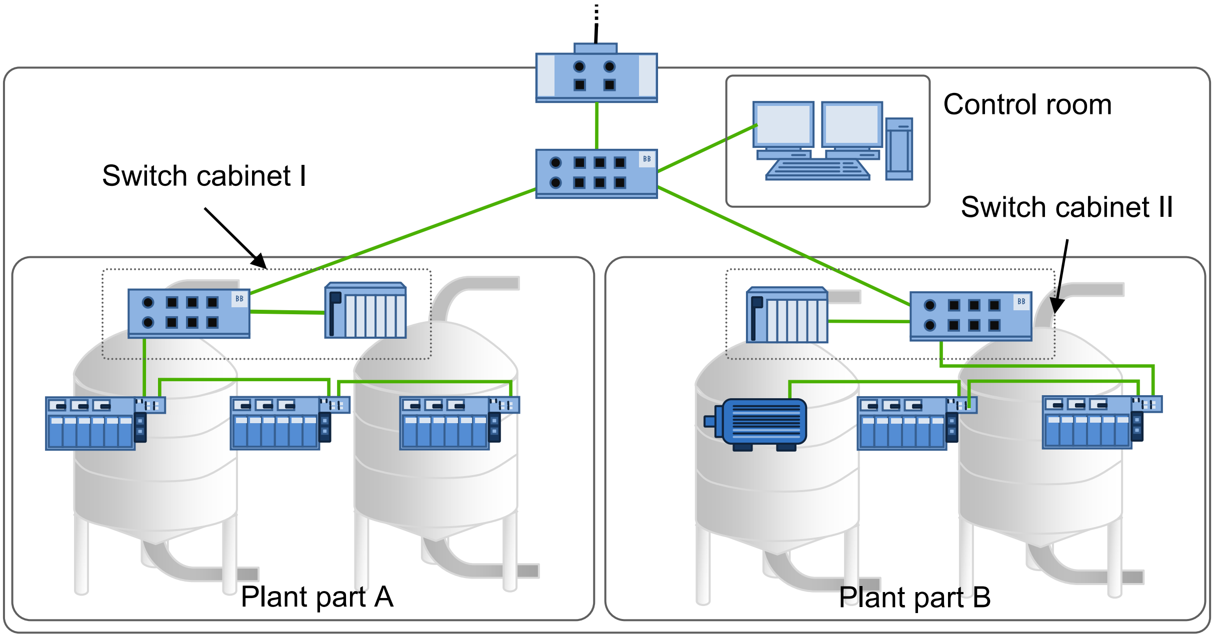


Figure 3-8: Example plant process automation

The control room monitors both processes which are divided into plant part A and B. Both plant parts have a local switch cabinet which is equipped with a switch and an IO controller.

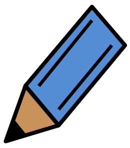
Due to the extensive distances involved in the plant, the network nodes are linked via a line structure. This reduces the amount of cabling required.

3.5 Topology check and refinements

After defining the topology and the transmission media deployed for the individual links you need to check whether the selected PROFINET devices support the corresponding chosen media.

Where possible, select devices that support the required transmission media. Where this is not possible, additional media converters or switches with support for different media may be required.

Bear in mind that the installation of a switch or media converter requires additional space.



Document the modification to the preview and analysis of the planned automation project and check whether it is necessary again to adjust the network topology.

3.6 Documentation of topology

To conclude the definition of the network topology, document all information about the selection of

- the transmission media and
- the connectors

It makes sense to use a predefined plant overview of the automation project. If necessary this can be extended by means of PROFINET network nodes and transmission links. Some engineering tools and design software provide additional functions that can generate documentation.

The topics covered in the following chapters, i.e. consideration of network performance and integration of additional network nodes, could lead to an adjustment of the network topology.

Figure 3-9 on the following page shows the first draft of a network topology for the plant example from chapter 2.3.

The plant is now networked via several switches. As agreed, all nodes of the network have been connected to the network in the first step. An additional switch may have extended the network. In the next step, areas with high determinism requirements have been taken into account. As a result, appropriate PROFINET devices have been integrated into the network.

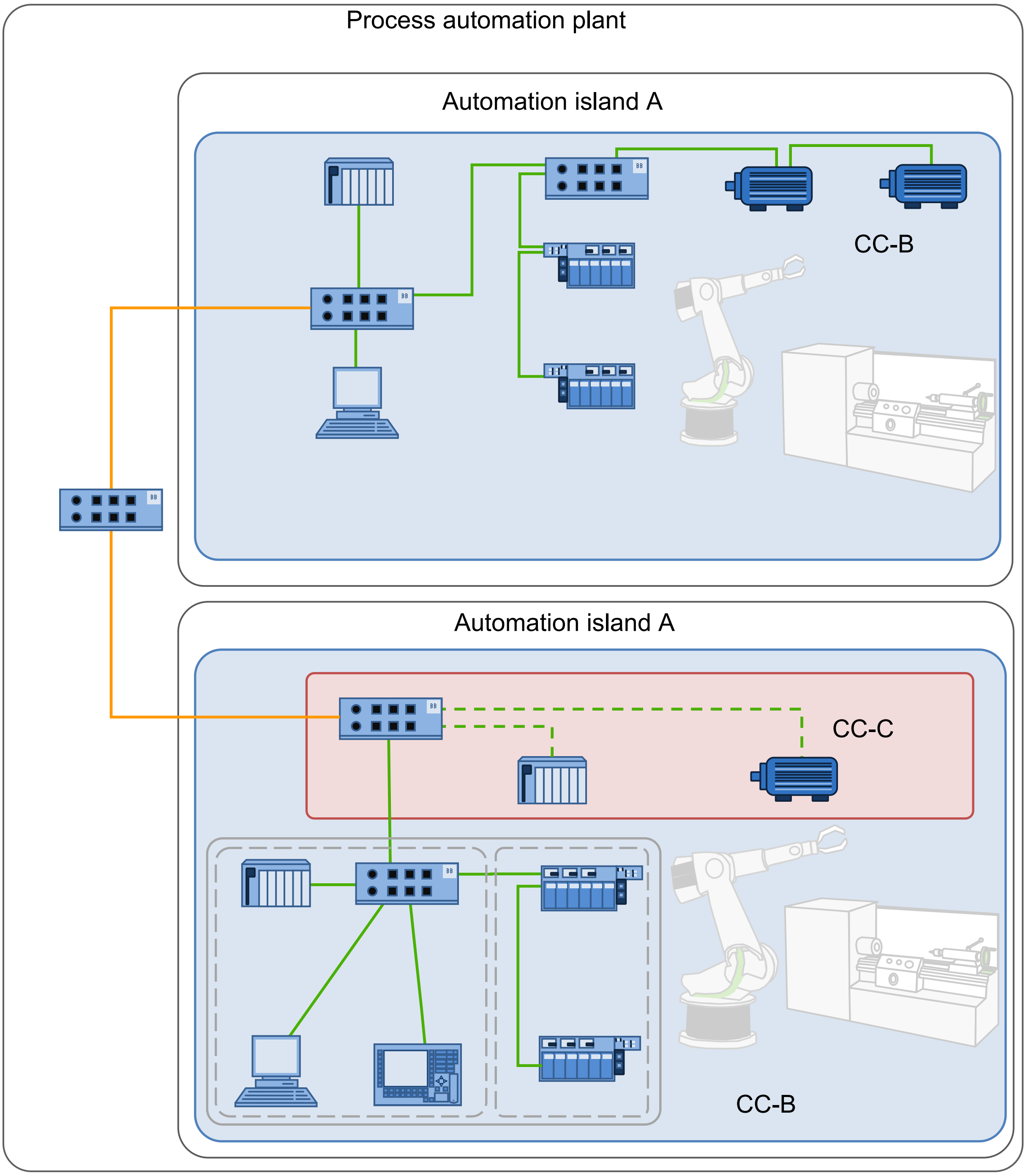


Figure 3-9: Plant example with preliminary topology

PROFINET automation plants can be extended with a variety of additional functions. This includes the integration of standard Ethernet devices as well as the connection to higher level networks. The following chapter covers these special design aspects.

4 Special design aspects

This section provides information about

- fast start-up (FSU),
- connection to higher level networks,
- utilization of existing cable infrastructure
- determination of firmware revision levels
- planning of access points for network diagnoses

The special design aspects may require an adjustment of decisions already taken for the design of topology.

4.1 Use of “Fast Startup“

In some applications it is necessary for PROFINET devices to be operational within a very short time. For example after a tool change on a robot. In order to minimize the startup time, PROFINET offers the “Fast Startup“ (FSU) protocol function. This function can be activated when configuring the devices that support fast start-up.

To be able to realize start-up times below 500 ms, it must be possible to deactivate the auto negotiation and auto crossover function at the relevant switch of the network node. Without auto crossover activated a crossover cable or a switch with internal cross connection is required. Figure 4-1 shows the implementation using a crossover cable.

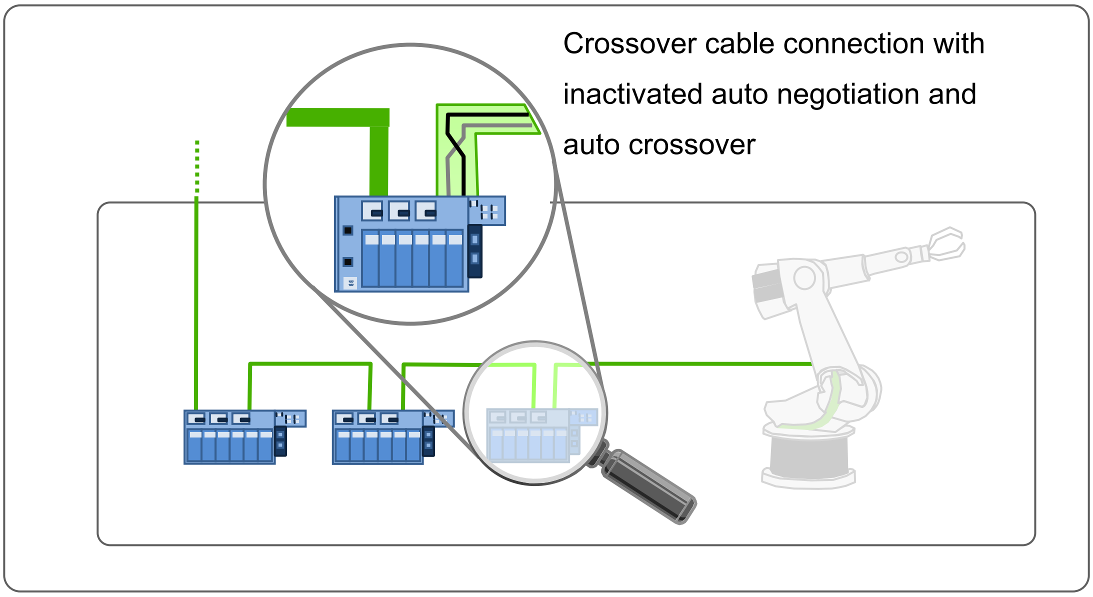


Figure 4-1: Implementation of “Fast Start-Up“ with PROFINET

Please see the manufacturers’ documents for details about FSU functionality and the connection of the relevant network nodes.

4.2 Utilization of existing cable infrastructure

Existing cable infrastructure can be used for the future use of PROFINET. This is however possible only in case the cable infrastructure is suited for PROFINET transmission.

This is the case if the cabling consists of a 4-core, symmetric twisted and shielded copper cable for the transmission of standard Ethernet.

When using PROFINET, the application-neutral cabling frequently used for standard Ethernet in industrial environments is categorized as a conformance class and application and may only be used as such.

If you plan to use existing cabling for the PROFINET plant to be designed you will find relevant information at www.profinet.com in the Conformance Class A Cabling Guideline (Order No.: 7.072).

When using existing cabling, the design should be based on the existing infrastructure. The existing cable infrastructure must be extended by the required transmission links. This corresponds to the preliminary topology definition as per the previous chapter.

When using standard switches in an existing infrastructure, make sure that they are suitable for VLAN and relay the priority information of the PROFINET data packet without changing it.

4.3 Connection to higher level networks (corporate network)

In many cases it is necessary for the automation plant to be connected to the operation control level. Any connection of PROFINET to a higher level network, which is usually based on standard Ethernet, must always be coordinated with the IT department.

In most cases routers are used for the connection to other networks. For security reasons, these routers should have firewall functionality.

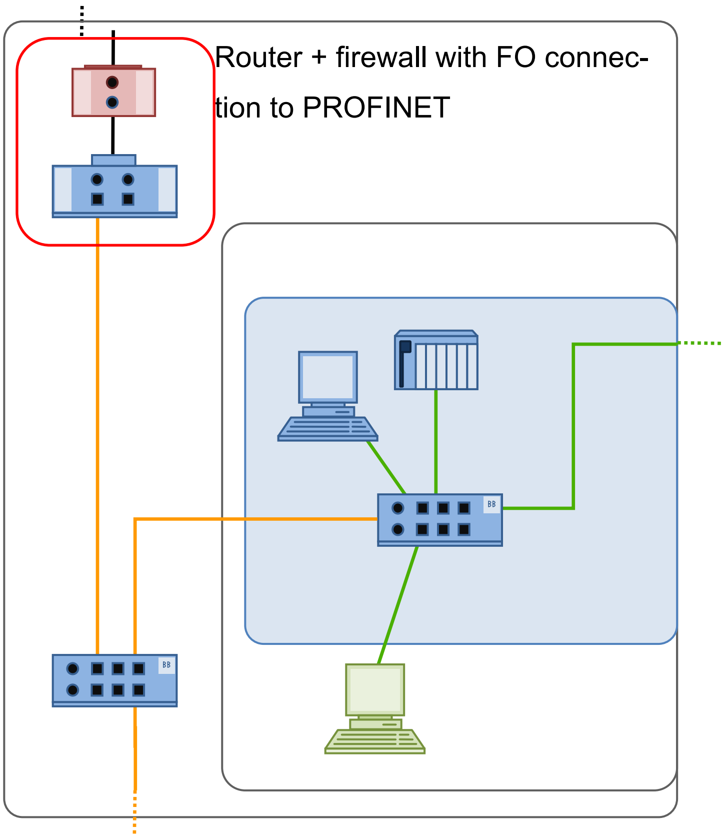


Figure 4-2: Plant example with connection to the corporate network

The connection via a firewall prevents unauthorized external access to your plant.

Special broadcast packets (so-called “Broadcast” or “Multicast”) will not be relayed by the routers, thus limiting data traffic to a single network area. This therefore minimizes the data volume to be routed in a network.

The router acts as a barrier in order to separate a network into several areas and routes the authorized data to the connected sub-networks.

For the connection of higher level networks to your PROFINET solution, please see the notes in the PROFINET Security Guideline (Order No.: 7.002)

!

Please bear in mind that PROFINET-RT- and IRT communication are not possible through a router.

!

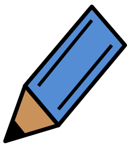
Consider that a router without configuration is not able to negotiate the traffic between the connected devices. This means that no data traffic through the router can be expected before the router has been configured accordingly.

Configuration of routers should be done only after coordinating with the IT department of your company.

4.4 Determination of firmware revision levels

Frequently, different firmware revisions are used for PROFINET devices, e.g. if functions have been extended in the software.

It is nevertheless useful to determine a corporate firmware revision level in the design phase of the plant and to make sure – prior to commissioning – that all PROFINET devices have the same firmware revision level. This ensures consistent device behavior and project planning. Please contact your device vendor for the latest firmware revision level and determine this level as a standard for each device type used. Different firmware revision levels for the same device type should be avoided.



Determine a common firmware revision level for each device type.

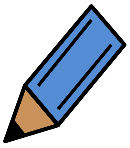
It may also be useful to determine a common hardware revision level.

Prior to commissioning, update all PROFINET devices with an older firmware version to the defined firmware revision level.

4.5 Planning of access points for network diagnoses

In the commissioning phase and for maintenance you will need network access points, e.g. for analyzing network traffic or reading device data. Such access points are also helpful for trouble-shooting or long-time diagnosis of the network condition.

In order to be able to connect diagnostic devices without interrupting normal plant operation, network access points should be available.



For diagnostic purposes, reserve easily accessible ports distributed over the entire plant.

In any case switches with diagnostic ports should be provided at the communication nodes, e.g. directly at the controller.

Free ports can be used for a first rough analysis of the network traffic, if the corresponding switch supports port mirroring.

A TAP (Test Access Point) can be used to analyze data streams for an exact data traffic diagnosis. A TAP is directly implemented in the communication link, as shown in Figure 4-3.

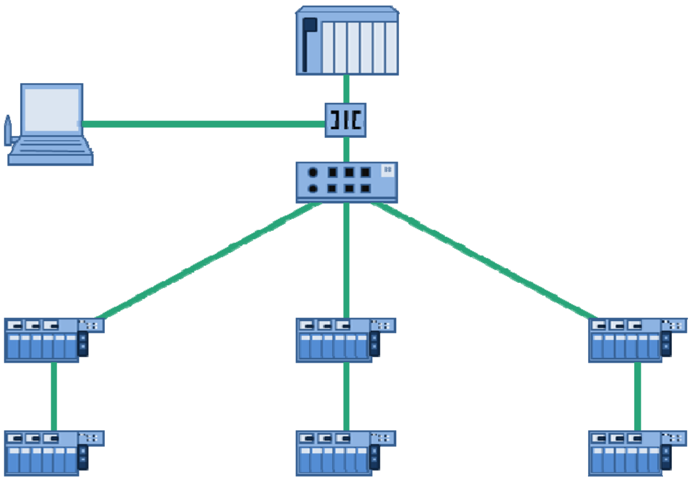


Figure 4-3: Reading data streams via TAP

A PC can be used for evaluating the data stream. Diagnostic devices with integrated TAP are also available on the market.

In order to be able to install or remove a TAP, you have to open the communication link. It may be useful to provide TAPs at important points in your plant design.

TAPs are additional network components which may affect the network availability. However, this effect is negligible when using passive, non-reactive TAPs.

Providing TAPs at important points, e.g. directly at the controller, may be advisable.

It is recommended to exclusively use passive TAPs without any reaction on the PROFINET communication.

4.6 Utilization of 4-pair cabling

A consistent cable infrastructure for PROFINET and Standard-IT can be implemented using 4-pair cabling. The corresponding connectors are described in chapter 9.5. This allows you to integrate other networked systems to the PROFINET network with consistent cabling.

!

Note that when using 4-pair cabling, PROFINET devices can currently only run at a transmission rate of 100 Mbit/s. M12 connectors may require the use of appropriate transition connectors from a Gigabit switch to a PROFINET device.

4.7 Documentation of modified network topology

You should update your documentation with the results that you have gathered while considering the special aspects.

Some engineering tools, company-internal documentation tools or design software provide additional functions that can generate design documentation.

5 Performance considerations

It is necessary to next consider the performance of the network. This chapter will guide you through the analysis of your design plan in a step by step manner and show which points have to be considered primarily in terms of the network performance. The following section deals with:

- the description of the PROFINET-IO cycle,
- the definition of the device parameters relevant for the performance of the network and
- the PROFINET network topology with a special focus on the cyclic and non-cyclic load which is generated by PROFINET devices and standard Ethernet devices.

The topology of your network may have to be adjusted to ensure reliable and timely communication.

Isochronous real-time communication (IRT) and the effect of safety and security concepts are beyond the scope of this chapter.

The following chapter 5.1 provides a short overview of general Ethernet functions and of the PROFINET functions relevant for performance. If you are already familiar with these topics, you can skip this chapter and continue with chapter 5.2.

5.1 PROFINET transmission cycle

This chapter describes the PROFINET functions relevant for the performance. It provides a good basis for the analysis of the design planning you have made so far.

5.1.1 Prioritization of PROFINET packets and switching technologies

Two types of communication may be used within a PROFINET network: real-time communication (RT) and non-real-time communication (NRT).
Real-time communication is prioritized. The standard Ethernet prioritization mechanism in the VLAN Tag, illustrated in the example in Figure 5-1, is used. It can be seen that the RT packet get higher priority compared to the NRT packets.

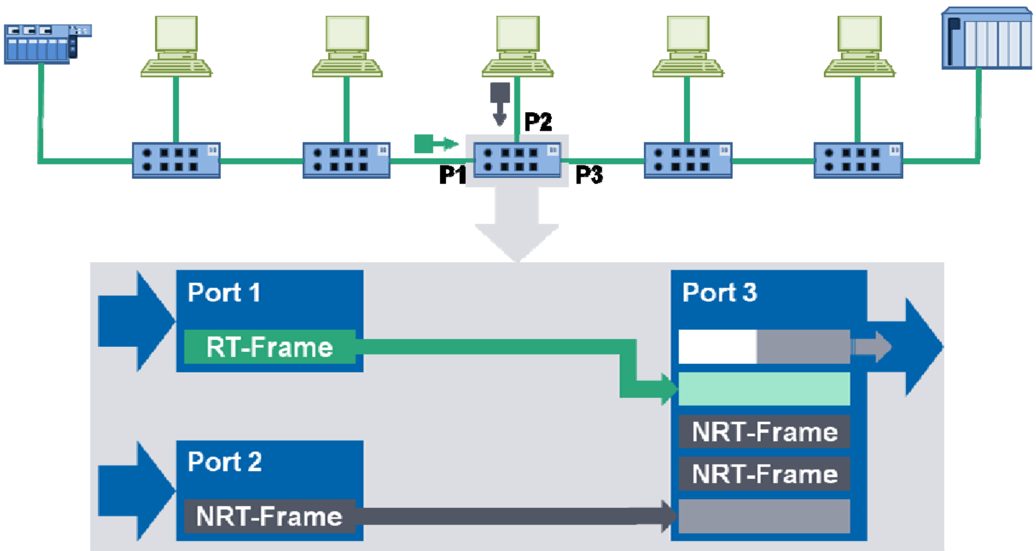


Figure 5-1: Prioritization of real-time communication with PROFINET

As a result, NRT communication is only executed in time periods when no RT communication occurs. Usually, the following switching technologies are applied:

- **“Store and Forward” Switches**: The packet is received in its entity, checked for errors and then forwarded or – in case of an invalid packet – dropped.
- **“Cut Through“ Switches**: Only the packet parts that are essential to the forwarding process (i.e. the address information) are read and then the packet is directly forwarded without further delay.

The switching technology used is of major importance to your topology design plan, especially regarding the line depth (i.e. number of switches between the controller and the device). For more details about this topic please see chapter 5.3.1.

5.1.2 Update time

PROFINET devices can be updated at different intervals depending on the process requirements and the hardware used. The update time may vary for different PROFINET devices within the same plant. The length of the transmission cycle, in which all PROFINET devices receive or transmit their data at least once, is determined by the PROFINET device with the slowest update time, see Figure 5-2.

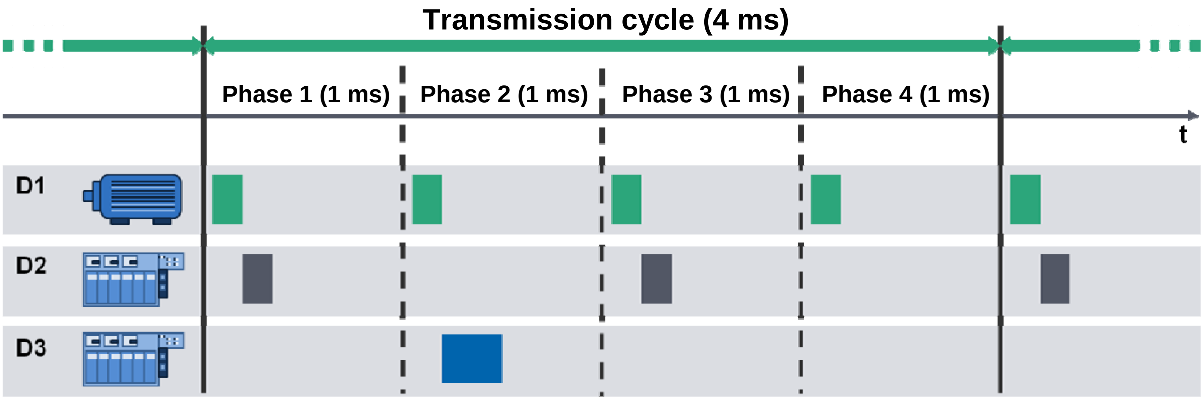


Figure 5-2: PROFINET transmission cycle

For fast update times the transmission cycle is subdivided into several phases. The phase time T_p is always an integer multiple of the PROFINET base clock of 31.25 µs, as given by the formula (5.1). This integer multiple is the *SendClockFactor*.

$$T_p = SendClockFactor \cdot 31.25 \mu s \tag{5.1}$$

Update times, T_a, other than the minimum transmission clock, are achieved by using *a ReductionRatio*, as given by the formula (5.2).

$$T_a = ReductionRatio \cdot SendClockFactor \cdot 31.25\ \mu s \tag{5.2}$$

In the example in Figure 5-2 the minimum transmission clock resulting in an update time of 1 ms is required by the IO device D1. A *ReductionRatio* of 2 would be assigned to the IO device D2, and a *ReductionRatio* of 4 to the IO device D3, giving a transmission cycle of 4 ms.

The transmission clock, which defines the minimum clock for the transmission of packets, can be set in the IO controller. You can additionally set the transmission clock that defines the minimum clock for the transmission of packets. The chosen controller transmission clock will generally correspond to the fastest update time assigned to a device.

The following example illustrates the choice of timing for a typical application. Note that the values in this example have been chosen arbitrarily to illustrate the principle.

Example Controller data is to be transmitted to 4 devices with an update time of 4 ms.

If the controller transmission clock is chosen as 1 ms, a data packet will be transmitted every millisecond.

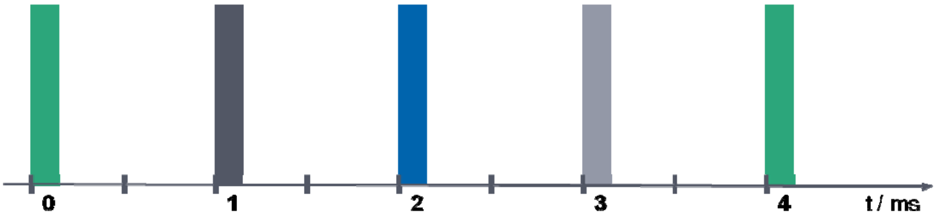


Figure 5-3: Network load, transmission cycle 4 ms, controller transmission clock 1 ms

However, if the controller transmission clock is chosen as 4 ms, the data packets will also be transmitted every 4 milliseconds.

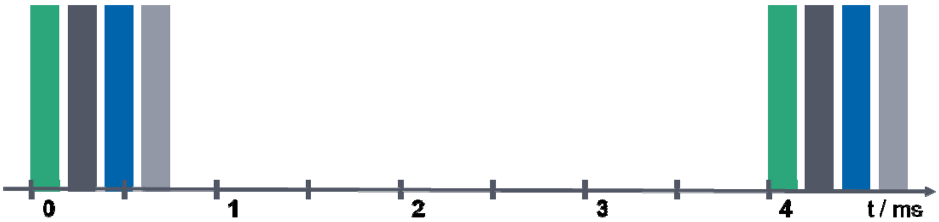


Figure 5-4: Network load, transmission cycle 4 ms, controller transmission clock 4 ms

In the first case, the load is evenly distributed within the transmission cycle, whereas in the second case the transmitted packets are bunched together giving an uneven load on the bus.

As shown in the example, it is recommended to keep the controller transmission clock short even with slower update times of the devices. This is done to achieve a better distribution of the generated network load. As a result, you should modify the *ReductionRatio* rather than the controller transmission clock when changing the update time of the devices.

Usually, these calculations are made by the engineering tool. Only the update time has to be preset by the user.

Once the update time has been defined, the PROFINET device will automatically transmit its data at the intervals given by the update time. With PROFINET RT-communication only this time interval, at which the data packets are to be sent and not the exact time, is defined.

The preset update time has a major impact on the transmitted data volume and, thus, the network load. This aspect will be detailed in the following chapter.

5.1.3 Network load

The ratio of the used bandwidth and the maximum available bandwidth is called the network load. The load distribution of the load over the considered time period is can be considered as random.

The period under consideration is important to the definition of the network load, because 100% of the entire network bandwidth is occupied for specific time periods during a transmission process, as shown in Figure 5-5, using a transmission cycle as an example. Packets of different length – 108 bytes (green, gray) and 300 bytes (blue) in the example – use the full bandwidth while being transmitted.

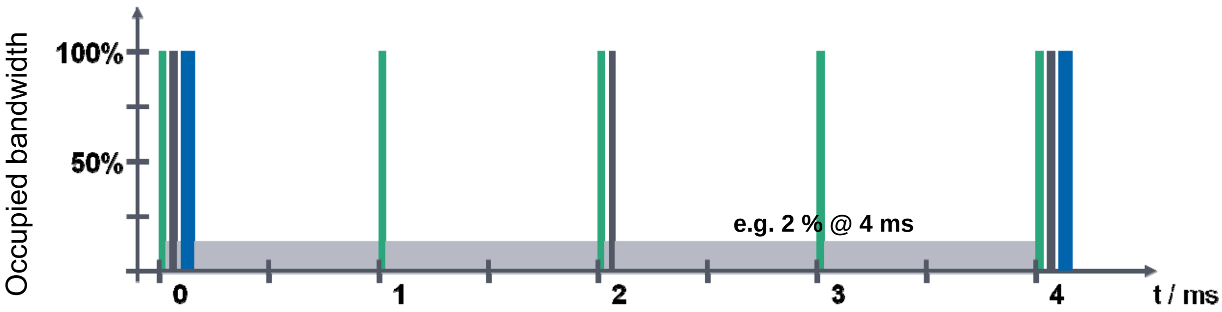


Figure 5-5: Example of the network load development during a transmission cycle

The distribution of the network load over the time period under consideration cannot be determined directly, as the values are always averaged. The longer the period under consideration, the more the averaging effect takes effect, i.e. short network load peaks are simply "blurred". In the example shown in Figure 5-5 the network load is 2% related to 4 ms.

With PROFINET the data is usually transmitted in full-duplex mode, i.e. data is simultaneously transmitted and received. As a result you can individually consider each communication direction.

The ratio of the used bandwidth and the maximum available bandwidth is called the network load.

Depending on the data volume to be transmitted and the preset update time the bandwidth required for the RT communication varies. The bandwidth available for NRT communication changes accordingly.

5.1.4 Response time of processing chains

Every PROFINET device sequentially executes its program within a specific cycle time. The inputs are read at the beginning and the outputs are set at the end of each cycle. The relative timing of these cycles to each other (see Figure 5-6) has an impact on the response time in a processing chain.

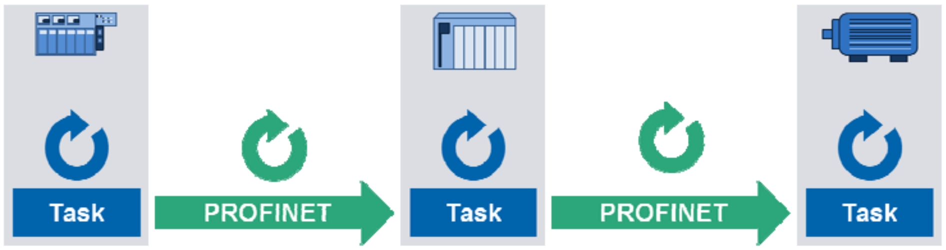


Figure 5-6: Cycles in the processing chain

Figure 5-7 shows an example for processing an event. This event could be, for example, the entry of a stop command for a motor.

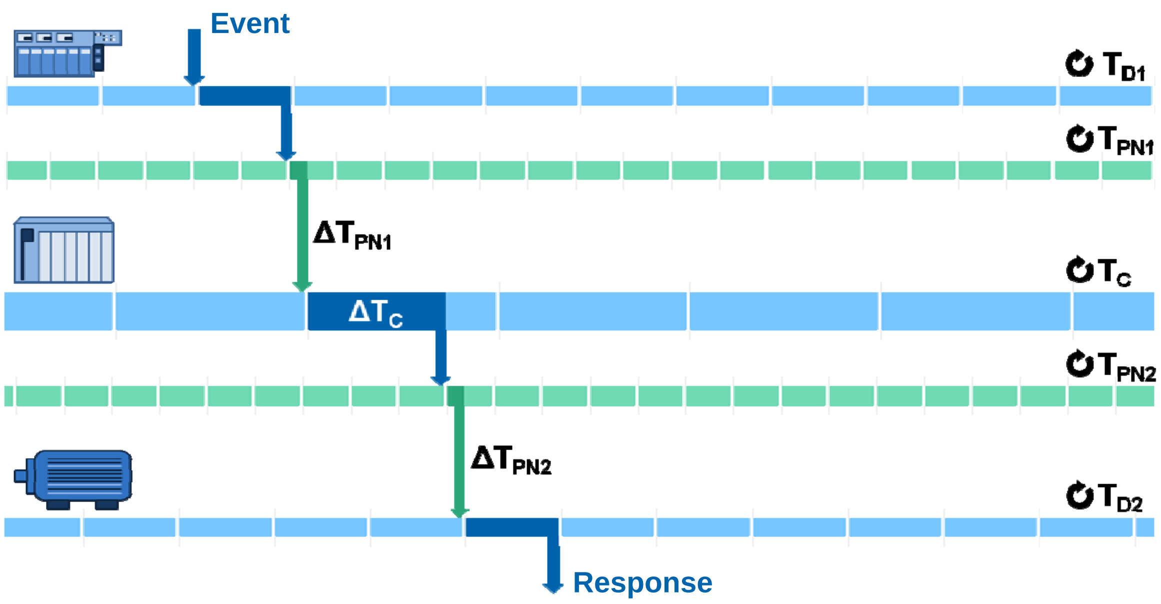


Figure 5-7: Examples of cycles in the processing chain, shortest response time

The execution time is determined by:

- The cycle time of the controller T_C.
- The processing time in the controller ΔT_C.
- The cycle times of the devices T_{D1} and T_{D2}.
- The cycle times / update times of the devices T_{PN1} and T_{PN2}.
- The transmission times of the data through the network ΔT_{PN1} and ΔT_{PN2}.

In this example it is assumed that the PLC tasks are cyclically executed in the controller, e.g. with IEC 61131-3-systems. It is assumed that the processing time of the PLC task ΔT_C is faster than the cycle time T_C of the task. If the tasks are executed in the controller cyclically ("PLC mode"), the cycle time of the controller T_C corresponds to the processing time in the controller ΔT_C.

In the best case, the data are received "just in time" right before the start of the next cycle and can be directly processed. No additional delay occurs.

In the worst case the execution must wait for an entire cycle in each processing step until evaluation and response will be possible again, see Figure 5-8. This consideration is based on the assumption that with cyclic processing the event has "just been missed" and processing will not be possible before the next cycle starts.

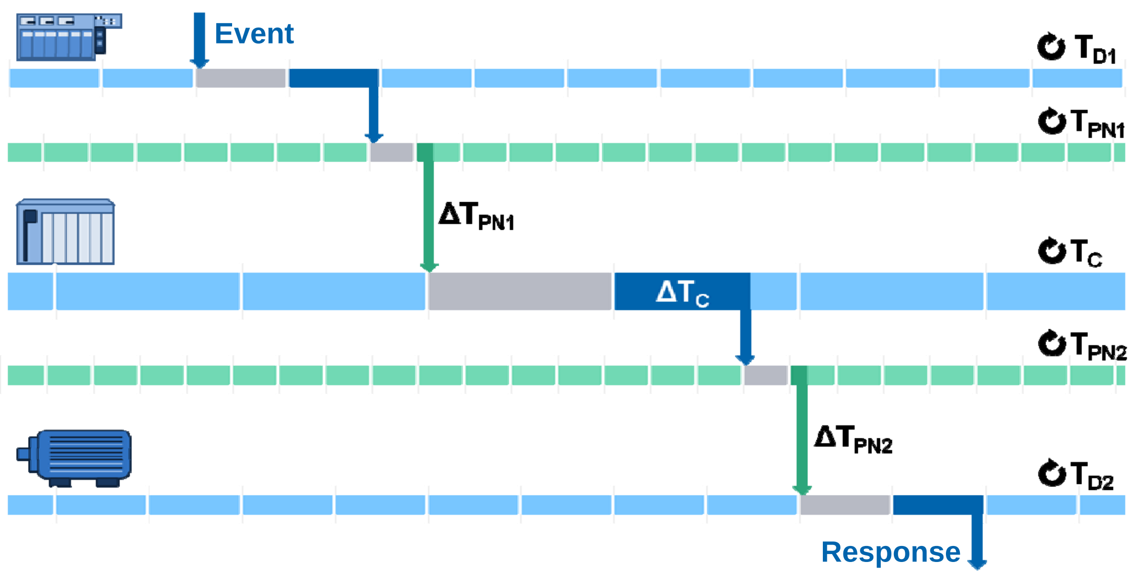


Figure 5-8: Examples of cycles in the processing chain, longest response time

As the cycles of the components in a system are not synchronized with each other, variations of the response time must be expected.

In the worst case the response time in the processing chain may be twice the time required in the best case, as shown in the following example:

Example Assuming

T_C = 15 ms

ΔT_C = 10 ms

T_{D1} = T_{D2} = 3 ms

T_{PN1} = T_{PN2} = 2 ms

$\Delta T_{PN1} = \Delta T_{PN2}$ = 100 µs

gives a response time of

min.

$$T_{D1} + \Delta T_{PN1} + \Delta T_C + \Delta T_{PN2} + T_{D2} = \mathbf{16.2}\ \boldsymbol{ms}$$

max.

$$2 \cdot T_{D1} + T_{PN1} + \Delta T_{PN1} + T_C + \Delta T_C + T_{PN2} + \Delta T_{PN2} + 2 \cdot T_{D2} = \mathbf{41.2}\ \boldsymbol{ms}$$

In the example described above, the impact of the PROFINET update time is rather low, as shown in the example below:

Example Reducing the response time T_{PN1} and T_{PN2} from 2 ms to 1 ms while maintaining the assumptions specified in the previous example will result in a minimum response time of 16.2 ms and a maximum response time of 39.2 ms.

In this case, the ratio of the update time and the controller cycle time is 1:15.

In the above example the reduction of the controller cycle time has a considerably higher impact on the response time:

Example Reducing the controller cycle time T_C from 15 ms to 10 ms with a controller processing time ΔT_C of 5 ms while maintaining the other assumptions of the first example gives a minimum response time of 11.2 ms and a maximum response time of 31.2 ms.

In this case, the ratio of the update time and the controller cycle time is 1:5.

A change of the ratio of the update time and the controller cycle time will result in a change of the response time.

Make sure that the response time of your control system is sufficiently fast for your application.

5.2 Planning of the IO cycle

The following section deals with the definition of the device configuration. In this context, the PROFINET update times and monitoring functions are discussed.

5.2.1 Planning of update times

Controllers operate cyclically with a specified update time. The update time of all other PROFINET devices must be defined as a function of the controller cycle time. For multi-controller applications the devices assigned to the corresponding controller must be considered.

With fast update times the data will be updated at shorter intervals. As a result, they will be available for processing more quickly. However, the data volume transmitted in a time period and, thus, the network load are increased.
Figure 5-9 illustrates how the network load increases as a function of the update time and the number of network nodes, using the typical PROFINET packet size 108 bytes (60 bytes payload data) as an example.

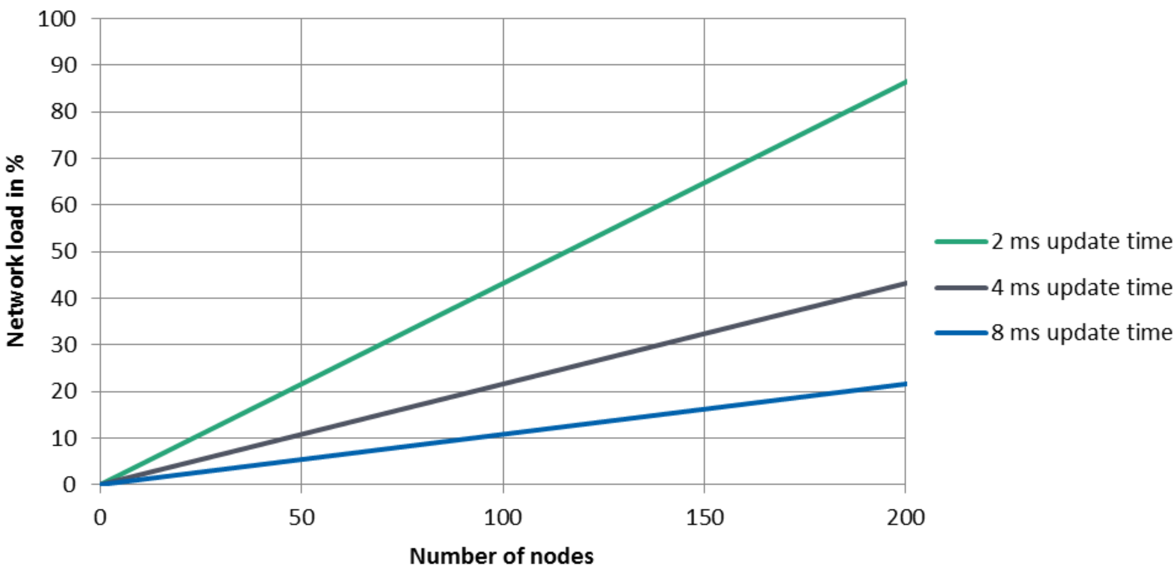


Figure 5-9: Cyclic PROFINET network load as a function of update time and number of network nodes (typ. PROFINET packets)

When the network load is increased by cyclic real-time communication, the bandwidth available to other communications decreases. The network load topic is detailed in chapter 5.3.2.

The faster the update time, the larger the bandwidth occupied by cyclic real-time communication.

The slower the update time, the slower the response time.

It is therefore recommended to choose the update time per PROFINET device as fast as required and as slow as possible.

Observe the line depth and update time specifications in chapter 5.3.1.

- Define the update time for all devices.
- Bear in mind that you have to adapt the update times accordingly when using wireless transmission technologies.
- Check the response time of the entire system resulting from this.
- Document these specifications.

5.2.2 Definition of PROFINET communication monitoring

Data transmission errors may occur in a network. As a result, communication monitoring must be fault-tolerant to a certain extent. However, it must be possible to detect an error as early as possible to be able to react accordingly in the event of communication failure, e.g. by setting outputs to a defined state. The goal is to check and, if required, adapt communication monitoring.

The communication monitoring function in a PROFINET network checks if valid data are received. If no valid data are received within a preset time or number of communication cycles, it is assumed that an error has occurred.

In the following description, the number of communication cycles without valid data after which an error is assumed is called the threshold.

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

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

Figure 5-10 illustrates the process of setting the standard threshold to 3.

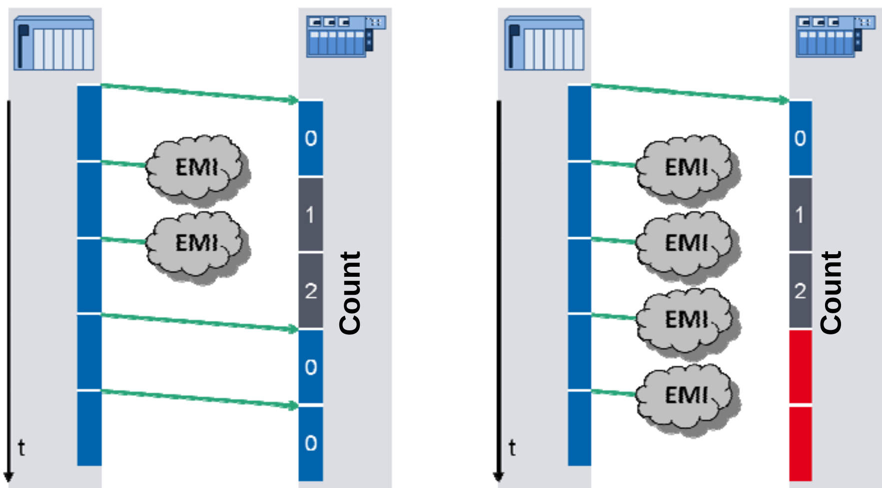


Figure 5-10: Communication problems with error threshold 3

In the first case (left part of the figure) the communication is disturbed for two cycles, for example by electromagnetic interference (EMI). As the threshold is not reached, the counter is reset at the restoration of the communication, and normal communication continues.
If the problem persists for a longer time (right part of the figure) a communication error is assumed and the communication is terminated.

The threshold value determines the time from which on the absence of data will be considered as an error.
The higher the threshold, the later a communication error will be recognized. Figure 5-11 shows the situation of a persistent communication error, using the standard threshold of 3 and a threshold of 10 as an example.

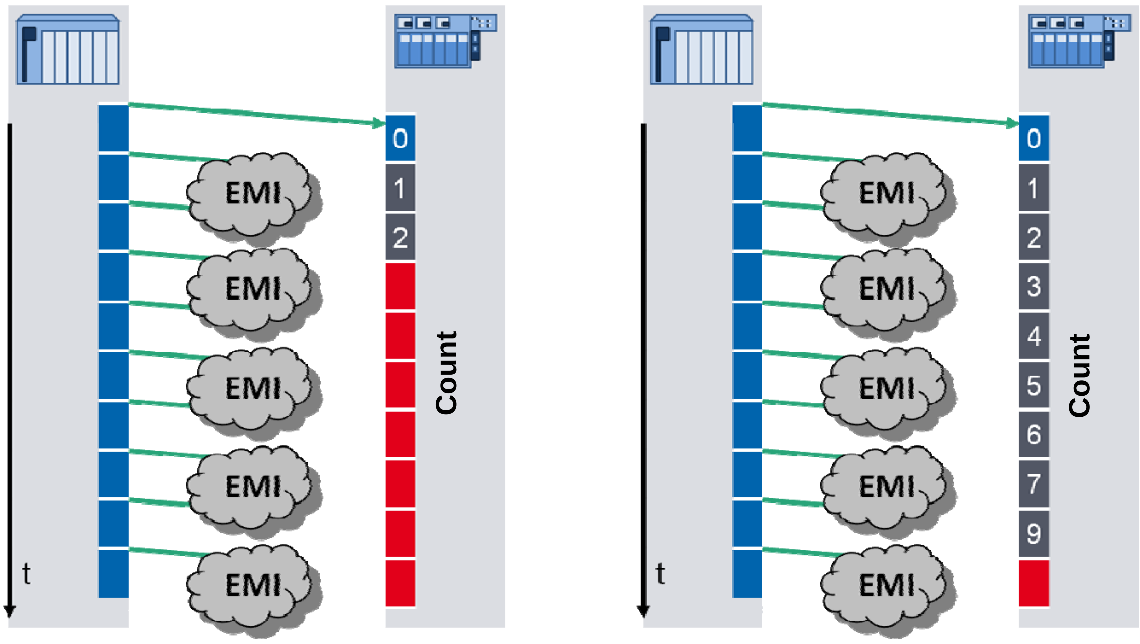


Figure 5-11: Comparison of low (3, left) and high (10, right) threshold

The time until an error is recognized is given by the communication cycle time and the threshold. This means that with a standard threshold of 3 and an update time of 2 ms an error would be detected after 6 ms, whereas an update time of 4 ms would result in an error detection time of 12 ms, etc.

A higher threshold increases the fault tolerance in case of problems, but also delays the detection of an error.

It is recommended to keep the standard threshold setting of 3. If you should choose another threshold value, you have to check if the response time in the event of an error is sufficiently short.

Define the thresholds for the monitoring function and document your settings.

5.3 Checking the performance of the planned network topology

Having defined the update times and the monitoring functions, the designer should check the expected performance of the planned topology.

5.3.1 Checking the line depth

Each switch that is placed between a device and its controller introduces a delay in the data transfer. The number if switches between a controller and a device is called the line depth. The designer must take account of the line depth in the proposed topology. A line topology will exhibit a significant line depth because of the integrated switches in the devices. A large line depth will introduce delay which must be taken into account when planning the topology. Figure 5-12 shows an example with a line depth of 9.

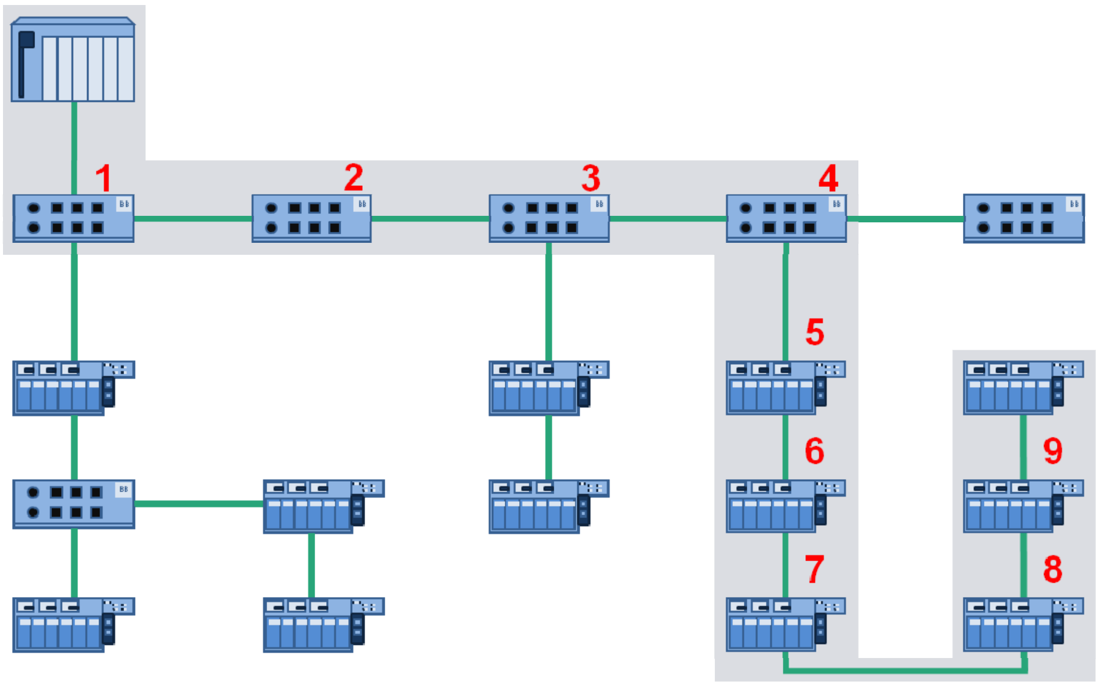


Figure 5-12: Line depth example

Usually, critical communication relations occur between devices and controllers. If more than one controller is involved, the devices assigned to each controller must be considered.

The larger the line depth, the larger the delay of data transmission. As a result, the data will have a certain age when it arrives at the destination. Excessive line depth should be avoided for time-critical applications.

A large line depth may affect the response time.
Check which type of switches ("Store and Forward" or "Cut Through") are to be used in your network. Store and Forward switches give more delay than Cut Through switches. If you do not know the type of switches used, assume "Store and Forward" switches, to be on the safe side.

The maximum line depths listed in Table 5-1 are valid for "Store and Forward" switches.

Table 5-1: Maximum line depths with "Store and Forward" switches

Maximum line depth with update time			
1 ms	**2 ms**	**4 ms**	**8 ms**
7	14	28	58

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

The maximum line depths listed in Table 5-2 are valid for "Cut Through" switches.

Table 5-2: Maximum line depth with "Cut Through" switches

Maximum line depth with update time			
1 ms	**2 ms**	**4 ms**	**8 ms**
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 it is recommended to assume the limit values for “Store and Forward” switches or explicitly calculate the processing time.

If it should not be possible to observe the values specified in Table 5-1 resp. Table 5-2. You should re-design the structure of your network. It is, for example, possible to segment line topologies to achieve several short lines, as shown in Figure 5-13.

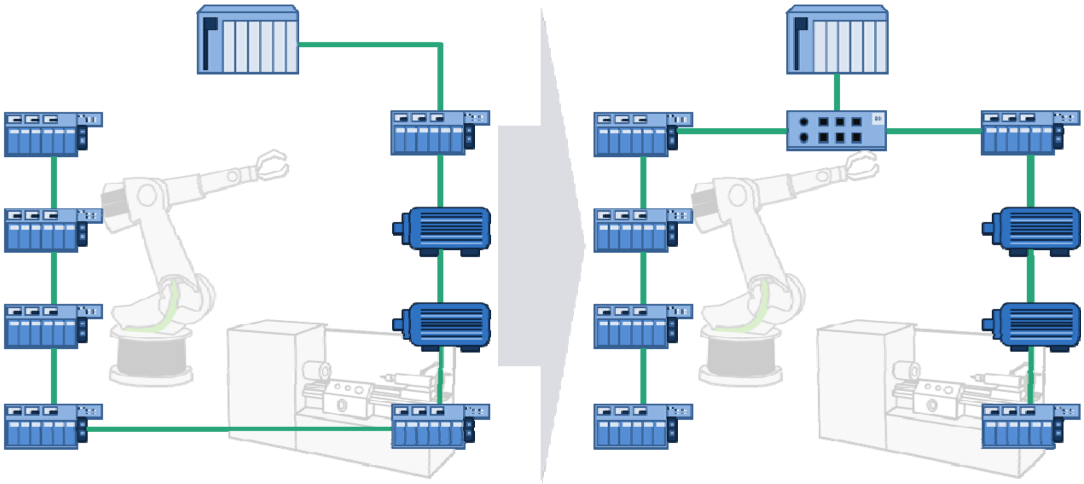


Figure 5-13: Example of reduced line depth

The re-structuring options depend on the structure of your individual plant. Possible additional expenditure for supplementary switches or cabling is compensated by a higher plant availability and shorter plant response time.

Check the line depth of your plant. If required change the topology. Take into account the specifications in Table 5-1 resp. Table 5-2.

5.3.2 Checking the cyclic real-time network load

You should have defined update times of the PROFINET devices in a previous step.

As already mentioned in chapter 5.2.1, every PROFINET device generates a specific cyclic network load with a given update time. In this chapter, the cyclic real-time network load (RT network load) is analyzed and evaluated.

Figure 5-14 shows a PROFINET network with one controller and several devices as an example. For illustration purposes, it is assumed that each device in the example generates a cyclic real-time network load of 1%. This value is used for illustration, only. In a real plant it is usually smaller. In the example only the direction from the IO device to the controller is investigated, although the data are actually transmitted in both directions.

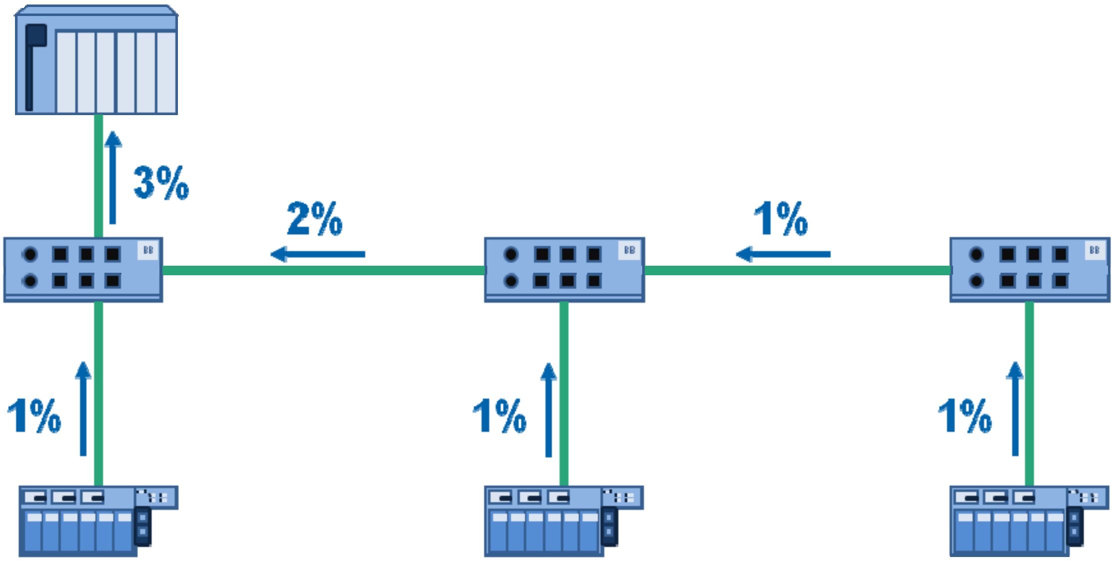


Figure 5-14: Example of network load distribution in a single controller application

As shown in the example, the data streams in the same direction add up. The highest network load, i.e. the total of all network loads generated, occurs in the link between the switch and the controller.

This applies also to applications with multiple controllers. As an example the given configuration is extended by another controller and three assigned devices, as shown in Figure 5-15. At the locations highlighted red the network loads of the different controllers add up.

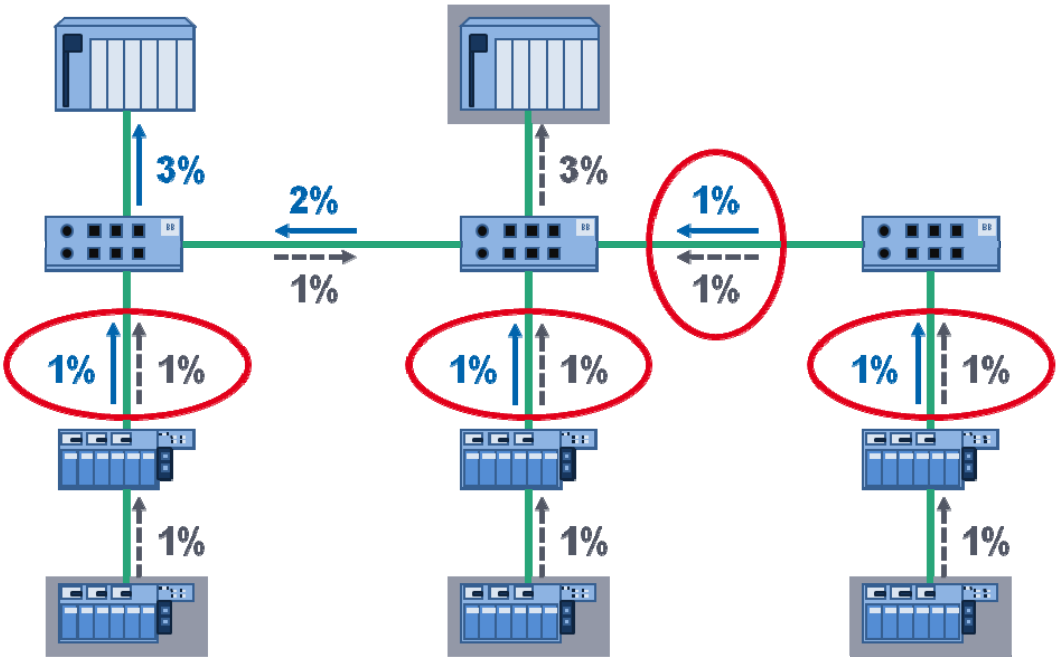


Figure 5-15: Example of network load distribution in a multi-controller application

It is important for your planning to identify the critical locations in your topology, i.e. the locations of maximum network load. In the given example these are the links to both of the controllers.

The critical locations are those of maximum network load.

The communication runs simultaneously in transmit and receive direction. In practice it is sufficient to analyze only the direction with the higher load.

In order to be able to identify the critical locations, you have to know the cyclic real-time network load generated by each PROFINET device, which depends on the update time and data volume.

Table 5-3 is an example of the cyclic real-time network load generated by PROFINET devices at different update times and assuming a network bandwidth of 100 Mbit/s. A typical PROFINET packet of 108 bytes (60 bytes payload data) is considered. As the data volume depends on the application, this table is only intended to give you a first idea. It is recommended to calculate the generated network load for your individual application.

Table 5-3: Generated cyclic real-time network load (typ. PROFINET packet size 60 byte of PROFINET pay-load data, 100 Mbit/s)

Update time	Generated cyclic real-time network load per PROFINET device
1 ms	0.86 %
2 ms	0.43 %
4 ms	0.22 %
8 ms	0.11 %

The specified values include Preamble, StartFrameDelimiter and InterFrameGap.

Determine the network load of your plant and identify critical locations.

The network load calculation tool is available free of charge for download at:

www.profinet.com
under “Download > Installation Guide > PROFINET Installation Guide”

An overview of the user interface as well as a short user manual is provided in the Annex.

Programs for network load calculation are also offered by various vendors. Usually, the engineering tool of your control system also provides this option.

Refer to Table 5-3 for an introduction.

In order to provide sufficient reserve for future extensions and especially for NRT communication, it is recommended to observe the limit values specified in Table 5-4 when designing your PROFINET network.

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

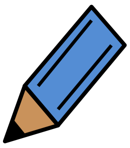
Network load	Recommendation
<20%:	No action required.
20…50%:	Check of planned network load recommended.
>50%:	Take the appropriate measures to reduce the network load.

There are various options, of which the following should be considered first:

- **Increasing the update time** (see chapter 5.2.1).

Other options:

- **For multi-controller applications: Separating PROFINET devices assigned to the corresponding controller to different network paths** , thus reducing the load of links with parallel data traffic as shown in Figure 5-15.
- **Connecting subnets via additional network adapters in the controller**
- **Using additional controllers for load distribution:** The controllers should be connected to the network via separate paths to actually reduce the network load in critical sections.



Change the topology as required and document the changes.

5.3.3 Checking the non-real-time network load

PROFINET allows standard Ethernet nodes such as video cameras, PCs or HMI stations to be directly integrated into the plant network.

Consideration must be given to the effect of such devices on the performance of the real-time communication. The PROFINET data traffic and the standard Ethernet data traffic may interfere. Standard Ethernet nodes may under certain circumstances exchange large data volumes.

The following scenarios are possible:

Regular NRT communication: For example a video stream from a camera to an evaluation PC. Additional network load is permanently generated.

Temporary NRT communication: Data streams that occur only occasionally, for example during a data backup on an archive server, or during call up of process graphics at an operator station.

Figure 5-16 shows an example topology with an archive server (temporary NRT communication) and a video camera and an operator station representing standard Ethernet nodes that regularly generate NRT communication (video stream).

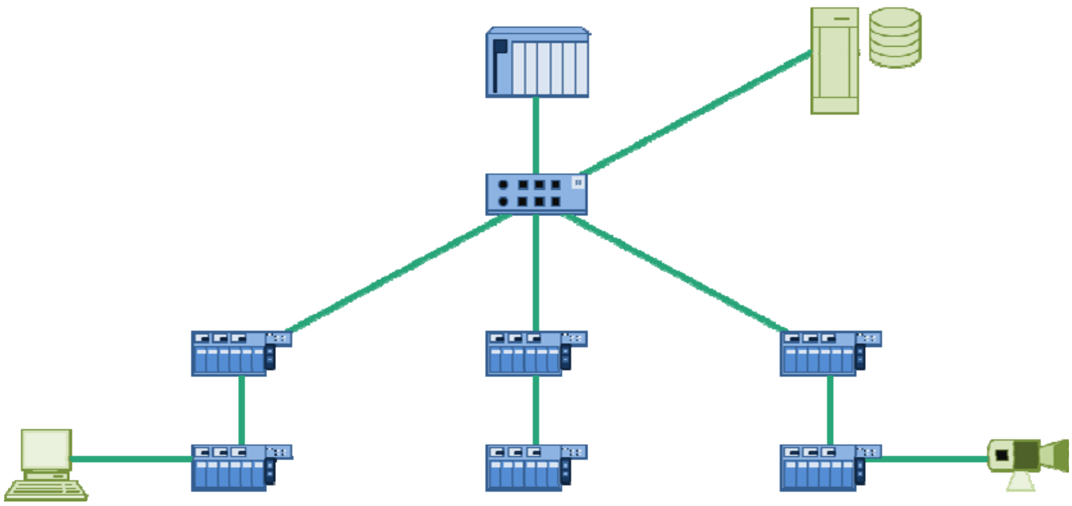


Figure 5-16: Example topology with standard Ethernet nodes

It is often very difficult or even impossible to exactly determine the additionally generated network load. If it can be determined, this information is useful for evaluating the total network load.

If possible, determine the **regular** NRT network load.

This load adds up to the cyclic real-time network load described in chapter 5.3.2. If required, identify the critical locations of your topology again and check if the network load limits specified in chapter 5.3.2 are complied with.

For temporary NRT communication it is often not possible to determine when communication actually occurs.

Some standard Ethernet nodes also prioritize their data packets. This may cause priority conflicts with PROFINET packets, which are consequently no longer getting higher priority against other prioritized packets.

This applies especially to image (camera) and voice (VoIP) data streams.

All network nodes that generate image or voice data streams should therefore be checked for possible message prioritization. Where present the prioritization should be disabled if possible. If, however, this prioritization cannot be disabled or you cannot reliably determine whether these devices conduct prioritized data transmission or not, it is recommended to separate these data streams.

If required separate network nodes that prioritize their messages.

Change the topology if required and document these changes.

Communication relations not only exist between controllers and devices. Devices can also communicate with each other. This type of communication often occurs between standard Ethernet nodes.

Figure 5-17 shows a typical example of this type of communication between standard Ethernet nodes. A large data volume is transmitted from a camera to an operator station.

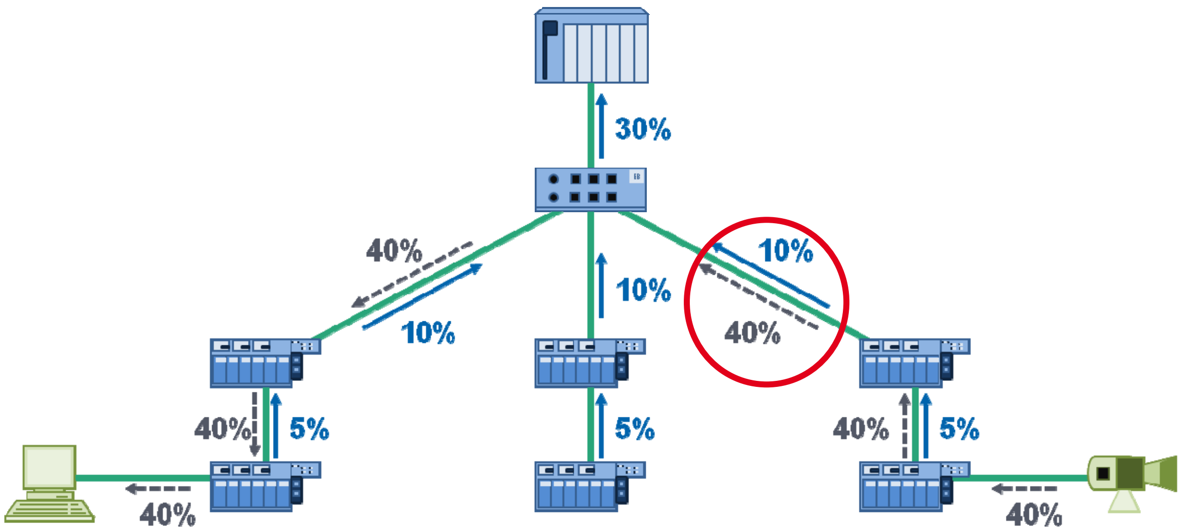


Figure 5-17: Integration of standard Ethernet nodes

Disadvantageous topologies as shown in the example in Figure 5-17 imply that the data stream runs throughout the entire plant network, generating additional load on the parts that convey cyclic real-time communication. In the example the additional communication volume would cause a network load of 50% in some locations (Figure 5-17, red circle).

To solve this problem the topology should be changed. In the example, the camera and the PC could be directly connected to the switch. As a result, the large data stream would no longer represent a considerable load for the other sections of the network, see Figure 5-18.

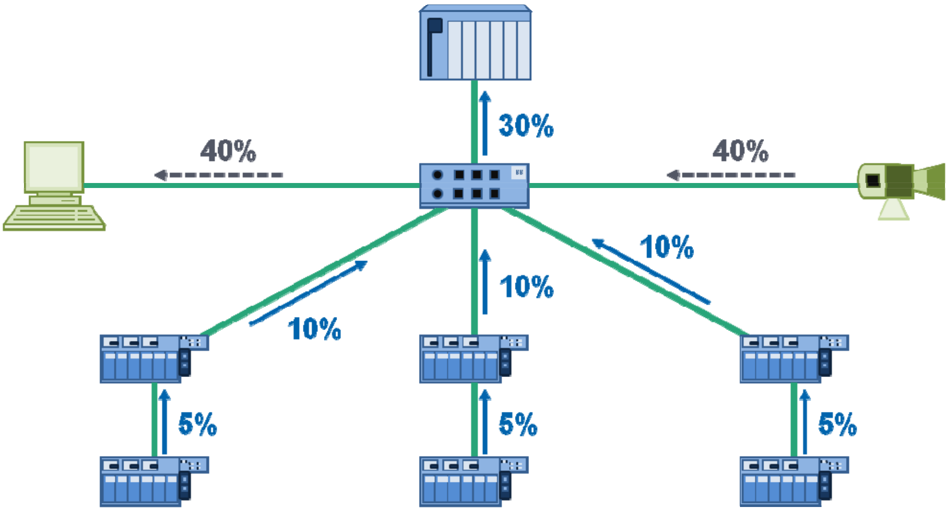
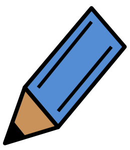


Figure 5-18: Optimized topology with reduced network load

Usually, switches have a sufficient internal bandwidth, so “crossing” data streams usually do not affect each other.



Check if it is necessary to separate data streams.

Change the topology, if required and document these changes.

5.4 Documenting your settings

Once all the settings described in the above-listed steps have been incorporated, they should be incorporated into the documentation. The settings to be documented include:

- Changes of the network topology
- Update time settings
- Monitoring function settings

It is important to ensure that all settings and changes are incorporated in your documentation and are up to date. If required, add missing items.

6 Planning of additional functions

In addition to the functionality described above, PROFINET offers a number of additional functions which need to be considered when designing the network.

This includes:

- the optimization of the plant availability,
- the use of a wireless connections and
- the Engineering access for commissioning and service.

The following section provides a short summary of these functions.

6.1 Increased availability

In some cases, automation plants require an increased availability. Several approaches exist for PROFINET systems. Here we will introduce the network structures to increase plant availability.

In addition, the properties of a redundant structure will be discussed. We differentiate between bumpless and non-bumpless changeover.

Adjustment of network infrastructure

Figure 6-1 shows a line topology of a plant part for which a device is to be exchanged.

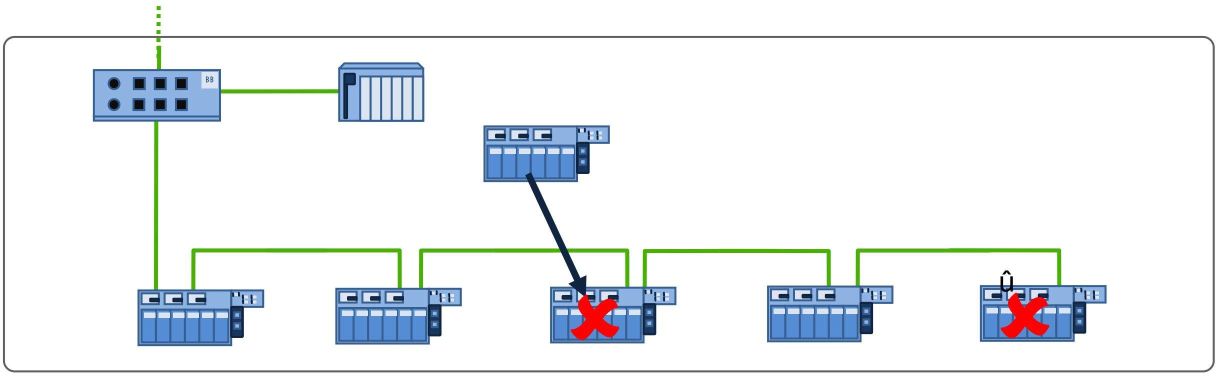


Figure 6-1: Device exchange in a line topology

Removal of a PROFINET device from a line structure causes the communication to downstream devices to be interrupted.

! A device exchange or the outage of a link interrupts the downstream communication.

The interruption of a link has the same effect. The primary solution to increase the availability and to reduce interruptions of communication in a line topology is the use of a star or tree structure.

Figure 6-2 shows two device exchange scenarios in a star or tree structure.

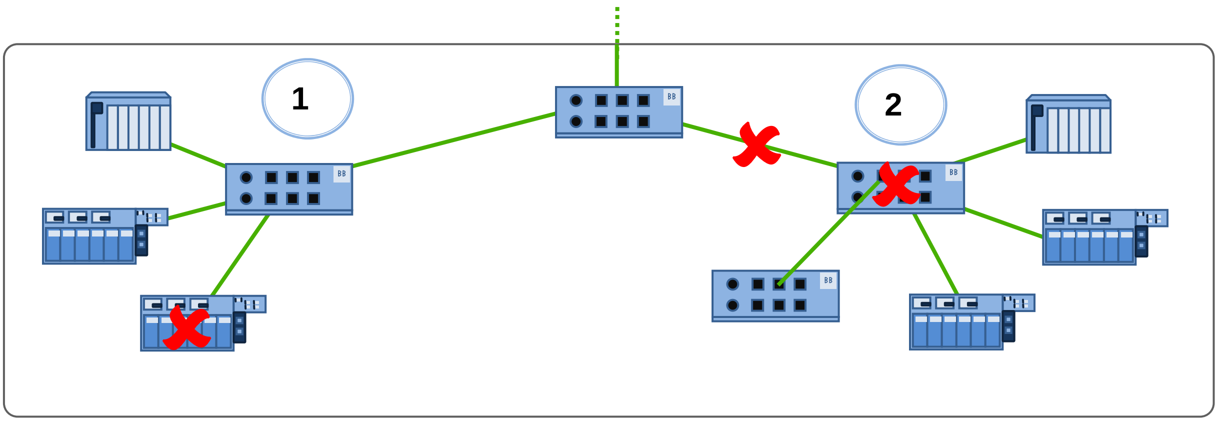


Figure 6-2: Device exchange in a star or tree structure

In **scenario 1**, the device exchange does not affect communication of the other network nodes since the process-related PROFINET devices in this topology do not communicate with each other. This means all PROFINET devices can be exchanged without any impact on communication.

In **scenario 2** the outage or change of the central switch or a link interruption will inevitably interrupt communication of the remaining nodes in this branch. This can be avoided by using a ring structure, as shown in Figure 6-3.

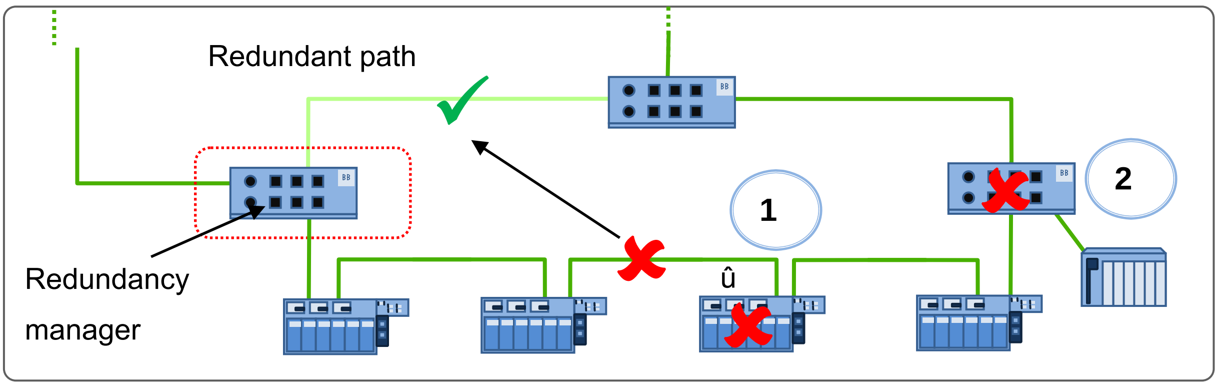


Figure 6-3: Upgrading a line topology to a ring structure

Ring structures are built up using switches. These can be separate switches or switches integrated in PROFINET nodes. To be able to use ring structures in PROFINET plants, all PROFINET nodes in the ring have to support the "**M**edia **R**edundancy **P**rotocol" (MRP). PROFINET nodes are differentiated according to their function as either MRP Manager or MRP Client. One of the PROFINET nodes within the ring structure assumes the function of MRP Manager. The MRP Manager monitors the link to all PROFINET nodes connected in the ring. All other PROFINET nodes in the ring structure assume a function as MRP Client.

The MRP Manager not only monitors the ring structure, but also controls the data traffic. The redundancy manager in case of error-free operation uses only one path to send data. The MRP Manager thus forms a line with the other PROFINET nodes in the ring structure: this line prevents data telegrams from circling within the ring structure without limitation, thus causing undesired network load.

If now the ring structure is interrupted (**case 1** in Figure 6-3), data will also be sent via the redundant path. The MRP Manager has two ring ports and thus forms two lines each with a subset of PROFINET nodes within the ring structure. The MRP Client only acts as a receiver of data.

In conformance class C PROFINET networks, the "**M**edia **R**edundancy with **P**lanned **D**uplication of frames" (MRPD) can also be used. In order to use MRPD, all PROFINET nodes in the ring have to support both MRP and MRPD.

MRPD, even in error-free operation, routes **only** certain PROFINET Realtime Telegrams from the MRPD Manager via the redundant path. The MRPD Client in error-free operation thus receives two telegrams containing identical information. In this case the data from the telegram which has the MRPD Client has received first will be used. The second telegram will be discarded without being used. Now if the ring is interrupted, the PROFINET nodes will continue to receive data without interruption via the redundant path. In **case 2** shown in Figure 6-3, the outage of the switch, in spite of the ring structure, will cause an outage of the control system which is connected to this switch. To further increase the plant availability, a high availability plant network can be designed. The case of a high availability plant network will be described on the following pages.

A ring structure minimizes downtimes caused by simple network outages, e.g. in case PROFINET node within the ring structure is exchanged.

When planning a redundant ring structure, all PROFINET nodes in the ring have to support the Media Redundancy Protocol (MRP). A PROFINET node has to support the function of Redundancy Manager and has to be defined as Redundancy Manager.

If one network component does not have this functionality, redundantly connected links can cause communication problems or even network outages. The PROFINET nodes can be configured using a web-based interface or a vendor-dependent software.

In order to remove the risks of common cause failure of both transmission paths, the return path to close the ring should be installed on a separate cable tray. Cabling documentation should be adjusted accordingly.

Figure 6-4 shows the structure of a network based on a high-availability plant network.

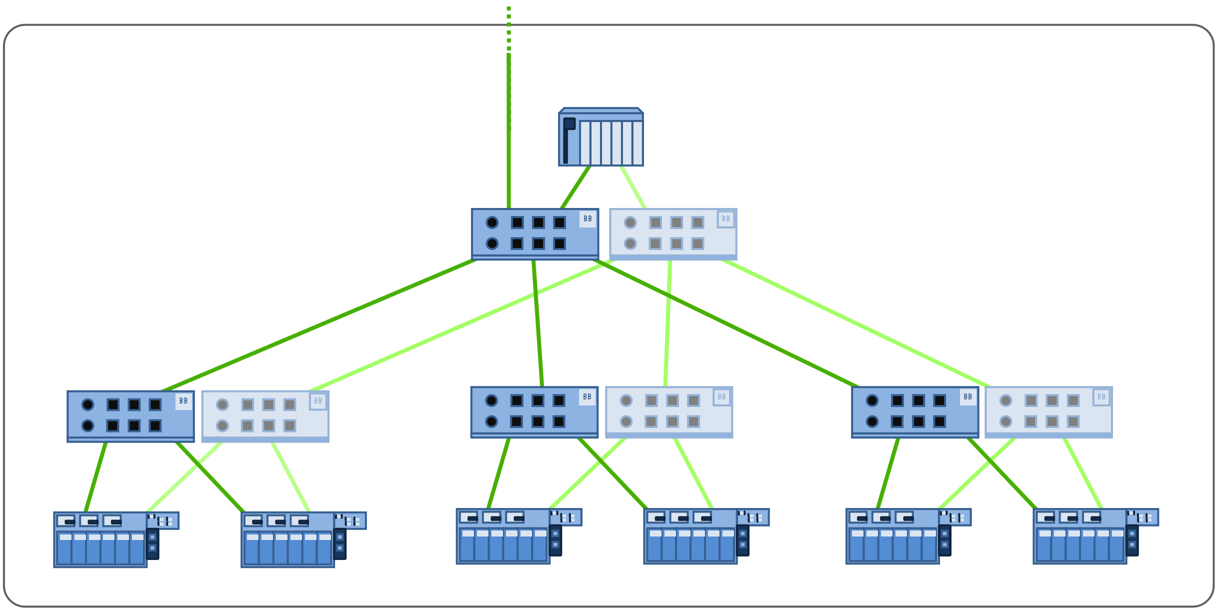


Figure 6-4: High-availability plant network

The redundant network construction is shown clearly. Each network node has two ports for connection to the network. Each of these ports is connected via a separate bus system. One of the systems each is in an active status.

A high-availability plant network requires considerable planning and involves high costs!

These systems are therefore only used in special cases, such as e.g. in process technology, which involve extremely high requirements in terms of plant availability and application.

Here, a device exchange does not affect the communication of the other network nodes, not causing any impact.

Switching times

Redundant systems always require some time to detect an interruption and to consequently switch-over to the redundant path. Two types of redundant switch over can be used:

- Bumpless Changeover – This provides redundant switchover such that no data is lost during an interruption or a device exchange
- Non-Bumpless Changeover – In contrast, is where some data is lost during the switching time.

In ring structures, PROFINET uses the Media Redundancy Protocol and the Media Redundancy for Planned Duplication Protocol (MRP and MRPD). In addition, PROFINET networks support the standard Ethernet redundancy protocols.

You should collect information about the scope of performance and the properties of the different protocols.

!

In particular, make sure that the switching time of the employed redundancy protocol matches the application of the plant. Pay special attention to the reconfiguration times.

6.2 Wireless transmission technology

PROFINET allows for the use of wireless transmission systems. In contrast to the use of cable-based links, wireless technology uses the free space as transmission medium. In automation technology, this commonly used medium is usually designed as an infrastructure network with a central access point. Spontaneous networks without any central access point are rarely used.

The usage of wireless technology requires the consideration of certain factors that do not occur in connection with wired transmission technology. This includes terms such as:

- Attenuation in the free field upon visual contact (free-field attenuation),
- Reflection of radio waves from obstacles,
- Interference of mutually impairing signal sources with identical frequency
- Interference from other signal sources or
- Scattering, diffraction and absorption of signals at surfaces and barriers,

All of which have an impact on the signal strength and quality of the wireless system. Figure 6-5 shows the different influences on wireless transmission technology.

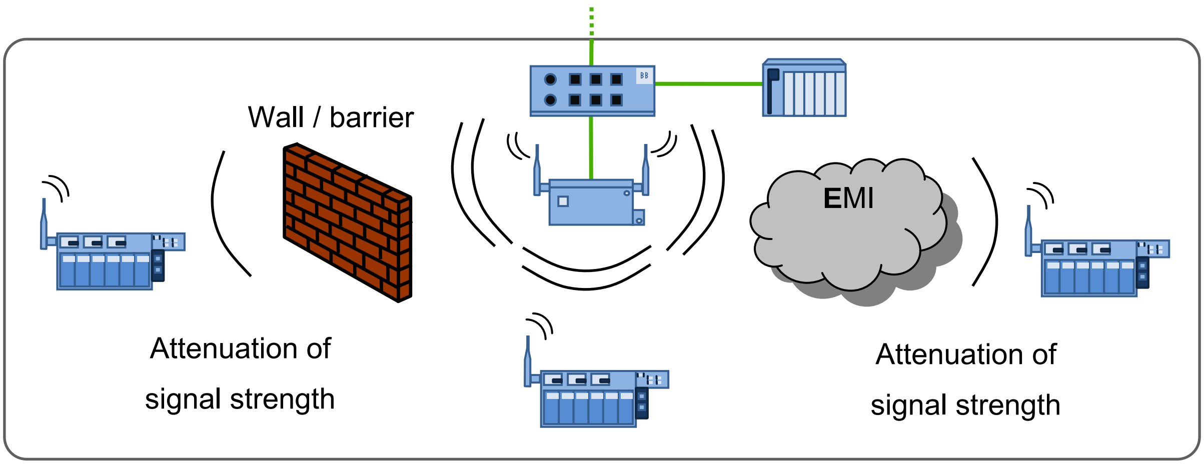


Figure 6-5: Use of wireless transmission technology

To ensure full coverage of the supply area, an appropriate transmission field planning and site survey must have been performed. The transmission field planning is used to determine the impact on the propagation and the behavior of radio waves. It considers points such as special conditions, i.e. factors such as also room dimensions, wall thicknesses, wall materials and metal objects etc.

These factors can e.g. be determined by means of on-site measurements or by means of checking the building and plant plans. Similarly it is possible to use simulation tools to model the transmission field allowing prediction and better planning of the signal propagation from building plans.

After completion of the installation, you should also measure the signal quality in the plant. For further information see PROFINET Commissioning Guideline Order No.: 8.081.

Note that a wireless access point will require a free switch port.

The fact that wireless systems support different data rates has an impact on the number of wireless PROFINET network nodes or their update rate. You should therefore select a suitable update time for the wireless network nodes.

Find out the gross or net data rate supported by your wireless access point and use the network load calculation tool to design the wireless transmission system.

The usually lower transmission rate of wireless networks, when compared to a wired infrastructure, reduces the update rate in a wireless PROFINET network.

This also reduces the maximum number of clients per access point.

The use of wireless transmission makes sense if a wired system cannot be used or can only be used with difficulties, or if the use of wireless transmission technology provides the required mobility and flexibility.

Good candidates for wireless transmission include autonomous guided vehicles and extensive conveying systems. Wireless can however also be used for short range sensor networks.

! Wireless networks must be protected against unauthorized access from outside. You have to take appropriate precautions for safeguarding your wireless network.

This chapter can only give a first introduction to the topic. When using wireless transmission technology, a more comprehensive design phase is required (e.g. regarding the geographical coverage, frequency planning, etc.). This work is beyond the scope of this design guideline.

6.3 Power over Ethernet

Power over Ethernet (PoE, IEEE 802.3 Clause 33) allows low consumption devices to be powered directly over the PROFINET cable. No separate power supply is therefore required. This may save installation costs. Typical devices which can be powered over Ethernet are:

- Access points (wireless)
- IP cameras
- HMIs and control stations
- Barcode readers

The PoE functionality must be supported by both the supplying device (e.g. a switch or separate injector) and the powered device.
Using PoE is recommended if the installation of a power cable in parallel to the PROFINET cable shall be avoided.

Please note that the utilization of Power over Ethernet implies limitations regarding the network topology. A direct link must be provided between the supplying device and the powered device (see Figure 6-6)

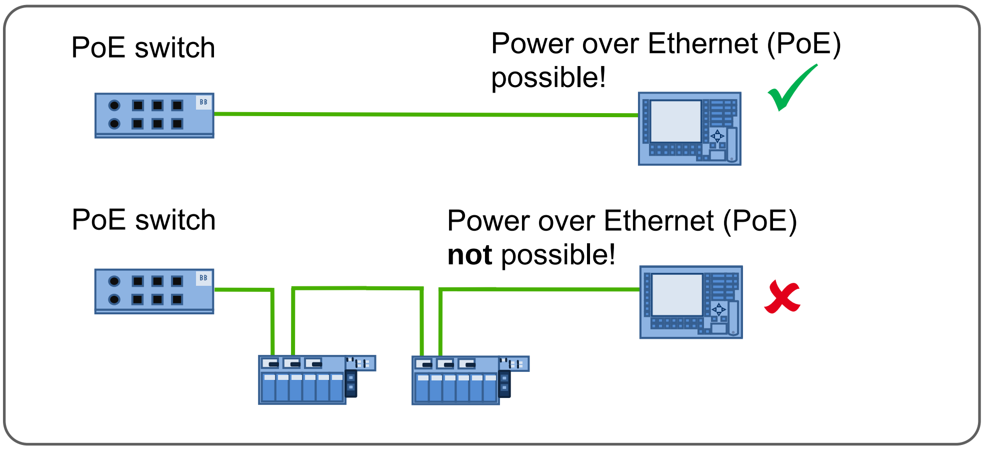


Figure 6-6: Topology limitations with Power over Ethernet

7 Definition of device parameters

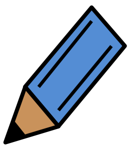
After completing the planning for network nodes and network infrastructure, appropriate parameters have to be assigned to the individual network nodes. These include the

- Device name and the
- IP address.

This chapter describes a systematic approach to the assignment of names and IP addresses. All PROFINET devices need to have a unique device name and unique IP address. For other network components such as switches this depends on their conformance class.

All PROFINET network nodes of conformance class B must have a device name and an IP address. Switches of conformance class B can therefore also be considered as PROFINET devices with device names and IP addresses.

Both address parameters can usually be assigned during the planning of PROFINET devices, provided that they are supported by the network node.



Document the required address parameters of the devices unless this has already been done during the device selection.

7.1 Assignment of names

Before a PROFINET IO device can communicate with a PROFINET IO controller, a device name must be assigned to both communication partners.

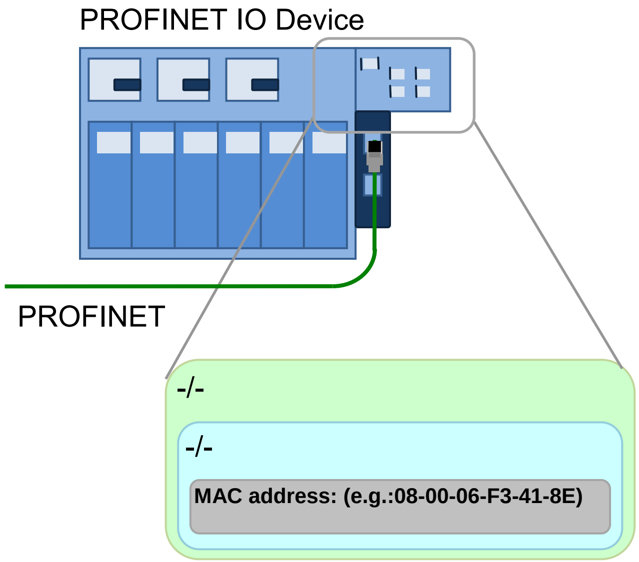


Figure 7-1: PROFINET IO device (delivery status)

For PROFINET, this procedure has been selected since self-explanatory names are easier to handle than IP addresses. In their original delivery status PROFINET IO devices do not have a device name, but only a MAC address. This is stored in the PROFINET device, it is globally unique and can usually not be modified. Many PROFINET devices have the MAC address printed on the housing or on the rating plate.

PROFINET IO devices can be accessed by a PROFINET IO controller only after its device name has been assigned. The device name must be stored by the IO device. If supported by the PROFINET IO device, it can alternatively be directly written to a storage medium (for example an SD card). The storage medium can then be inserted into the PROFINET IO device so that the device name is read by the PROFINET IO device.

The assignment of self-explanatory names will provide you with a better overview of the plant to be commissioned and it facilitates the diagnosis. You should therefore use such names for the individual communication partners which will allow for conclusions as to the relevant plant part.

!

Please bear in mind that PROFINET does not support the full character set for allocating device names. Only numbers, 0…9, lower case letters, “a…z”, hyphen “-“ and period “.” will be accepted. Up to 127 characters can be used, but each name component (i.e. between periods or hyphens) can on be 63 characters or digits in length. Spaces are not allowed.

When selecting device names, please bear in mind the following considerations:

The device name should include an indication of the type of device. It thus makes sense for the designation of a remote IO device to include the designation “remote-io” in the device name. A drive should perhaps include the word “drive” etc.

It is well worth carefully considering using a device naming convention that gives useful information to the maintenance engineer as to the location and function of the unit.

7.2 – Planning of IP addresses

Automatic address configuration

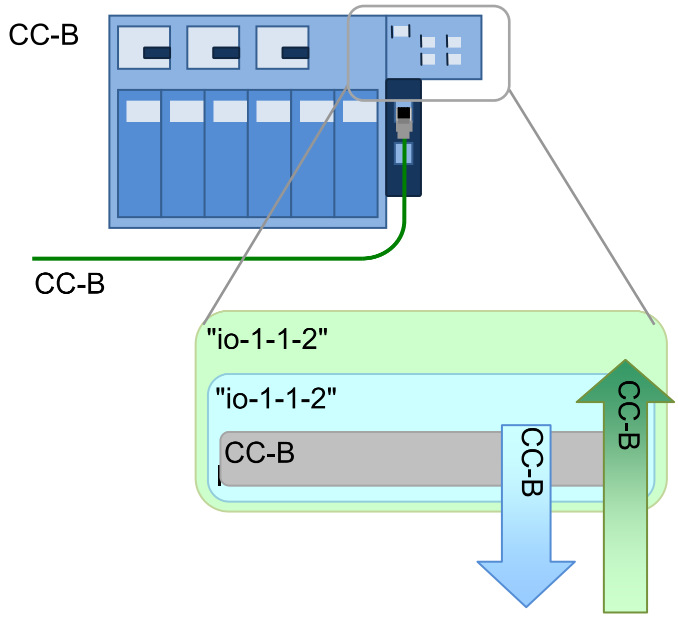


Figure 7-2: PROFINET IO device (address allocation)

The IP address is entered in the configuration of the PROFINET project. This is usually done automatically. The address thus allocated will be transferred to the PROFINET IO device when starting PROFINET IO controller. There is usually a fixed assignment of IP addresses to device names. In addition, this can also be stored permanently. Addressing of a PROFINET IO device therefore in total includes:

MAC address, which is predefined in the PROFINET device and can usually not be modified.

Device name, which can be flexibly selected, but which should be selected according to the relevant plant part to facilitate the overview.

IP address, for which, just as for the name, a firm plan should be defined for the assignment of addresses. You will thus facilitate the reference to the device types.

Information on address configuration

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.

In addition to the device name and the unchangeable MAC address, the IP address is required to clearly identify a network node. In addition to the IP addresses used in public networks such as the Internet, reserved address ranges have been allocated for private or non-public areas. Table 7-1 shows the various private address ranges. The bold-faced figure indicates the network, while the area behind it is uniquely assigned and thus clearly identifies the network node.

Table 7-1: Private IPv4 address ranges

No. of networks	Class	Address range	Network mask	Number of nodes per network
1	Class A	**10**.0.0.0 to **10**.255.255.255	255.0.0.0	16.8 million
16	Class B	**172.16**.0.0 to **172.31**.255.255	255.255.0.0	65534
256	Class C	**192.168.0**.0 to **192.168.255**.255	255.255.255.0	254

A network mask (sometimes called subnet mask) is assigned in parallel to the IP address. IP address and net mask form a firm pair. The net mask notation corresponds to the IP address.

We recommend the use of private IP addresses. The use of public IP addresses is under the responsibility of the plant operator.

For the assignment, the following points should basically be observed:

- From the previous considerations, given the **number of nodes** in a network, select an **address range of appropriate size**.
- **Define an address table.** Divide the PROFINET network nodes into classes. Define a separate address range for each class.
- **Any duplicate use of IP addresses is not permitted.** Any use of identical IP addresses will inevitably cause communication problems for the affected network nodes.

In most cases, addressing using the private class C address range is sufficient. For special cases where a larger address range with more than 254 addresses (Class C) is required, you can switch to a private class B or class A network.

Remember that in large companies, IP addresses are usually assigned by the department responsible for corporate networks.

Document the assignment of IP addresses and IO device names.

7.3 PROFINET plant example

The assignment of IP addresses for a PROFINET automation plant will now be described as an example, using the example plant previously used in this document.

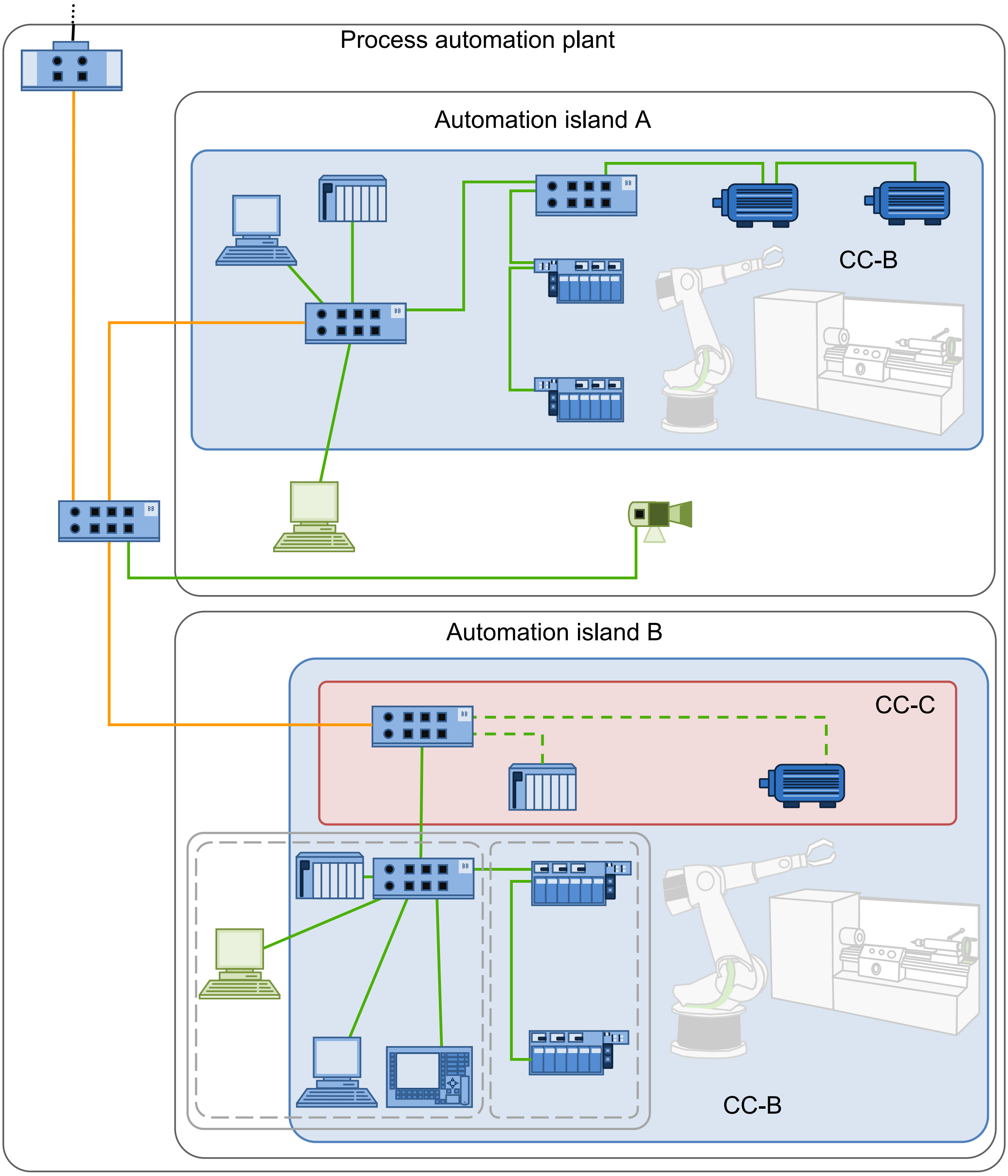


Figure 7-3: Overall structure of example plant

Plant overview

The topology and the number of PROFINET IO devices for the plant have been defined during the design. The result of this design has been assumed as follows:

Automation island A

- Number of PROFINET IO devices: 4
- Tree topology with connected line topology
- 2 switches, 1 controller
- IO supervisor, operating station, camera

Automation island B

- Number of PROFINET IO devices: 4
- Tree topology with connected line topology
- 2 switches (IRT function in one switch), 2 controllers
- IO supervisor, operating station

Higher level connection / control station

- Star or tree topology
- Optical fiber connection
- 1 switch and 1 router

The summary of requirements results in the following number of IP addresses for the example plant.

Table 7-2: Overview of number of PROFINET network nodes

Process automation plant							
Automation island A							
Number switches	2	Number devices	4	IO Controller / IO Supervisor	1 / 1	Other	2
Automation island B							
Number switches	2	Number devices	4	IO Controller / IO Supervisor	2 / 1	Other	1
Higher level connection / control station							
Number switches	1 (+ 1 Router)	Number devices	0	IO Controller / IO Supervisor	0 / 0	Other	0

Address selection

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.

Individual plant parts can be addressed using these addresses. It is a good idea to allocate addresses in blocks for each plant area. An alternative scheme is to allocate address ranges for different device types, such as switches, drives, remote IO etc. Some addresses should be reserved in each block for future expansion.

A possible scheme for address allocation for our example plant might be as follows:

Selection of IP Addresses

1. Different address ranges are assigned to the individual device types in the plant: (see example)

Example	Controller/Router:	192.168.2.1 to 192.168.2.19
	Switches:	192.168.2.20 to 192.168.2.49
	PN IO devices:	192.168.2.50 to 192.168.2.199
		I/O: 192.168.2.50 to 192.168.2.99
		Drives: 192.168.2.100 to 192.168.2.149
		IO Panels: 192.168.2.150 to 192.168.2.199
	Additional functions/ Reserve:	192.168.2.200 to 192.168.2.254

The net mask here corresponds to the standard class C address range (sub net mask "255.255.255.0").

In case the selected address range is too small, a similar structure can also be applied to the other private IPv4 address ranges (class A / class B).

2. Each automation plant receives an address range

Example	Higher-level connection:	192.168.1.xxx
	Automation plant 1:	192.168.2.xxx
	Automation plant 2:	192.168.3.xxx etc.

Only a class C network is normally used for automation plants. For the communication between the individual automation plants with different address ranges a router may be used for connection (IP-based communication, only).

Selection of device names:

According to the structure as per chapter 7.1, the name for a PROFINET device e.g. looks like:

1. The device name includes the designation of the type.

e.g.:	I/O device	"io"	Switch	"swi"
	drive	"drv"	IO panel	“hmi"

2. In addition to the device type, a consecutive numbering and / or a position identifier should be included in the device name to describe the position of the device in the plant.

   e.g.: The second IO device of automation plant 1 in automation island 2 is named

   "io-1-2-2"

In the selected example, "swi-1-0-1" includes the figure "0", indicating that this switch is assigned to automation plant 1, but it is not assigned to a certain island in this plant. This switch interconnects the islands and connects them to the higher level router.

Address selection

Using this notation, the following address assignment can be used for the plant example:

Table 7-3: Address selection in automation plant 1

Type	Name according to planning	Device name	IP address:
Router	ROUT_V1	-/-	192.168.2.1
-/-	-/-	-/-	-/-
PN IO controller	CPU-123-AB	cpu-1-1-1	192.168.2.2
PN IO controller	CPU-345-CD	cpu-1-2-1	192.168.2.3
PN IO controller	CPU-678-EF	cpu-1-2-2	192.168.2.4
Switch	Switch-AB1	swi-1-0-1	192.168.2.20
Switch	Switch-CD2	swi-1-1-1	192.168.2.21
Switch	Switch-EF3	swi-1-1-2	192.168.2.22
Switch	Switch-GH3	swi-1-2-3	192.168.2.23
Switch	Switch-IJ4	swi-1-2-4	192.168.2.24
PN IO device	I/O device V3	io-1-1-1	192.168.2.50
PN IO device	I/O device V2	io-1-1-2	192.168.2.51
PN IO device	I/O device V6	io-1-2-1	192.168.2.52
PN IO device	I/O device-98	io-1-2-2	192.168.2.53
PN IO device	DRIVE _IRT	drv-1-1-1	192.168.2.100
PN IO device	DRIVE _V2	drv-1-1-2	192.168.2.101
PN IO device	DRIVE _V4	drv-1-2-1	192.168.2.102
PN IO device	IO_PANEL_1	hmi-1-2-1	192.168.2.150

Video camera	CAM_V1	-/-	192.168.2.200
Control station	STAT_1	-/-	192.168.2.201
Control station	STAT_2	-/-	192.168.2.202
PN IO Supervisor	IO_SUP_1	-/-	192.168.2.203
PN IO Supervisor	IO_SUP_2	-/-	192.168.2.204

A table provides better overview of the plant, reducing the required work and saving time.

In this example, the switches receive a device name and an IP address. These are required for switches as of conformance class B and have therefore been selected in this example.

8 Summary

After completion of the PROFINET design, all information about your entire PROFINET automation plant should be available to you. This includes information such as:

Communication relations with the data volumes to be transmitted and the geographical as well as functional assignment of all PROFINET devices.

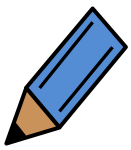
Component selection, such as PROFINET devices, switches, transmission media and connectors, corresponding to the Conformance Class according to the PROFINET component approach.

This also includes the requirements to communication and application.

Network topology of the automation plant under consideration of the data volumes to be transmitted and communication relations of the plant parts. Extensions such as standard Ethernet devices and potential network loads have been integrated in the topology structure.

A **performance consideration** reflecting common network loads of standard Ethernet devices and PROFINET devices as well as their update times has been added to the topology consideration.

Device parameters, such as IP address and device names.



In this context you should check whether all design information of your PROFINET automation plant is available to you.

9 Annex

9.1 Addresses

PROFINET Competence Center

The PROFINET Competence Centers can be contacted in case of any problems with PROFINET. The PROFINET Competence Centers have specialists who are able to help in case of problems. The PROFINET Competence Centers also provide training.

You can find the current contact data of the PROFINET Competence Centers online at

www.profinet.com

in the Support area.

9.2 Glossary

You will find important definitions about PROFINET in the PI Glossary on page

www.profinet.com

under the search term "Glossary".

9.3 Details about PROFINET copper cables

This section of the Annex provides detailed information about PROFINET copper cables.

Properties of PROFINET copper cables

Parameters of cable types

Table 9-1: Cable parameters PROFINET Type A copper cable

Parameter	**Specified limits**
Impedance	100 Ω ± 15 Ω
Loop resistance	<115 Ω/km
Transmission rate	100 Mbit/s
Max. cable length	100 m
Number of wires	4
Wire diameter	0.64 mm
Wire CSA	0.32 mm^2 (AWG 22/1)
Sheath color	green
Color of insulation	white, blue, yellow, orange

Table 9-2: Cable parameters PROFINET Type B copper cable

Parameter	Specified limits
Impedance	100 Ω ± 15 Ω
Loop resistance	<115 Ω/km
Transmission rate	100 Mbit/s
Max. cable length	100 m
Number of wires	4
Wire diameter	0.75 mm
Wire CSA	0.36 mm^2 (AWG 22/7)
Sheath color	green
Color of insulation	white, blue, yellow, orange

Table 9-3: Cable parameters PROFINET Type C copper cable

Parameter	Specified limits
Impedance	100 Ω ± 15 Ω
Loop resistance	<115 Ω/km
Transmission rate	100 Mbit/s
Max. cable length	100 m
Number of wires	4
Wire diameter	0.13 mm
Wire CSA	AWG 22/7 or 22/19
Sheath color	green
Color of insulation	white, blue, yellow, orange

Table 9-4: Cable parameters PROFINET 8-core Type A copper cable

Parameter	Specified limits
Impedance	100 Ω ± 15 Ω
Loop resistance	<85 Ω/km (AWG 23/1)
Transmission rate	1000 Mbit/s
Max. cable length	100 m
Number of wires	8
Wire diameter	≥0.546 mm (AWG 23/1)
Sheath color	green
Color of insulation	white / orange, white / green, white / blue, white / brown

Table 9-5: Cable parameters PROFINET 8-core Type B copper cable

Parameter	Specified limits
Impedance	100 Ω ± 15 Ω
Loop resistance	<85 Ω/km (AWG 23/7)
Transmission rate	1000 Mbit/s
Max. cable length	100 m
Number of wires	8
Wire CSA	≥0.254 mm^2 (AWG 23/7)
Sheath color	green
Color of insulation	white / orange, white / green, white / blue, white / brown

Table 9-6: Cable parameters PROFINET 8-core Type C copper cable

Parameter	**Specified limits**
Impedance	100 Ω ± 15 Ω
Loop resistance	<95 Ω/km (AWG 24)
Transmission rate	1000 Mbit/s
Max. cable length	100 m
Number of wires	8
Wire diameter	Application-specific
Wire CSA	Application-specific
Sheath color	Application-specific
Color of insulation	white / orange, white / green, white / blue, white / brown

Mechanical properties

In addition to the physical data (e.g. diameter and conductor material), the cable manufacturers specify additional mechanical properties of the cable which provide information about the application ranges and installation options of the cables. Typical manufacturer specifications are:

- Bending radius
- Bending frequency
- Tensile strength

While the bending radius and the bending frequency mainly depend on the wire design (fixed / flexible), additional elements such as aramid fibers are added to the cable to achieve a higher tensile strength.

The limit values listed in Table 9-7 have been taken from the IEC 61784-5-3 standard.

Table 9-7: Mechanical properties of PROFINET copper cables

Parameter	**Specified limits**
Minimum bending radius, single bent	20…65 mm
Bending radius, multi-bent	50…100 mm
Tensile force	<150 N
Permanent tensile load	< 50 N
Maximum shear force	--
Temperature range during installation	-20…+60 °C

The limit specifications depend on the cable type. For more detailed information, please see the manufacturer specifications.

Chemical properties

PROFINET copper cables are available with different sheath materials to protect them against environmental influences.

Cable manufacturers specify the properties or the existence of a certain material (e.g. halogen / silicone) in the cable datasheets. Typical manufacturer specifications are:

- UV resistance
- Freedom from silicone
- Resistance against mineral oils and greases
- Permissible temperature ranges

Special attention must be paid to the flammability of the cables. The relevant data are usually provided separately by the cable manufacturers, with reference to the following properties:

- Freedom from halogen
- Flame retardance
- Smoke density

The smoke density is closely related to the freedom from halogen and is not specified by all manufacturers. Therefore, also pay special attention to additional specifications like FRNC (Flame-Retardant-Non-Corrosive). The acronym FRNC indicates that a cable is halogen-free and flame-retardant.

Only halogen-free and flame-retardant cables may be used in areas where, in case of fire, human life is endangered by toxic gas and smoke gas.

Types of copper cables

PROFINET cable

This section describes PROFINET cables with 2 wire pairs. The specifications for 4-pair cables are similar.

The most usual material for the PROFINET cable sheath is PVC (PolyVinylChloride). PVC is generally UV resistant & chemically non-reactive. It is resistant to water, salt solutions, alcohol and light caustic/acid/oil. However, PVC is not suitable for hydrocarbons or organic solvents and has a restricted temperature range (-30 °C to +70 °C).

Type A PROFINET cables usually meet most requirements of automation projects and therefore they are the most frequently used type of cable. As a round cable they have four wires and are radially symmetric. The wires are stranded to form a so-called star quad.

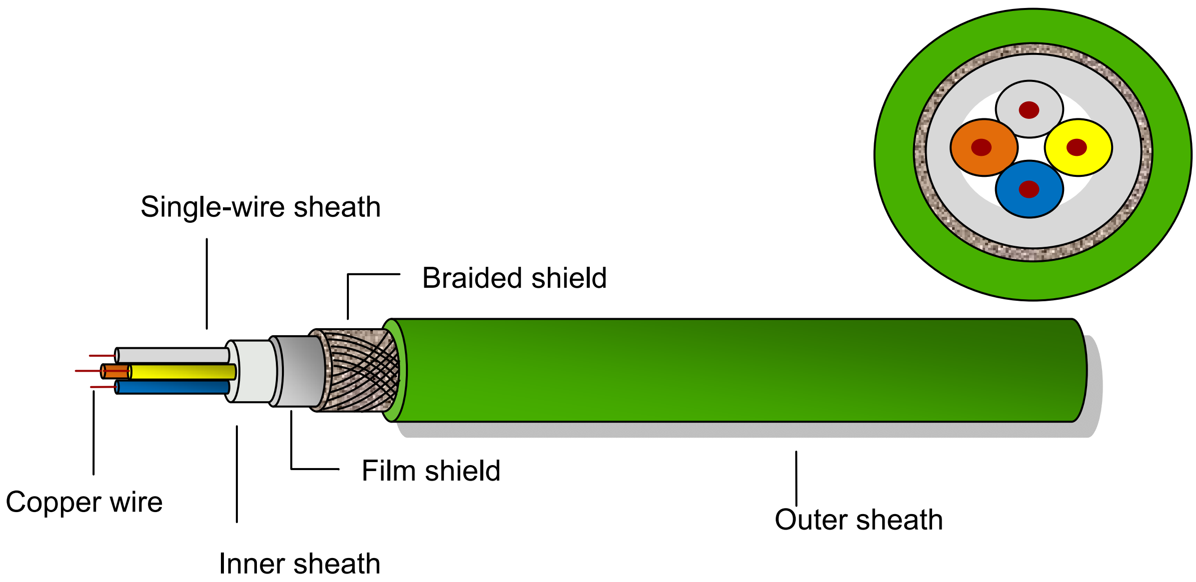


Figure 9-1: PROFINET cable type A

The PROFINET cable type A has been designed for static installation, e.g. in cable trays.

PROFINET PE cable

A PE (PolyEthylene) sheath has better electrical properties than PVC.. Excellent moisture resistance makes PE cables suitable for direct burial and damp environments. PE cables with black sheath are in addition UV resistant. The only difference to type A copper cables is the different sheath color and the sheath material.

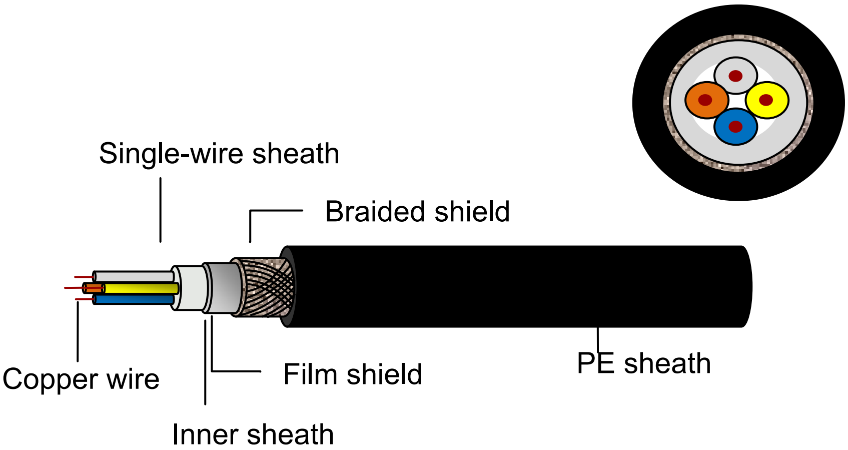


Figure 9-2: PROFINET PE cable

PE cables are suitable for installation in areas where constant humidity must be expected. Due to the PE sheath, the cable, without any flame-resistant additive, is flammable.

PROFINET ground cable

PROFINET ground cables have robust, black outer sheaths made of PE. In many cases, this is applied to the PROFINET cable as an additional sheath. After removing the outer sheath, the uncovered PROFINET cable can be used and assembled as usual.

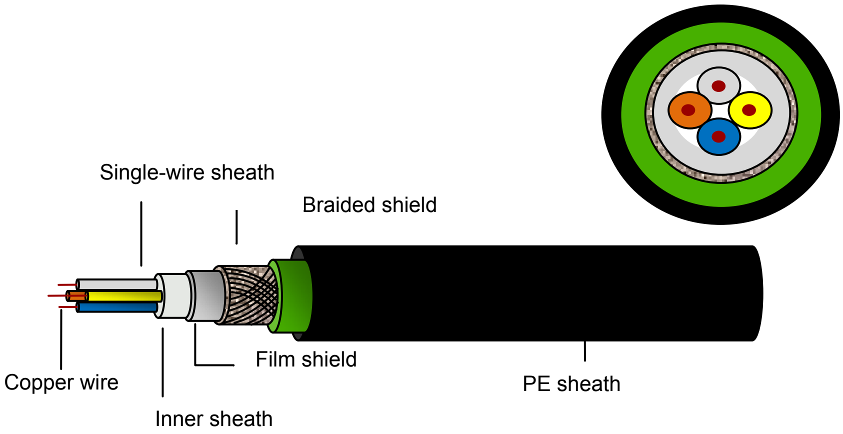


Figure 9-3: PROFINET ground cable

Suitable for outdoor installation or installation in the ground.

Cables with additional protection against rodents are also available. This protection is ensured by means of additional, metal or fiber-based mesh. Observe the manufacturer information about this.

Trailing cable

The wires of this cable type consist of thin-wired braid, enabling the cable to be used at flexible machine parts. The quad star four-wire structure increases the crush and tread resistance. The sheath of this cable type is usually halogen-free and resistant against mineral oil and grease.

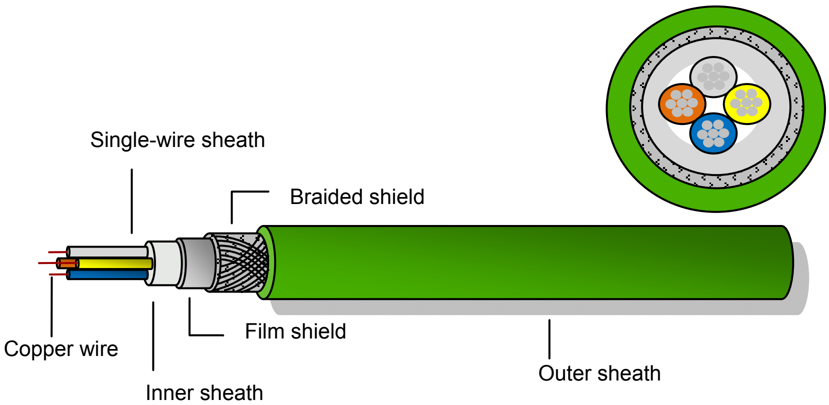


Figure 9-4: Trailing cable

Specially designed cables should be used in cases where the cable will be subject to frequent flexing or bending, such as with mobile machine parts for example. Special cables are also available for trailing chains.

Festoon cable

The wires of this type of cable (similar to trailing cables) consist of thin-wire braid, enabling the cable to be used for festoon applications. The quad star four-wire structure increases the crush and tread resistance. The sheath of this cable version is usually halogen-free and resistant against mineral oil and grease.

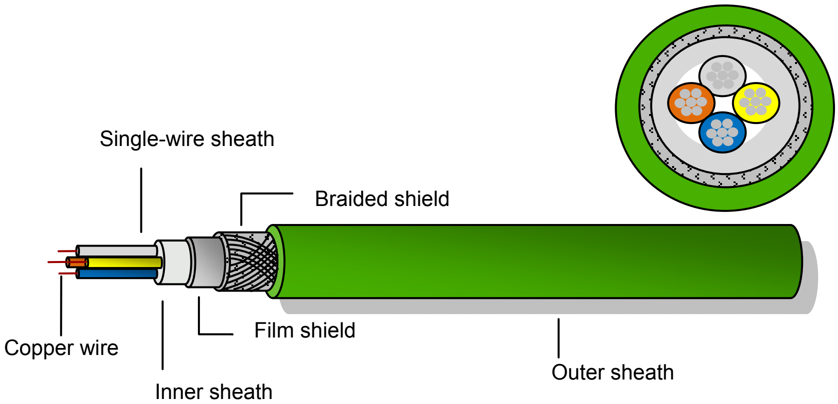


Figure 9-5: Cables for festoons

Specially designed festoon cables should be used in cases where the cable will be subject to permanent movement, such as with mobile machine parts, hoists and cranes. Special cables are also available for torsional movement.

Flame retardant non corrosive cables (FRNC cable)

FRNC (Flame Retardant Non-Corrosive) cable is made with a sheath of halogen-free material for use where flammability is to be avoided. The sheath color of FRNC cable is normally green.

You should use halogen-free cable for applications in areas where in case of fire there are more demanding requirements to the fire behavior of the cable. Possible places of application e.g. are residential buildings or hospitals.

9.4 Details about PROFINET optical fibers

This section of the Annex provides detailed information about PROFINET optical fibers.

Properties of PROFINET optical fibers

Mechanical properties

The mechanical properties of cables give information about possible types of application and installation. In order to get an overview, the following tables show detailed values for typical mechanical properties of optical fibers. The tables differentiate between the fiber types used.

The limit values listed in Table 9-8 and Table 9-9 have been taken from the IEC 61784-5-3 standard.

Table 9-8: Mechanical properties of single / multimode FO

Parameter	Specified limits
Minimum bending radius, single bent minimum	50…200 mm
Bending radius, multi-bent minimum	30…200 mm
Tensile force maximum	500…800 N
Permanent tensile load maximum	500…800 N
Shear forces maximum	300...500 N/cm
Temperature range during installation	-5…+50 °C

Table 9-9: Mechanical properties of POF optical fibers

Parameter	Specified limits
Minimum bending radius, single bent minimum	30…100 N
Bending radius, multi-bent minimum	50…150 N
Tensile force maximum	50…100 N
Permanent tensile load maximum	not allowed
Shear forces maximum	35…100 N/cm
Temperature range during installation	0…+50 °C

The limit values listed in Table 9-10 have been taken from the IEC 61784-5-3 standard.

Table 9-10: Mechanical properties of PCF optical fibers

Parameter	Specified limits
Minimum bending radius, single bent minimum	75…200 mm
Bending radius, multi-bent minimum	75…200 mm
Tensile force maximum	100…800 N
Permanent tensile load maximum	< 100 N
Shear forces maximum	75…300 N/cm
Temperature range during installation	-5…+60 °C

The limit specifications depend on the cable type. For more detailed information, see the manufacturer specifications.

The cable properties in the tables above meet the requirements of common industrial applications. Special applications such as trailing cables, festoons or torsional movements require adjusted cable designs with extended properties.

Chemical properties

FO cables, just as the previously described copper cables, have different sheath materials, giving them certain properties.

- Typical manufacturer specifications are:
- UV resistance
- Freedom from silicone
- Resistance against mineral oils and greases
- Permitted temperatures

For FO cables as well, special attention must be paid to the fire behavior of the cable. Manufacturer data for this include:

- Freedom from halogen
- Flame retardance
- Smoke density

Only halogen-free and flame-retardant cables may be used in areas where, in case of fire, human life is endangered by toxic gas and smoke gas.

Types of FO cables

The cable types most commonly used for PROFINET, with their applications, are listed in Table 9-11. The cable types described can use all fiber types mentioned in section 3.2.2. Additional protection including rodent-protection or special cables for ground installation, are also available.

Table 9-11: Types of FO cables

Cable version	Applications
PROFINET FO cable	For simple point-to-point links between two PROFINET devices
PROFINET FO trailing cable	For installation at moving machine parts.

PROFINET FO cable

Figure 9-6 shows the general structure of a PROFINET FO cable. It consists of two parallel wires. The wires are suitable for direct assembly of connectors. The orange wire is printed with directional arrows to facilitate the assignment of wires to the transmit and receive connections.

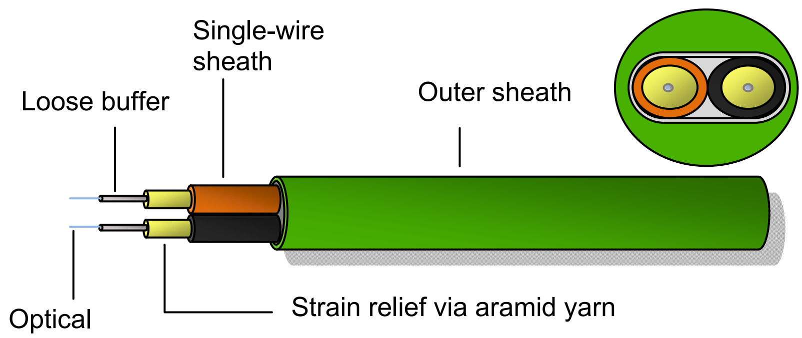


Figure 9-6: PROFINET optical fiber cable

PROFINET FO trailing cable

The FO trailing cable (**Figure 9-7**) has additional non-woven wrapping as well as strain relief elements and an additional support element. The sheath of this cable type is usually halogen-free and resistant against mineral oil and grease.

You should use specially designed cables in case the cable will be subject to frequent movement, such as e.g. the use at mobile machine parts. PROFINET FO trailing cables are available with all common fiber types.

Cables for use in trailing chains can normally not be used as festoons.

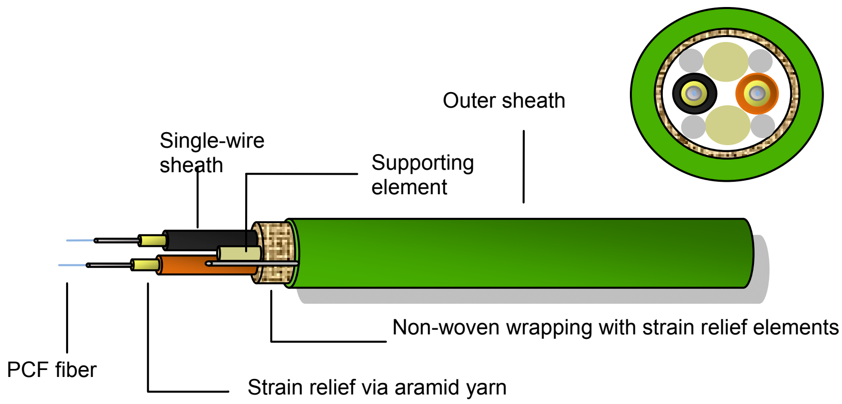


Figure 9-7: PROFINET FO trailing cable

9.5 Selection of connectors

This chapter will describe these requirements in more detail so that your previous planning can be completed with suitable connection technology as required for your application.

This chapter covers the following subjects:

- Explanation of differences between pre-assembled cables and cables for field-assembly
- Introduction of available connection systems
- Selection of required connectors

Differences between pre-assembled cables and cables for field-assembly

Pre-assembled cables

Pre-assembled cables are delivered with connectors fitted on both ends of the cable. Such pre-assembled cables can only be used if you know the exact distance between the individual network components (observe cable routing).

Advantages of pre-assembled cables:

- Reduction of installation time since no cable assembly is required.
- Potential assembly mistakes are avoided.
- The installation personnel does not need any training for the assembly of PROFINET cables.
- No special assembly tools required.
- Suitable in particular for wiring cabinets.

Disadvantages of pre-assembled cables:

- The assembled connectors could be obstructive or could be damaged when installing the cables.
- Cable lengths must be specified when ordering the cables.
- If pre-assembled cables are too long, the excessive cable length must be accommodated correctly.

Cables for field-assembly

Cables for field assembly are delivered by the manufacturer as bulk material without any connectors and have to be assembled on site by the installation personnel.

Advantages of cables for field-assembly:

- Cable lengths do not have to be specified when ordering the cables.
- Cables are easier to install without connectors attached.

Disadvantages of cables for field-assembly:

- Assembly on site requires additional time.
- Special tools are required.
- The installer needs to be trained for the assembly of PROFINET cables.
- Potential source of errors (acceptance measurement is recommended).

Please contact your cable manufacturer or the manufacturer of the connection system required for your installation to find out which assembly tools are required.

For more detailed information about the assembly of connectors and cables, please see the PROFINET Installation Guideline Order No.: 8.072.

Connection systems for copper cables

This chapter describes the connection systems for copper cables with different protection types, using various figures.

The connectors shown in the figures below (Figure 9-8 and Figure 9-9) are generic drawings based on models typically available on the market. The real design depends on each manufacturer.

Connectors

RJ45 connectors

RJ45 connectors are suitable for use with terminal devices and network components. A major criterion for the potential use of connectors is their manageability on site. Inside cabinets, RJ45 connectors are used in the IP20 version. Outside cabinets, the rugged environmental conditions must be accounted for. In such cases, an RJ45 push-pull connector in IP65 or IP67 version can be used. Another advantage of RJ45 connectors is that they are often used for connection of engineering tools or laptops etc allowing these to be easily and quickly connected for service purposes.

Figure 9-8 and Figure 9-9 show two versions of RJ45 connectors with different protection classes.

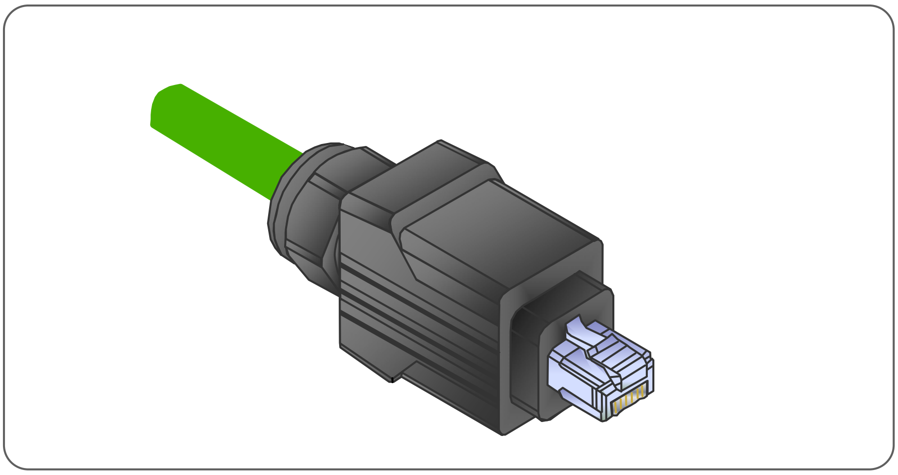


Figure 9-8: Typical RJ45 push-pull connector with IP65 rating

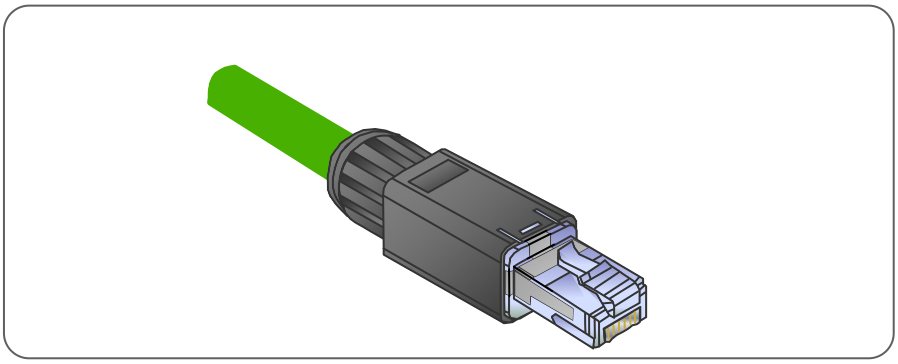


Figure 9-9: Typical RJ45 push-pull connector with IP20 rating

M12 D-coded connector

For applications in rugged industrial environments with IP67 protection class, the PNO has specified the M12 connector which allows for the safe connection of sensors / actors. The M12 D-coded connector has been standardized in IEC 61076-2-101.

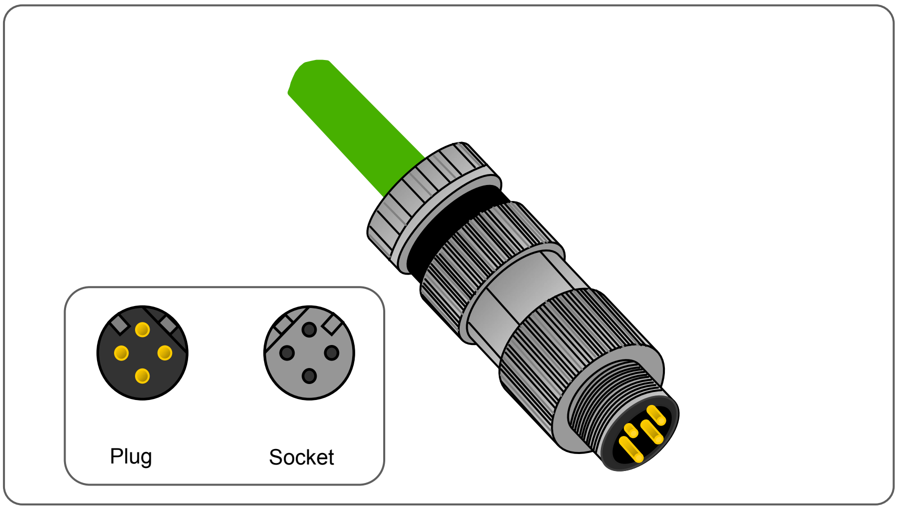


Figure 9-10: Typical D-coded M12 connector

M12 TypeX connector

The M12 TypeX connector is suited for applications in rugged industrial environments with high transmission rates. The M12 Type X has been standardized in IEC 61076-2-109.

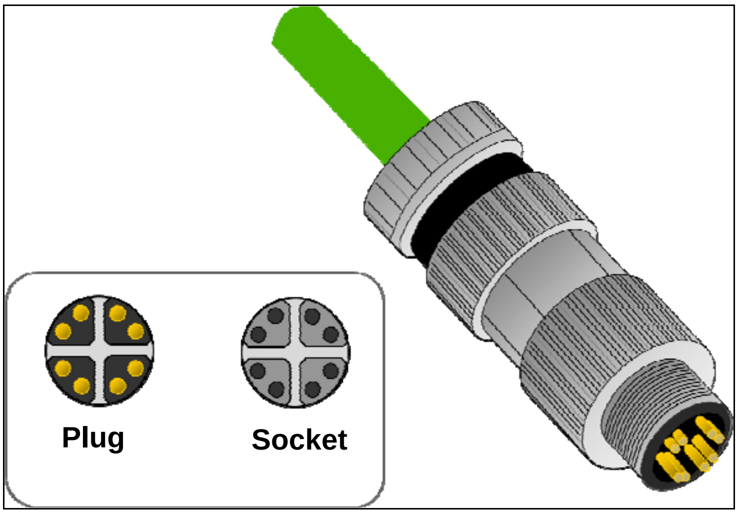


Figure 9-11: Typical M12 TypeX connector

Connection systems for optical fiber

The optical interfaces of PROFINET devices have to meet the specifications for multi-mode fibers (IEC 9314-3) and for single-mode fibers (IEC 9314-4). Non-permanent and permanent connections of PROFINET FO connectors are differentiated. These connectors should only be assembled by trained personnel using appropriate special tools.

For more detailed information about the assembly of FO connectors and cables, please see the PROFINET Installation Guideline Order No.: 8.072.

Please contact your cable manufacturer or the manufacturer of the ordered connection system required for your installation to find out which assembly tools are required.

Permanent FO connections are always implemented by means of so-called splicing. Splicing is mainly used in order to extend FO cables or to repair broken fiber.

Connectors

The connectors shown in the figures below (Figure 9-12and Figure 9-13) are generic drawings based on models typically available on the market. The real design depends on each manufacturer.

SCRJ connectors

The SCRJ is used for PROFINET data transmission via FO. The basic version of this connector has been developed for use in switch cabinets (IP20 protection class). The SCRJ push-pull version (Figure 9-13) is used for rugged environments or IP65 / IP67 requirements.

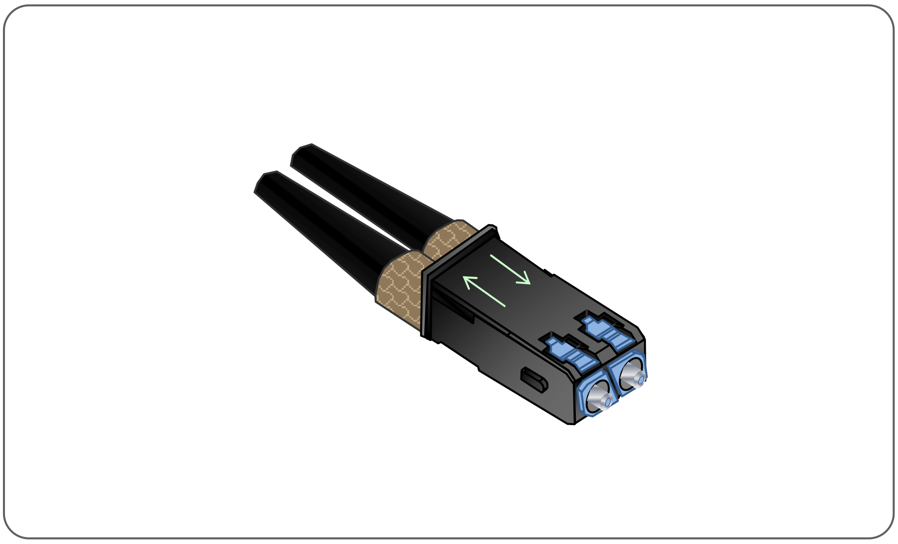


Figure 9-12: Typical SCRJ push-pull connector with IP20 rating

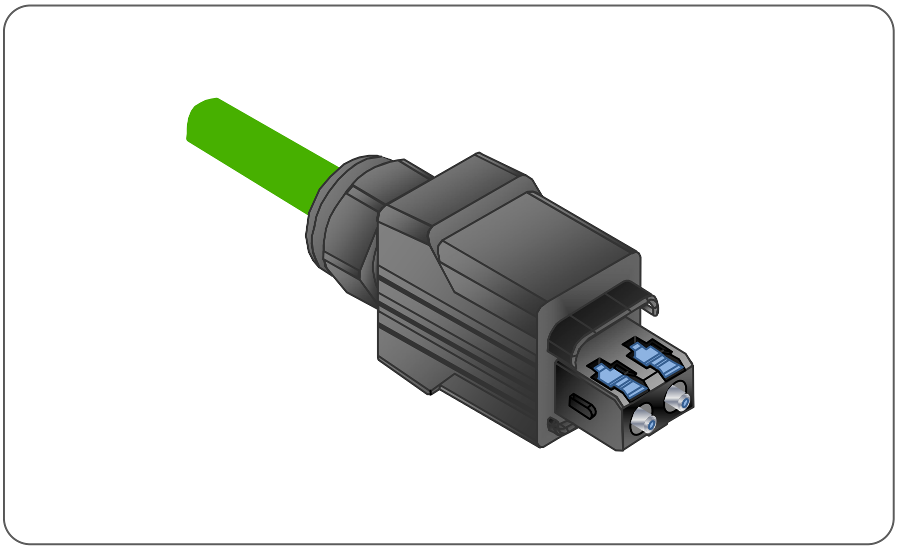


Figure 9-13: Typical SCRJ push-pull connector with IP65 rating

M12 hybrid connector

The M12 hybrid connector (Figure 9-14) provides two optical connections for data transmission plus two optional electrical connections. For PROFINET applications, the electrical connections are normally not used. The connector is available for use with multi-mode, single-mode, POF and PCF fibers.

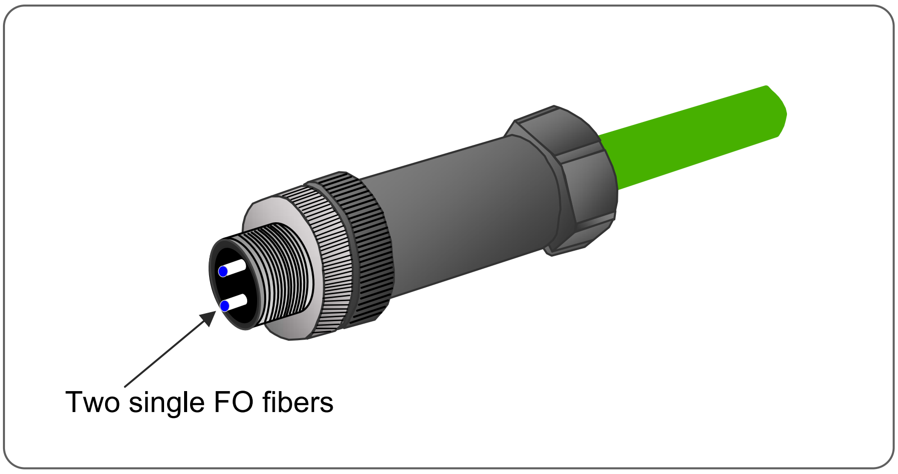


Figure 9-14: Typical M12 hybrid connector

Connector types BFOC and SC

The use of connector types BFOC / 2,5 (IEC 60874-10) and of the SC plug system (IEC 60874-14) is not recommended for new automation plants.

Transition points

Transition points are potential connection points for PROFINET cables for further distribution. Connectors with protection class IP65 / IP67 are available for use in rugged environments, while modules with protection class IP20 are available for use in switch or distribution cabinets.

The various distributors and sockets are also differentiated by:

- the number and type of ports (copper or FO),
- maximum number of plug cycles (insertions),
- the connection technology (special tools may be required) and
- the protection class.

Please see the manufacturer data for more detailed information concerning the technical properties of the required transition points.

Figure 9-15 and Figure 9-16 show two examples of RJ45 distributors with different protection classes which are based on the models available on the market.

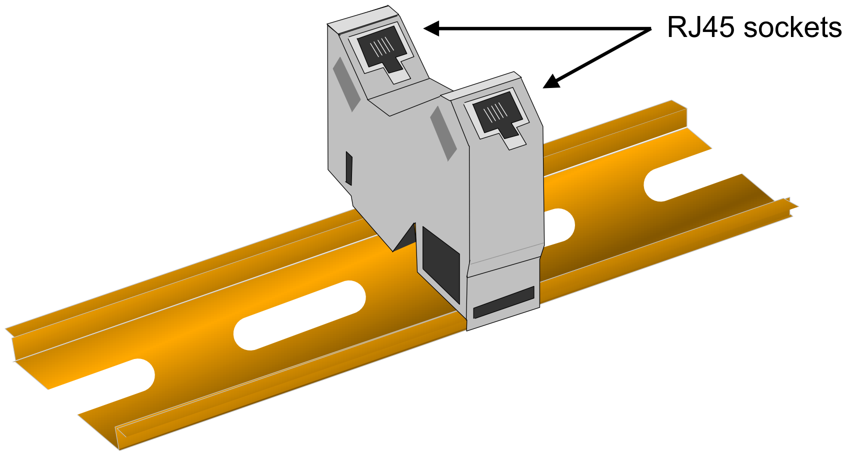


Figure 9-15: RJ45 distribution module for top hat rail mounting in IP20 environments

Distribution modules are available for IP20 environments for all commonly used FO and copper connectors with appropriate sockets.

Top hat rail mounted distribution modules should be used for the transition of the fixed cabling to the internal cabling of the cabinet with patch or adapter cables.

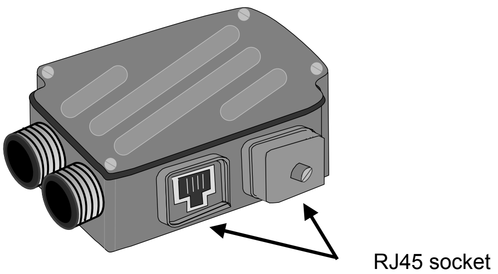


Figure 9-16: RJ45 connection socket for IP65 / IP67 environments

Connection sockets for all commonly used FO and copper connectors with appropriate ports and sockets are available from many different manufacturers.

Connection sockets should be used for the transition from fixed to flexible cabling in the field. Connections in trailing chains can thus be replaced easily.

Bulkhead Connectors

Bulkhead connectors can be used for securely passing external PROFINET copper cables or optical fibers into a cabinet. Such connectors provide transition from an IP65 / IP67 external environment to an IP20 internal environment..

Please see the manufacturer data for more detailed information concerning the technical properties of the required bulkhead connectors.

Figure 9-17 shows an RJ45 Push-Pull wall duct and Figure 9-18 shows an M12 wall duct. These wall ducts are generic drawings based on models currently available on the market.

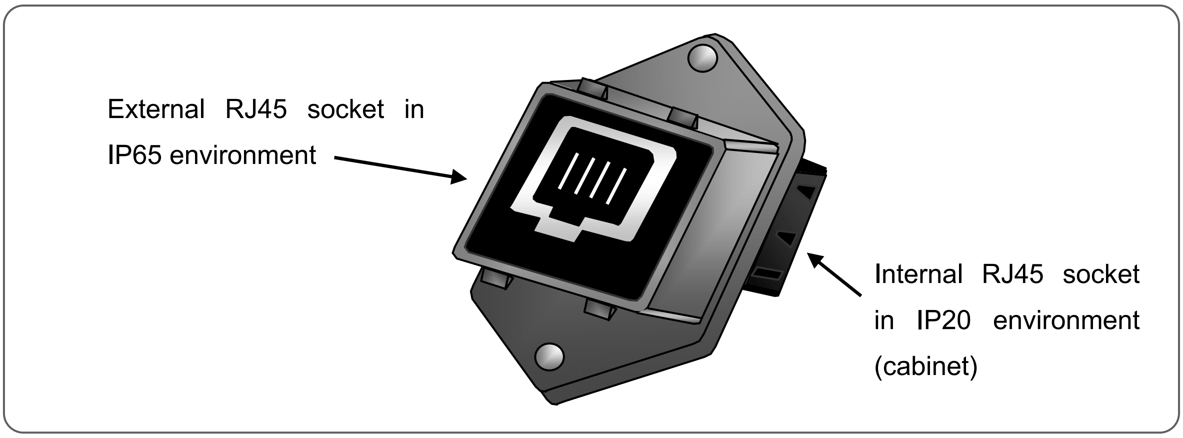


Figure 9-17: RJ45 Push-Pull bulkhead connector for use with cabinets

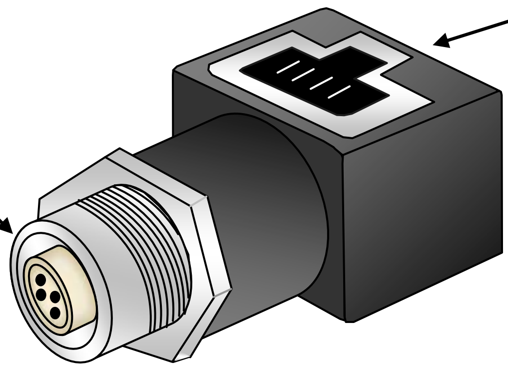


Figure 9-18: M12 bulkhead connector for use with cabinets

9.6 Cabling examples

Two examples for the component selection for FO and copper cabling are shown below. A sample calculation of the attenuation balance is also provided.

Example Copper cables

The copper-based, star-topology cabling shown in Figure 9-19 illustrates how the required components could be selected.

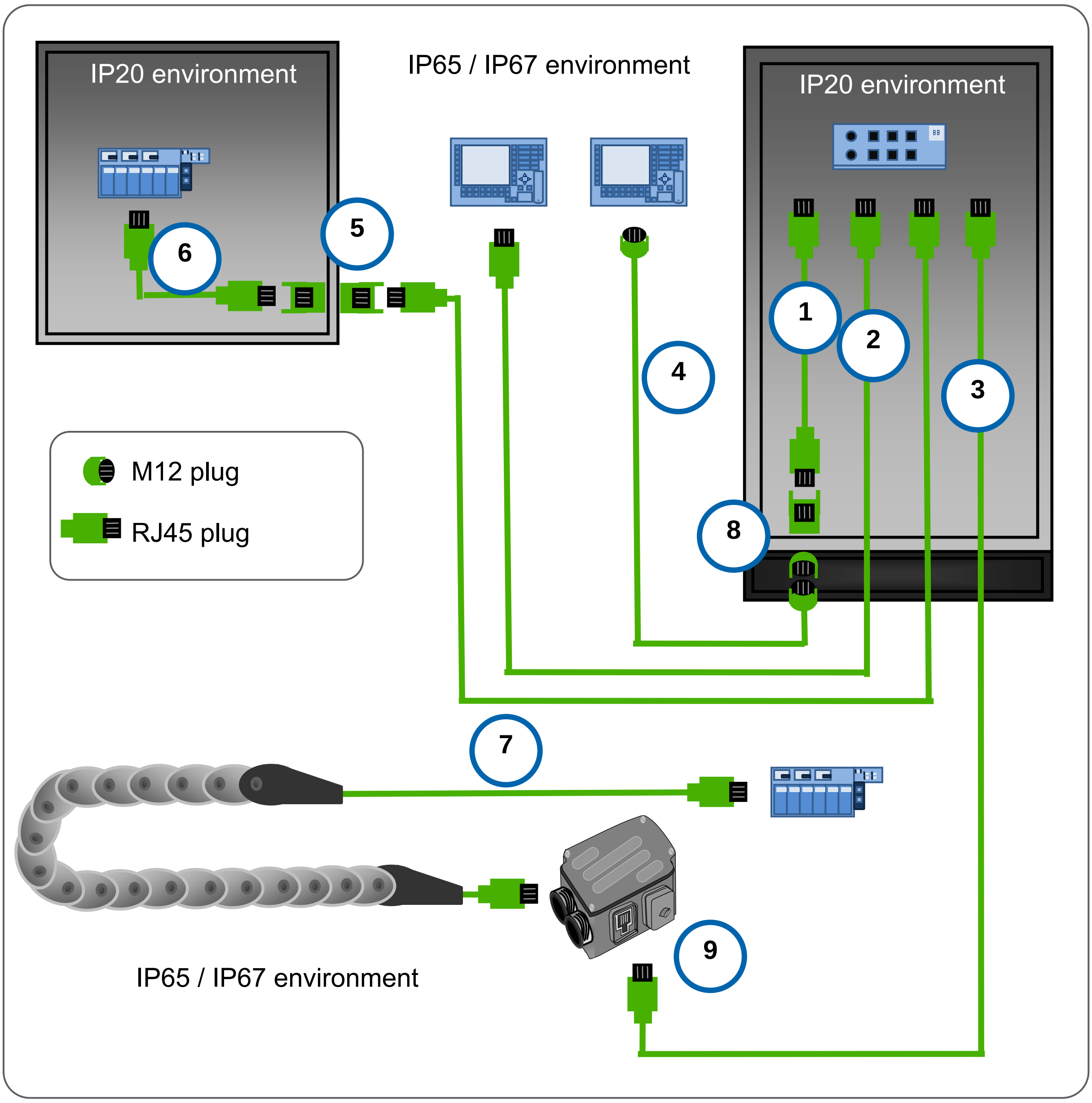


Figure 9-19: Examples of copper-based cabling

Table 9-12 shows the material list for the copper-based cabling described on the previous page.

Table 9-12: Material list copper-based cabling

Number	Name
1	Pre-assembled PROFINET cable with RJ45 connectors within an IP20 environment.
2	Pre-assembled PROFINET cable with RJ45 connectors in IP65 / IP67 environment.
3	PROFINET cable for field assembly, for static installation with RJ45 connectors in IP65 / IP67 environment and RJ45 connectors in an IP20 environment.
4	Pre-assembled PROFINET cable with M12 connectors for use in an IP65 / IP67 environment.
5	Bulkhead connector from RJ45 IP65 / IP67 to RJ45 IP20
6	Pre-assembled PROFINET cable, for fixed installation with RJ45 connectors in an IP20 environment.
7	PROFINET cable for assembly in the field, suited for trailing chain, with RJ45 connectors in an IP65 / IP67 environment.
8	Bulkhead connector from M12 IP65 / IP67 to RJ45 IP20
9	RJ45 connection socket for an IP65 / IP67 environment.

Example of FO cabling

The FO-based, star-topology cabling shown in Figure 9-20 is supposed to illustrate how the required components could be selected.

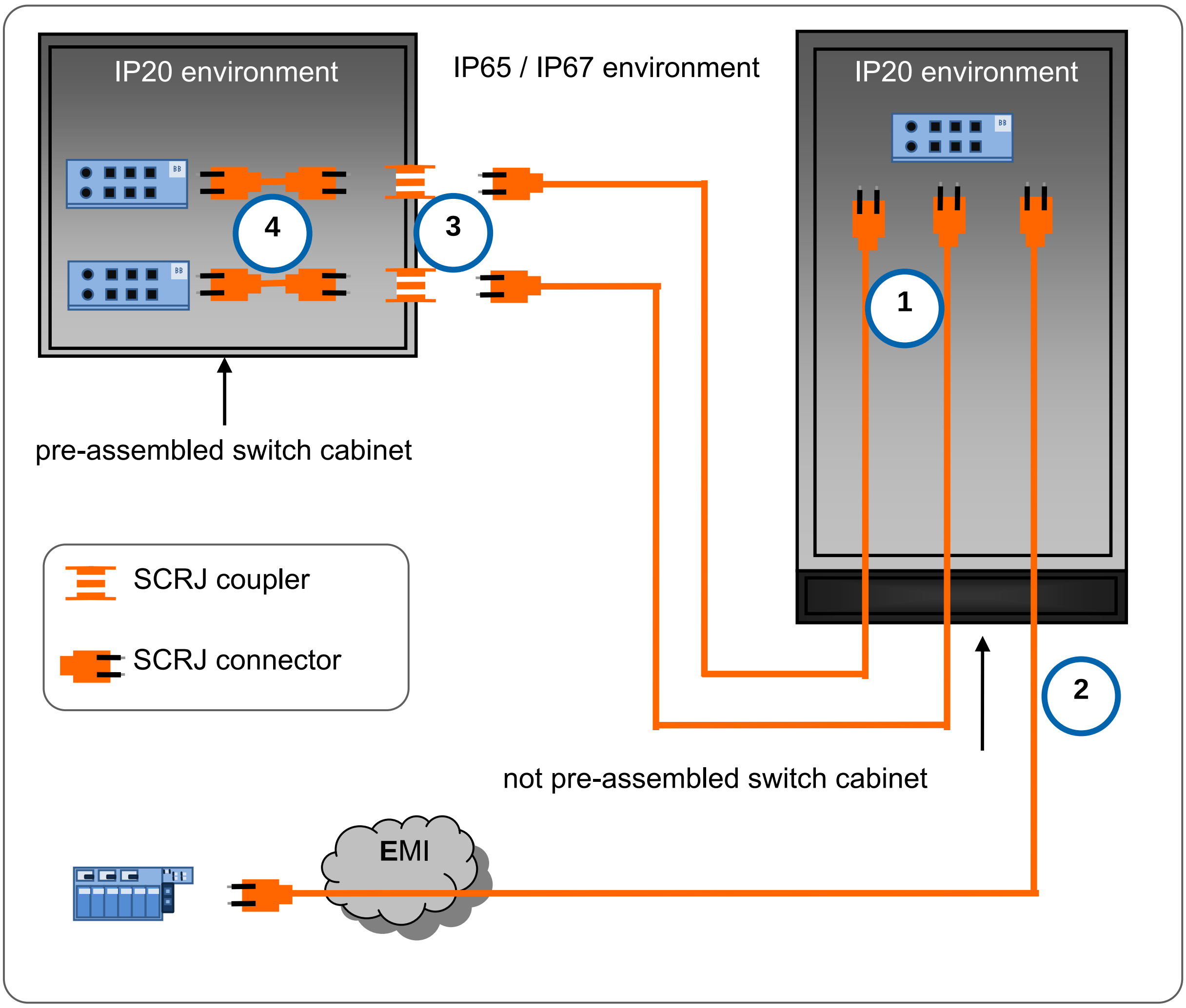


Figure 9-20: Example of FO cabling

Passive couplings such as bulkhead connectors or connection socket will increase the signal attenuation and thus reduce the available cable length.

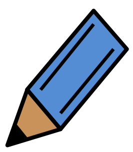
For example, each passive coupling used in POF cables will reduce the maximum cable length by 6.5 m. Thus two passive couplings will reduce the maximum POF cable length from 50 m to 50 m - 2 · 6.5 m = 37 m.

Table 9-13 shows the material list for the FO-based cabling described on the previous page.

Table 9-13: Material list FO cabling

Number	Name
1	Pre-assembled FO cable, with SCRJ connectors in IP65 / IP67 and IP20 environments at each end.
2	Pre-assembled POF cable, with SCRJ connectors in IP65 / IP67 and IP20 environments at each end.
3	SCRJ bulkhead connector from IP65 / IP67 to IP20 environment.
4	Pre-assembled adapter cable with SCRJ connectors in an IP20 environment.

Couplings and connectors are available from many different manufacturers, in multiple versions for different environments and applications. Consult manufacturers' information to select suitable connection technology for your application.



Document your selection of connection technology.

Calculation examples

Two examples will now be examined illustrating the calculation of attenuation and power budget.

Figure 9-21 shows a simple example based on a single-mode optical fiber cable.

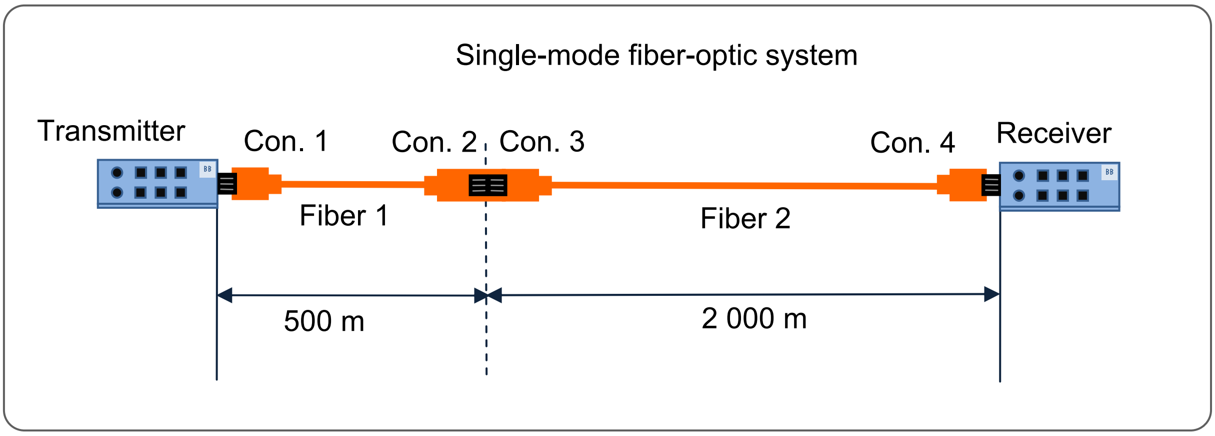


Figure 9-21: Representation of attenuation balance for single-mode optical fiber links

Note that it is important to account for the total number of connections used and not the number of connectors.

Table 9-14 shows the individual passive components, the attenuation caused by them and the total attenuation for the example in Figure 9-21. The attenuation of the fiber is based on 0.5 dB/km and the connections introduce 0.75 dB each. According to Table 3-4, the maximum permissible PROFINET end-to-end-link attenuation is 10.3 dB.

Attenuation balance:

Table 9-14: Calculation of end-to-end link attenuation for single-mode fibers

Fiber 1 **500 m**	**Connections** **(Con. 1+2/3+4)**	**Fiber 2** **2 000 m**	**Total attenuation** ✓
0.25 dB	3 ·0.75 dB	1 dB	= 3.5 dB
maximum permissible attenuation is 10.3 dB			

Figure 9-22 shows the attenuation calculation based on a polymer fiber link (POF).

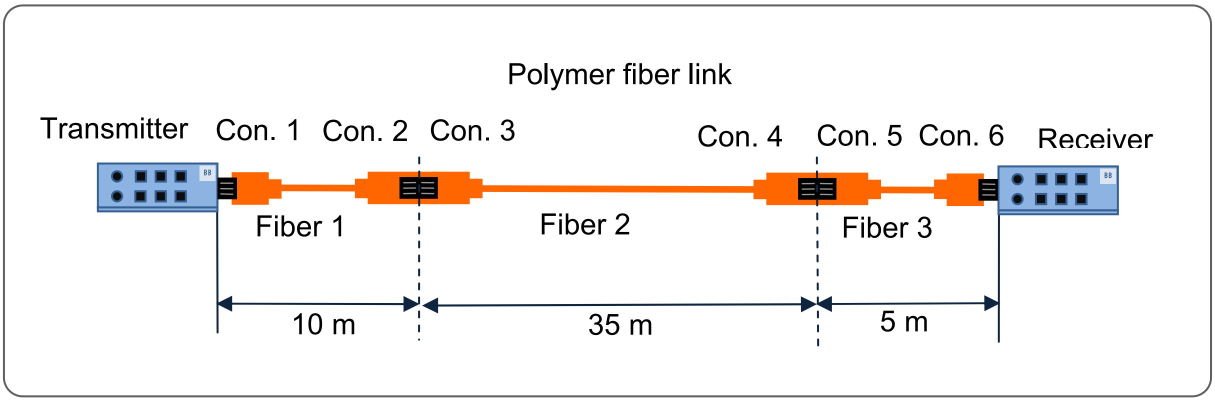


Figure 9-22: Representation of attenuation balance for POF FO link

Table 9-15 shows the individual passive components, the attenuation caused by them and the total attenuation for the example in Figure 9-22. Acc. to Table 3-4, the maximum permissible PROFINET end-to-end-link attenuation is 11.5 dB.

Attenuation balance:

Table 9-15: Calculation of end-to-end link attenuation for polymer fiber links

Fiber 1 **10 m**	**Connections** **(Conn 1+2/3+4/5+6)**	**Fiber 2** **35 m**	**Fiber 3** **5 m**	**Total attenuation** ✗
2.3 dB	4 ·1.5 dB	8.05 dB	1.15 dB	= 17.5 dB
maximum permissible attenuation is 11.5 dB				

As can be seen, the PROFINET end-to-end link attenuation in this example exceeds the maximum permissible value. To achieve a value of ≤ 11.5 dB, either the transmission link or the number of passive couplings would have to be reduced.

The calculation and, if applicable, the graphical representation of the attenuation balance shows whether the planned FO link meets the transmission requirements.

9.7 Selection of switches

Switches suited for PROFINET are designed for Fast Ethernet (100Mbit/s, IEEE 802.3u) and full duplex transmission. In full duplex operation a switch simultaneously transmits and receives data at the port. There are no collisions.

Switches are available in IP20 versions for top hat rail installation and in IP65/67 versions for field installation. The following section describes some functions of switches which are considered in the selection. The switches are first categorized in two types:

- Unmanaged switches
- Managed switches (with additional PROFINET functionality)

The advantage of PROFINET is the prioritization of the PROFINET data traffic. This feature however is only ensured if switches with „Quality of Service“ (QoS) support are being used (IEEE 802.1q / p).

Unmanaged switches

Unmanaged switches route the entire data traffic based on the address / port allocation table. Users are not able to intervene manually. This is a low-cost version of a switch.

Unmanaged switches do not offer a web interface and have no diagnostic functions.

This type of switch is used in conformance class A networks.

Managed switches

Managed switches offer several advantages over unmanaged switches. These include user option selection based on a web interface and diagnostics capability. The functionality of the management software is different among various switch types, including features ranging from redundancy control up to statistical analysis of network data traffic.

Managed switches support diagnosis functions. The offered switch functionality is controlled and read out either via a web-based interface or via a suitable engineering tool.

To make sure a switch can be identified as PROFINET device, the switch has to support the PROFINET IO services. The identification of a switch as PROFINET device is foreseen as of conformance class B networks.

Managed switches should be used in conformance class B and C networks

Switches can also be selected as “cut through” or “store and forward”.

Cut through switches

Cut through switches give less delay than store and forward switches. This is because the frame is forwarded directly once the destination address is determined. The switch will buffer only as many bytes of the data packet as are required for analysis of the address / port allocation table. Then all incoming bytes of the data packet are sent directly to the relevant port without any buffering. The routing delay thus does not depend on the frame size.

Store and Forward Switches

Store and Forward switches read and buffer the complete data packet on the incoming port. The switch checks the whole frame for errors and, if error free, sends it to the relevant port. This can cause longer delay times than for switches using the cut through technology. The delay depends on the telegram size of the data packet to be transmitted.

Auto-sensing / Auto-negotiation

Auto-sensing describes the ability of a device to automatically identify the transmission rate of a signal.

Auto-negotiation additionally allows the involved devices to jointly negotiate and agree upon the transmission rate before the first data transmission is started.

If Fast Start-up is used at one port, auto-negotiation should be disabled in order to further optimize the start-up time.

Auto Cross-Over

Auto Cross-Over provides automatic crossing of transmit and receive lines at a port interfaces. If this function is deactivated, a cross-over cable or a switch with port wiring for crossing of connections is sometimes required.

If Fast Start-up is used at one port, auto cross-over should be disabled in order to further optimize the start-up time.

Redundancy support

The redundancy support allows for bumpless or non-bumpless changeover of failed links to a redundant link.

The implementation of redundancy with PROFINET IO is only achieved by means of managed switches which support an appropriate Media Redundancy Protocol (MRP) and which are configured via an engineering tool or a web-based service.

Port mirroring

Port mirroring is a helpful function for diagnosis in a network. It provides a copy of all the inbound and outbound data from one port (the mirrored port) of a switch to another port (the mirror port) in order to analyze the data frames. Most switches with port mirroring allow the selection and configuration of the mirrored and mirror port from a web-page in the switch.

Note that port mirroring is generally only available on managed switches. Also note that many managed switches do not support port mirroring. Always ensure that the selected switch supports port mirroring if required.

You will find further information about the diagnostics options in the PROFINET Commissioning Guideline Order No.: 8.081.

Power over Ethernet

Power over Ethernet (PoE) allows devices with this facility to be powered from the Ethernet cable. A switch with a PoE injector is required.

Switches with PoE functionality are available in various variants with different maximum power specifications. Select the appropriate type according to the number of components to be supplied.

Gigabit Ethernet

If the implementation of PROFINET networks with a transmission rate of 1 000 Mbit is intended, this must also be supported by the switches. Select the corresponding models with the required number of ports supporting Gbit transmission.

Support of the relevant conformance class

As mentioned before, a switch also has to meet the respective requirements to the conformance class.

! The manufacturer must indicate the conformance class for which the switch is suitable. You should only use switches that have been certified by PI.

9.8 Power supply

This chapter describes the issues related to the planning of the power supply.

This chapter is arranged as follows:

- Different network types
- Grounding
- Protection against electrical shock

Different network types

The implementation of power supply concepts is part of the general planning of electrical systems and will not be explained in detail in this guideline. For the planning, the basic difference of the concepts with reference to the use of PE and N conductor is important:

TN-C

TN-C system do not have separate PE and N conductors (4-wire system), but combined PEN conductors.

TN-S

This concept is based on separate PE and n conductors (five wire system). This type of network is used for the implementation of PROFINET automation plants.

Equipotential bonding

Ground potential differences between cabling and grounding points may cause current flow in the cable screen and interference in the system. This refers in particular to shielded cable systems. It is therefore important to foresee a correct grounding and shielding according to applicable installation guidelines already in the planning stages.

The following points should be considered in your planning:

- Please check, if necessary in cooperation with the owner of the building and the automation plants, how the existing grounding system has been realized, and determine the resistance of the ground connection.
- The grounding resistance should be below 0.6 Ω and must be below 1 Ω. The grounding resistance can be measured at any two points where network components or cable shields are grounded.
- All network components should be grounded via a common connection. This connection should have a high ampacity.

To ensure a long-term reliability of the grounding, you should plan for suitable measures to protect the contact points against corrosion.

Grounding methods

Two methods are available to ensure correct grounding.

Meshed grounding

Meshed grounding should be used if only one connection between the grounding point and the network component or the shielding is required.

Star-shaped grounding

Plan for a star-shaped grounding in case there is only one connection point to the building grounding system.

If the existing grounding meets the requirements according to current installation guidelines, it can be realized as a grounding system in combination with the grounding of the PROFINET network. A subdivision into a grounding sub-system is not required.

If this is not the case, the grounding should be separated into several grounding sub-systems.

Each grounding sub-system can be realized using the proven grounding and equipotential bonding methods according to applicable installation profiles. Document the selected grounding system for the complete PROFINET network in order to avoid mistakes during installation.

For details about the technical implementation of correct equipment grounding, please see the applicable installation guidelines and the PROFINET Installation Guideline (Order No.: 8.072).

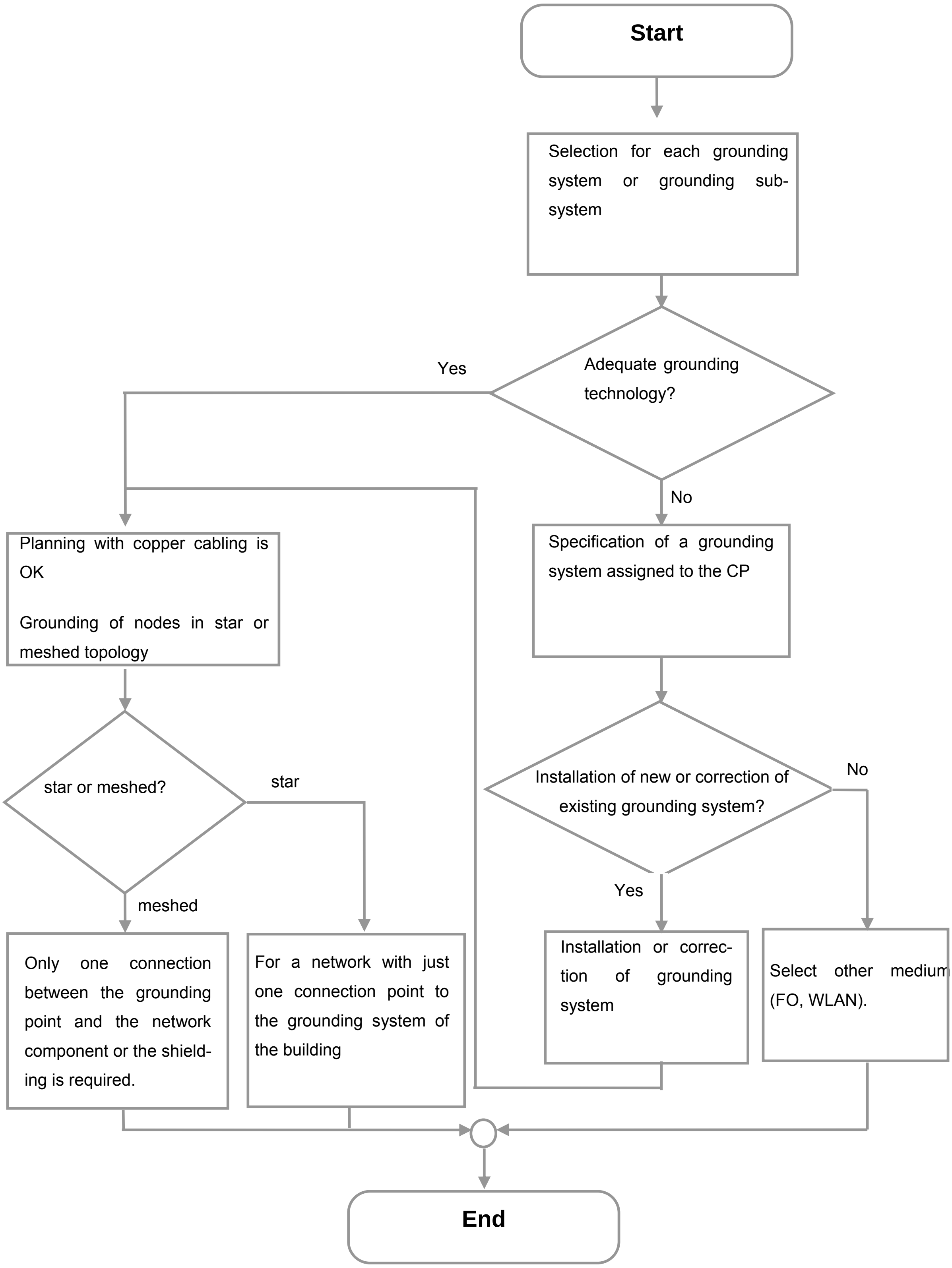


Figure 9-23: Flow chart: Selection of grounding method

Avoiding multiple groundings

In automation plants, system ground (plant reference potential) are grounded to avoid the unintended triggering of switching operations due to ground leakages after the isolation has been violated. For extensive automation plants including equipment from different providers, it makes sense to establish a comprehensive grounding concept for the system ground. Faults and system outages can be caused by the interaction with other grounded electrical systems, e.g. high-voltage systems.

For the system ground, only one connection to ground needs to be planned. In the life cycle of a system, it frequently occurs that more connections happen to come up in addition to the planned and intended ground-earth connection. In case there is no clear concept, uncertainties about handling the grounding and shielding, about connecting to ground, over-voltage protection etc. frequently result in one or the other ground-earth connection being added for “to be on the safe side“. Such multiple grounding of system grounds draws currents into the mass system which may cause equipment outages.

In order to detect potential multiple groundings, you should measure the isolation during the installation. Observe the PROFINET Commissioning Guideline Order No.: 8.082.

!

During planning you should clearly determine that the system ground is only connected to ground once.

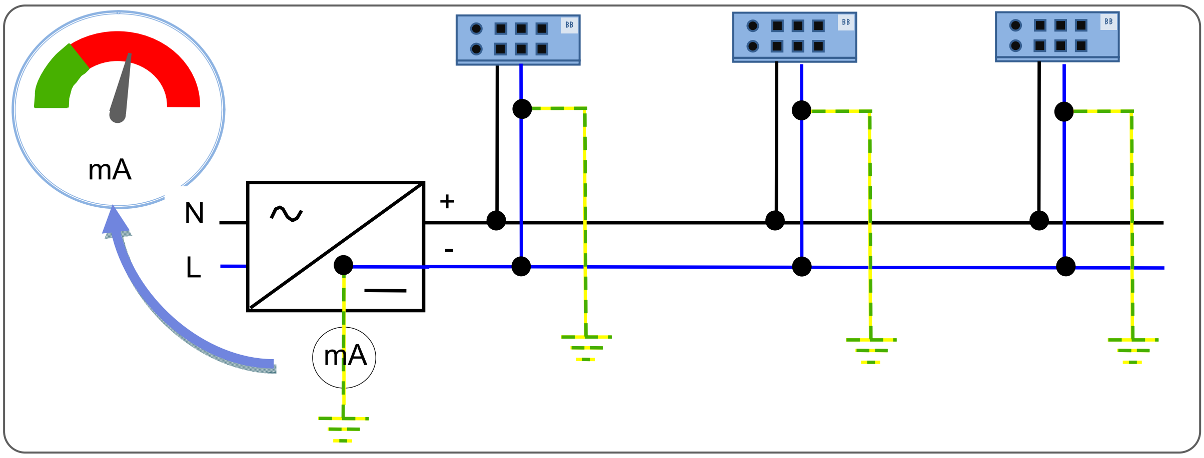


Figure 9-24: Multiple grounding of system grounds

Figure 9-24 shows a basic system ground structure. The 24 V system is supplied via a source and supplies three physically separate switches. The negative terminal must be directly connected to ground at the power supply **and** at the three switches. This multiple grounding causes undesired currents in the mass system. A typical error is the outage of switches because the maximum permissible electrical strength is exceeded. Such breakdowns can cause the outage of entire system parts. In order to detect and remove incorrect ground connections as early as possible, it makes sense when planning new installations to foresee a measurement system which permanently monitors whether the mass ground connection (Figure 9-25) is without current. Existing automation plants can be modernized accordingly.

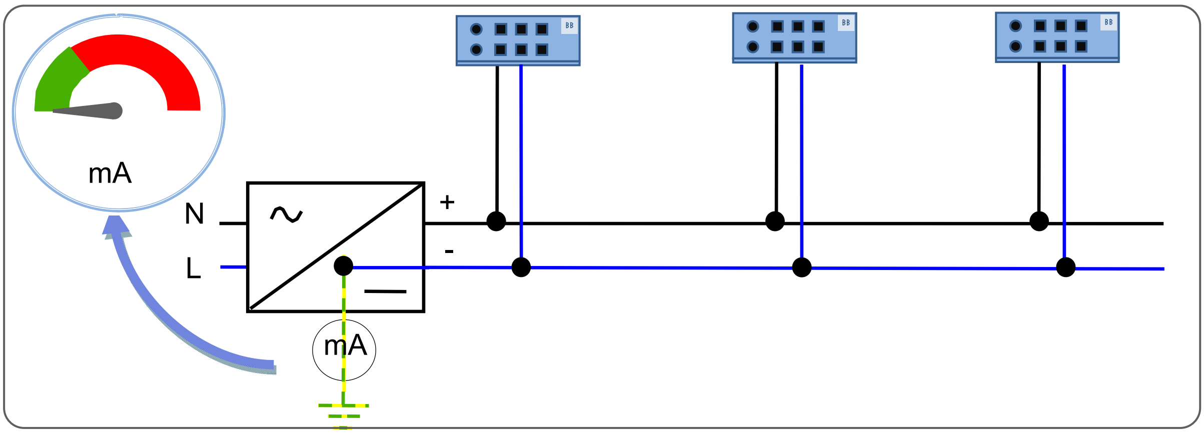


Figure 9-25: Measuring facility for monitoring of system ground zero potential

Plan for a comprehensive concept for the grounding of system masses. The required mass ground connection should only be realized once. Make sure to permanently monitor this connection for zero potential.

Protection against electrical shock

IEC 60364 defines general requirements for the protection against electric shock. Electrical facilities of buildings part 4-41: Precautions; Protection against electrostatic shock. These requirements must be met by all PROFINET devices. You should also observe the requirements as described in IEC 60204 “Safety of machinery - Electrical equipment of machines“.

This standard also defines the low voltage supply via SELV (Safety Extra Low Voltage) and PELV (Protective Extra Low Voltage). When planning your PROFINET system, you should use only power supplies which generate SELV or PELV output voltage.

9.9 Network load calculation tool

Figure 9-26 shows the user interface of the network load calculation tool in Microsoft Excel. The purpose of the network load calculation tool is to facilitate the network load calculation for users.

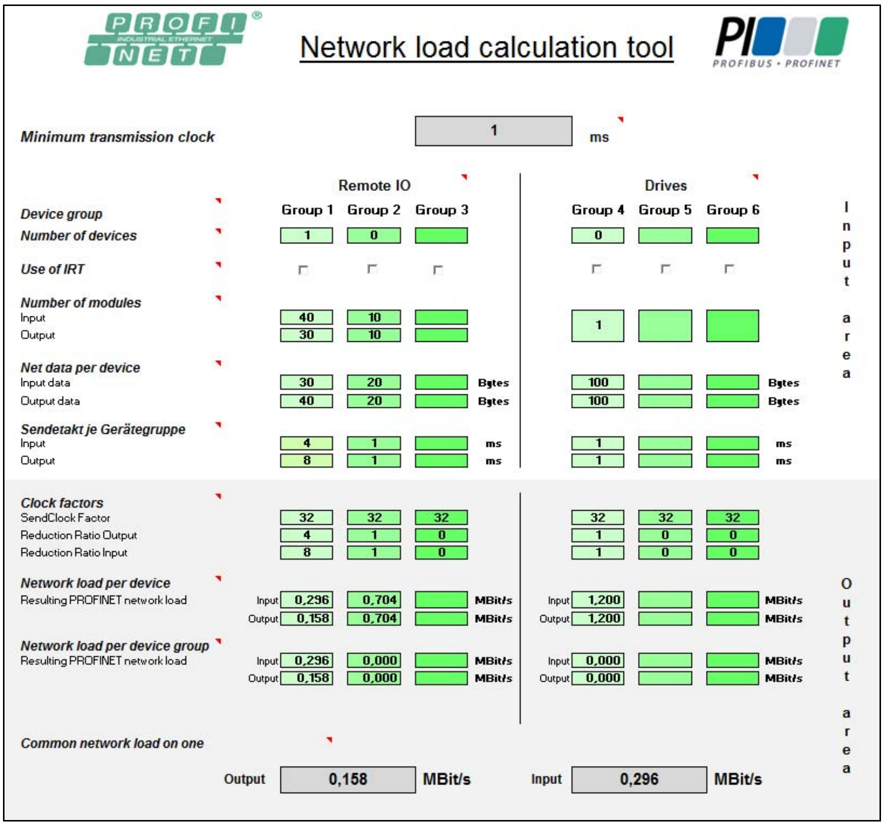


Figure 9-26: User interface of the network load calculation tool

The upper area, highlighted in white in Figure 9-26, has been defined as entry area. Here, users can define possible device configurations by entering values. The output area, highlighted in dark gray, displays the calculation results.

The “percentage network load“, with reference to the available bandwidth of a link, must be calculated by the user (*see separate example provided later on*). Make sure to consider the network load separately for the input and the output direction.

The network load calculation tool uses simple Excel formulae which are hidden when using the tool. You can however edit these formulae after inactivating the Excel worksheet protection and making the hidden areas of these formulae visible.

A detailed description of the network load calculation is included in the additional Excel worksheets "Description" and "Program flowchart" of the network load calculation tool. The user manual shown on the following pages can also be found in the calculation tool in the worksheet "User manual".

!

All entries are checked for consistency. In addition, error messages are displayed in case of incorrect entries. Entries are possible only in the entry fields. The other fields are blocked for entries.

User manual

Figure 9-27 shows the different sections for entry of the calculation basics and the output fields grouped according to the device groups.

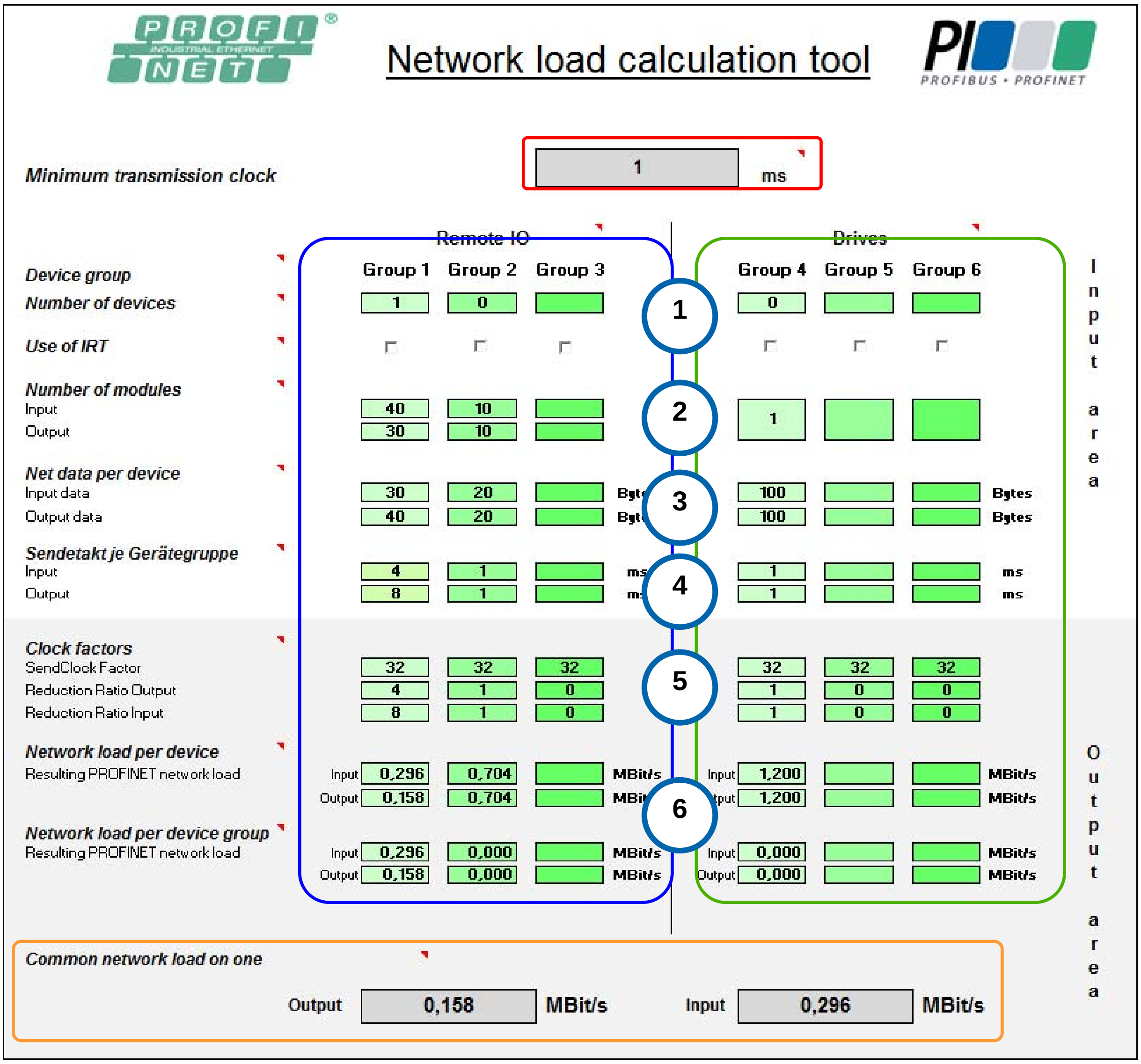


Figure 9-27: Network load calculation using average values

The upper red frame is used to select the minimum transmission clock via a dropdown menu. A manual entry is possible, but the entered value will be checked for usefulness when applied in a PROFINET transmission system. The minimum transmission clock is usually pre-determined by a fast PROFINET device. This information primarily helps to determine the clock factors of a PROFINET transmission system.

On the left side of the entry mask, device data are entered with separate number of modules for input and output, such as for remote IOs. On the right side of the entry mask, device data are entered with identical number of modules for input and output (e.g. drives).

For each side, entry values for three device groups can be specified, with entries made underneath each device group. The entry is checked for consistency. **Integers are permitted only.** Some entry fields also provide dropdown selection options.

PROFINET uses the full duplex technology. Data are therefore entered separately for each transmit direction. The individual entry and display areas are used for:

1. Entry of the number of PROFINET devices per group and selection whether this group has an isochronous connection (IRT: Isochronous Realtime).
2. Entry of the number of modules per PROFINET device. This is done separately for each transmit direction, except for device groups 4 to 6.
3. Entry of user data (net data) of the PROFINET device in byte, separately for each transmit direction.
4. Entry of transmit clock in ms, separately for each transmit direction. The transmit clock may be different for both directions.
5. Display of required clock factors for configuration of transmission. Clock factors are usually determined via the engineering tool so that his data is only provided here for information purposes.
6. In addition to the network load generated by a device group, the network load of individual PROFINET devices is also shown here. The value of the device group results from the multiplication of a single device with the number of PROFINET devices in the group.

The network load of all PROFINET device groups added up is provided as a result (orange frame). The result is provided separately for both transmit directions. The determined network load can now be used in order to determine the percentage network load on a PROFINET network.

The following example shows how the percentage network load is evaluated:

Example: The network load calculation tool, after entering the device configuration and the update times, has determined a total network load of:

3.086 Mbit/s in output direction and

7.538 Mbit/s in input direction.

If in the network a:

100 MBit/s transmission link is used, this results in a percentage network load of :

3,086 % in output direction and

7,538 % in input direction.

As explained in previous chapters, the total network load only occurs at communication nodes where several data streams meet. The network load generated by PROFINET should not exceed the 50% limit at these nodes. Based on the individual device groups in the entry mask, the group creating a high network load can be analyzed.

Some of the device groups have been left empty in this example. As shown in this example, they can be individually configured per transmission direction.

The network load depends on several influencing factors. The network load calculation tool provides an estimate of these influencing factors.

Based on the individual device groups and their device types in the entry mask, the group creating a high network load can be analyzed. It is then possible to modify if necessary.

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