AUTOMATION

User manual

UM EN PROFINET SYS

PROFINET basics

PHOENIX CONTACT
INSPIRING INNOVATIONS

AUTOMATION

User manual
PROFINET basics

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This user manual is valid for:

PROFINET devices from Phoenix Contact

Please observe the following notes

In order to ensure the safe use of the product described, you have to read and understand this manual. The following notes provide information on how to use this manual.

User group of this manual

The use of products described in this manual is oriented exclusively to qualified electricians or persons instructed by them, who are familiar with applicable national standards and other regulations regarding electrical engineering and, in particular, the relevant safety concepts.

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Explanation of symbols used and signal words

This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety measures that follow this symbol to avoid possible injury or death.

DANGER

This indicates a hazardous situation which, if not avoided, will result in death or serious injury.

WARNING

This indicates a hazardous situation which, if not avoided, will result in death or serious injury.

CAUTION

This indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.

The following types of messages provide information about possible property damage and general information concerning proper operation and ease-of-use.

NOTE

This symbol and the accompanying text alerts the reader to a situation which may cause damage or malfunction to the device, either hardware or software, or surrounding property.

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Published by

PHOENIX CONTACT GmbH & Co. KG
Flachsmarktstraße 8
32825 Blomberg
Germany
Phone +49 - (0) 52 35 - 3-00
Fax +49 - (0) 52 35 - 3-4 12 00

PHOENIX CONTACT
P.O. Box 4100
Harrisburg, PA 17111-0100
USA
Phone +1-717-944-1300

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tecdoc@phoenixcontact.com

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1 PROFINET (Process Field Net)

1.1 PROFINET documentation

The PROFINET documentation is modular, providing you with optimum information.

Available PROFINET documents

"PROFINET basics" user manual
UM EN PROFINET SYS

This manual describes PROFINET system basics.
This includes:

– PROFINET development
– PROFINET versions
– PROFINET properties
– PROFINET installation and startup
– PROFINET and wireless

Quick start guides

– "Installing and starting up the starterkit 3.0" quick start guide
UM QS EN PROFINET STARTERKIT 3.0.
– "Configuring INTERBUS devices in a PROFINET IO network using the example of STEP 7"
UM QS EN PROFINET PROXY IB

Device-specific data sheets

The data sheets describe the specific properties of PROFINET devices.
This includes:

– Function description
– Ordering data and technical data
– Local diagnostic and status indicators
– Pin assignment and connection example
– Programming data/configuration data

Make sure you always use the latest documentation.
It can be downloaded at:
www.phoenixcontact.net/download

PROFINET documents in preparation

– "Controller/device functions" application note
AH EN PROFINET CTRL DEV
– "Acyclic communication" application note
AH EN PROFINET AZY KOM
– "PROFINET diagnostics"
AH EN PROFINET DIAG

1.2 Ethernet in factory automation

Increasing the productivity of machines and plants while at the same time cutting costs has always been the driving force behind innovations in industrial automation. Machine engineers and manufacturing companies can hold their ground in international markets all the better if their solutions are more competitive.

Therefore production processes need to be optimized continuously. On the one hand, productivity can be increased through a better flow of information for faster and well-founded decisions. On the other hand, integration of machines and components into the respective network must be simplified in order to reduce engineering and startup times.

At present company networks are characterized by complex interfaces and data exchange mechanisms between the many island solutions in the production area and between the factory and command level. Transparent access to machine data as would be necessary for perfect job and production control is not possible without a great deal of effort. The aim must therefore be to develop a uniform network structure that will guarantee that all machine and plant parts are networked and connected to the production planning and company command level. The key to putting this into practice is Ethernet. This transmission medium has established itself in office communication and is already used in the industrial environment to connect distributed machine and plant parts to each other and to higher level systems.

1.3 PROFINET is an industrial Ethernet standard

PROFINET has established itself as an open industrial Ethernet standard for automation. PROFINET is a network protocol on the basis of standard Ethernet so that it can be integrated into proven Ethernet technology.

Since Ethernet is widely used in office communication, it is still possible to exchange data worldwide between office and production levels using the world wide web (WWW). Remote control and monitoring as well as remote maintenance are possible.

PROFINET is a consistent continuation of

- PROFIBUS DP and
- Industrial Ethernet

Experiences from both systems are integrated into PROFINET.

PROFINET

- Is automation in real time
- Uses TCP/IP and IT standards
- Allows seamless integration of fieldbuses
- Improves vertical integration

1.4 Ethernet/PROFINET development

PROFINET will not replace PROFIBUS. 15 years of experience with PROFIBUS guarantee a seamless transition into worldwide and established communication with Ethernet. Both systems will coexist for many years.

The situation is as follows:

Standard Ethernet

Ethernet was widely used for office communications, various fieldbuses have been used in the field. Using two different communications systems made it very difficult to access data on different levels. A complex data transfer between the field and office level was required. Ethernet could not establish itself in the field for a long time. The main reason being the lacking realtime capability of Ethernet. Standard Ethernet is based on CSMA/CD (carrier sense multiple access with collision detection). Depending on the system collisions may occur on the Ethernet line. These delay the individual data packet and realtime cannot be guaranteed.

Switched Ethernet

The situation changed fundamentally when Switched Ethernet was introduced. The full-duplex operating mode replaced CSMA/CD. And Ethernet communication became also an option for automation technology. For years Ethernet has established in the production plant in the operating and control area. But automation solutions used more and more PCs and PC-based devices. More and more controllers were equipped with an Ethernet connection. PROFINET combines these networks, some of which sometimes existed in parallel to the automation network, in one system now. All information can be transported over one network. The determinism for I/O signals is maintained and open TCP/IP-based communication is not lost.

Modern systems feature direct PROFINET communication with distributed I/O.

Figure 1-1 Seamless connection of the office and factory world

1.5 PROFINET areas of application

Applications

There are various areas of application for PROFINET. In addition to the automotive industry there are also reference application in water/waste water treatment, in shipbuilding, in logistics, in process technology, in machine production, and in building automation.

Figure 1-2 PROFINET applications

Investment protection

The considerable investments made to date by manufacturers and users in automation products and solutions are protected since a smooth transition from fieldbus to Ethernet was provided. Older systems or part segments, for which Ethernet communication does not offer any advantages, can be integrated into the PROFINET network without loosing any information. This means investment protection for existing systems and step-by-step access to PROFINET technology.

1.6 PROFIBUS user organization promotes technology

PNO

The PROFIBUS Nutzerorganisation e. V. (PNO) is a technical committee defining the PROFIBUS and PROFINET standards and developing them further.

More than 260 manufacturers and users of the standardized communications technologies PROFIBUS and PROFINET joined forces to advance the development and international establishment of these technologies. The PROFIBUS user organization is a registered association. All companies and research institutes at home and abroad may become members. Every component manufacturer may get the protocol specification from the PNO.

IEC 61158

Since the standard has been published, the different working groups within the PNO managed to present the most important demand in the IEC 61158 international standard. The PROFINET technology is deeply integrated into the non-proprietary specification processes of the PROFIBUS user organization (PNO).

Certification

PNO develops and maintains open specifications of actual communication, installation guidelines and connector definitions as well as certification activities and user profiles. Certification is mandatory for PROFINET and guarantees seamless interoperability of PROFINET devices. Test and certification centers test the PROFINET devices according to defined tests and divide them into various conformance classes. The PNO centrally monitors test lab accreditations.

1.7 PHOENIX CONTACT provides know-how

To facilitate PROFINET users access to this technology, **Phoenix Contact**, **Phoenix Testlab** as well as software manufacturer **KW-Software** to combine their know-how in the PHOENIX CONTACT COMPETENCE CENTER (PCCC). The PHOENIX CONTACT COMPETENCE CENTER has been accredited by the PROFIBUS user organization.

By cooperating, the three companies can offer services throughout the entire lifecycle of a PROFINET solution.

Concept and technical specifications

During development, the experts working at the accredited PROFINET test laboratory, which is integrated into the Phoenix Testlab, give advise and certify products in the areas of EMC, radio, environmental simulation and electrical device safety. All relevant standards are considered and the product requirements deriving from these standards are documented.

Development

The PROFINET business field at KW-Software supports device manufacturers and solution providers during the development phase with a special portfolio of products and services. Suitable technology components for integration into the customer's target platform are available for the different PROFINET device types (IO controllers, IO devices). This integration/porting is carried out based on your requirements.

Conformance test

In October 2007, Phoenix Testlab GmbH was certified as a test lab for conducting conformity tests for PROFINET devices. Phoenix Testlab carries out the certification test for end products ready for series production, as well as the development-accompanying tests. The advantage of the latter is that possible device problems that could endanger a positive result of the entire test are detected at an early stage and can thus be corrected during development. The device developer decides which functions are tested at what point.

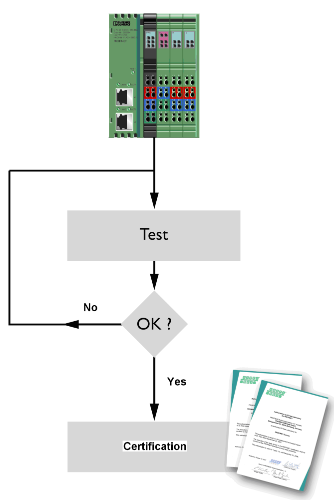

Figure 1-3 PROFINET certification

The test comprises five individual tests that have to be taken without any objection:

– **State machine test** to ensure repeatable testing with an expandable number of test cases
– **Hardware test**, so that the IO controller of the device complies with all applicable standards
– **Interoperability test** for the smooth interaction between IO devices and IO controllers from various manufacturers
– **GSD file test** to check all entries in the device description file offline
– **EMC validation** for checking the EMC test results.

After successful testing, the customer receives an official test report which he can use to apply for a certificate from PROFIBUS/PROFINET International (PI). For these devices, PI issues certificates valid for three years.

User service

With the provided service, Phoenix Contact concentrates on the solution-oriented use of PROFINET products. The focus is on configuration, start-up, service, system modernization and training.

As one of the three PROFINET International Training Centers in Germany, the PCCC is an authorized center for training certified PROFINET installers and engineers. In addition, the PCCC can accredit users as a PROFINET Training Center to train engineering and service personnel with their own certified trainers.

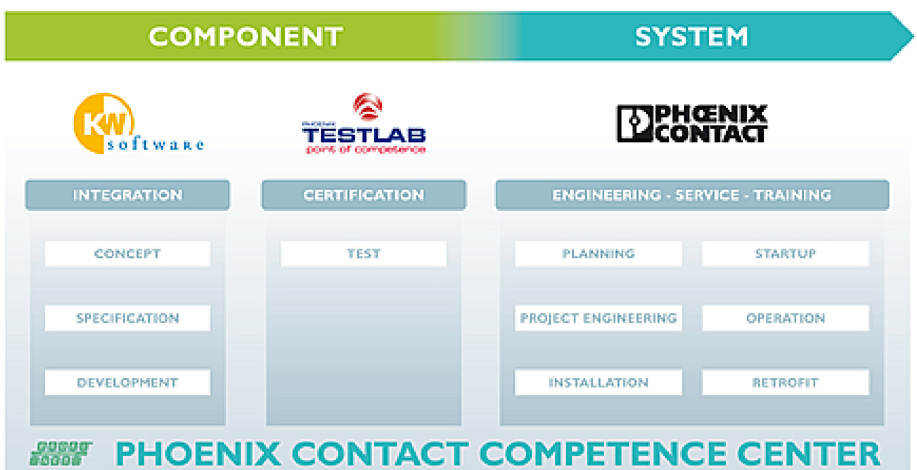

Figure 1-4 Structure of the PHOENIX CONTACT COMPETENCE CENTER

2 PROFINET versions

The PROFINET concept is modular so that the user can select the required functions. These functions mainly differ in the type of data exchange to meet the high demands on speed. For PROFINET there are the versions **PROFINET IO** and **PROFINET CBA**. Both communication paths can be used in parallel. They can be operated either separately or in combination.

2.1 PROFINET IO

Connecting distributed I/Os

PROFINET IO is the system to connect distributed I/Os. Thus distributed IO devices can be directly connected to Ethernet. PROFINET IO describes the entire data exchange between IO controllers (devices with master functions) and IO devices (devices with slave functions) as well as parameterization and diagnostics.

PROFINET components

Since all Ethernet devices operate with equal rights in the network, the master/slave process of fieldbus technology becomes a provider/consumer model with PROFINET IO. The provider is the transmitter who sends data without request to the communication partners, the consumers, who then process the data. In the framework of PROFINET IO, a difference is made between the following roles:

- **IO controller** as a control system which controls the automation task. The IO controller addresses all connected IO devices. It is generally a controller that exchanges input and output signals with the assigned field devices. The IO controller receives all alarms of the connected I/O devices. The IO controller also initiates the complete device identification, the connection establishment, and the start-up parameterization of the respective devices.
- **IO device** as field device that is controlled by an IO controller. An IO device consists of several modules and submodules. An IO device is a distributed field device (e.g., remote I/O, drive, valve manifold, switch) that is assigned to one or more IO controllers and that transmits not only process and configuration data, but also alarms.
- **IO supervisor** as an engineering tool for parameterizing and diagnosing individual IO devices. The IO supervisor is typically based on a PC. The IO supervisor, which can be a programming device for example, has access to all process and parameter data in parallel to the IO controller.

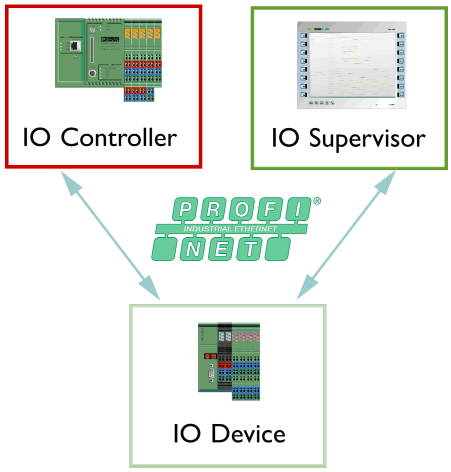

Figure 2-1 PROFINET components

PROFINET IO device model

For addressing, the IO controller uses a device model which represents the functions of one particular field device from the viewpoint of PROFINET IO.

This view must be the same for all field devices in a network to enable communication regardless of the manufacturer or device type. The IO device itself defines slots in which modules can be integrated. These comprise at least one submodule that represents the actual function.

This flexible device model is made available to the user with the device-specific GSD file. The engineering automates signal addressing.

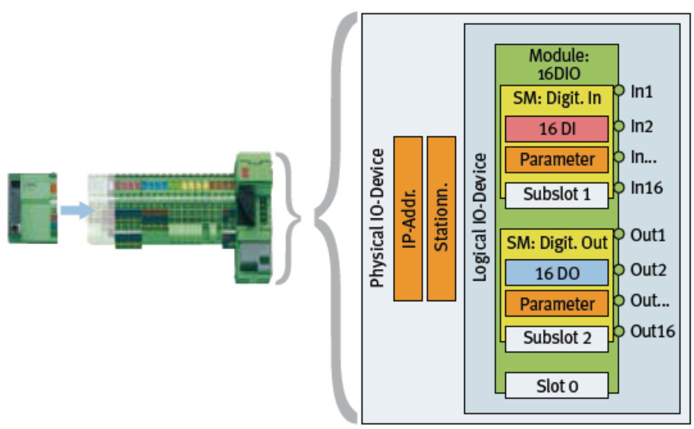

Figure 2-2 The device model provides the functions of the field device from the PROFINET IO point of view.

Fast cyclic data exchange

PROFINET IO has been designed for a fast cyclic data exchange. The cyclic data telegram to a device must not exceed the Ethernet limit of 1400 bytes user data, maximum.

Cyclic update rates that can be entered individually for each device range from 250 µs to 512 ms. It depends on each device which update rates an IO controller or an IO device supports.

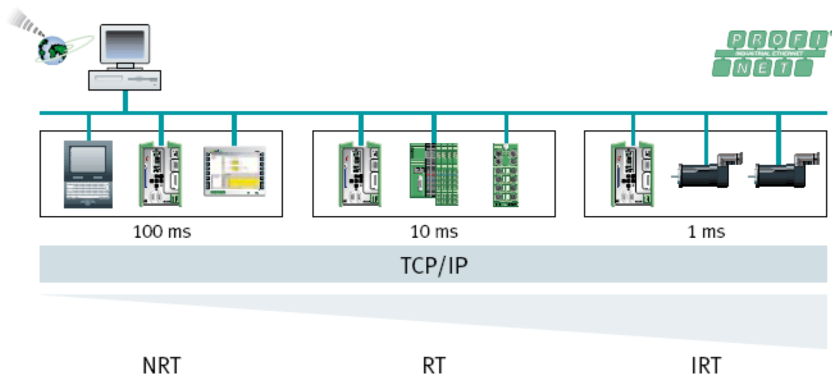

Figure 2-3 PROFINET communication channels

Powerful acyclic communication

Besides the cyclic data exchange, the communication model also allows powerful acyclic communication that exceeds all previous fieldbus specifications. The available address area and the parameter length are only limited by the memory areas on the IO devices and the IO controllers.

TCP/IP communication

In addition to cyclic and acyclic PROFINET communication each device also supports TCP/IP communication. Webserver or other IP-based technologies can be used on every device. Other "non PROFINET devices" (such as cameras, printers, PCs) may also be operated in the network.

Proxy concept

PROFINET IO features the integration of subsystems into a seamless communication and diagnostic concept via a proxy. Field devices of a lower-level fieldbus system be integrated into the PROFINET IO system via a **proxy**. In the PROFINET network the proxy is an IO device, in the lower-level fieldbus system it is a master. This allows seamless integration of existing fieldbus systems into the PROFINET network. The proxy represents the lower-level fieldbus to the PROFINET IO system by mapping the data between both systems.

The user can access all field devices on the basis of the standardized PROFINET specifications. Double configuration or addressing on the control system and proxy side is not required. Data exchange, diagnostics and parameterization of the proxy are carried out via the PROFINET protocol.

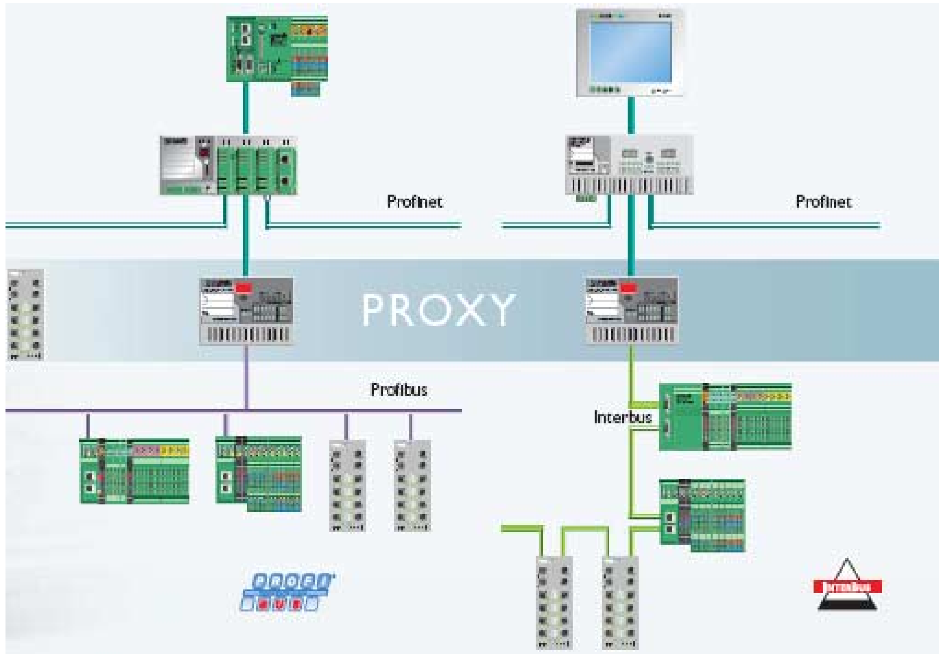

Figure 2-4 Vertical communication PROFINET IO with proxy

PROFIBUS proxy

The PROFIBUS proxy is available whenever a control systems has to be used in combination with PROFIBUS networks. Via the proxy, integrated into the PC WorX automation software, every Profibus device can be directly configured and diagnosed. The signals of PROFIBUS devices are directly linked with the program variables from the application.

INTERBUS proxy

The INTERBUS proxy acts as a link and connects an INTERBUS application to any PROFIBUS-compatible control system. Thus, its parameterization is done using the relevant programming tool. The integrated switch can take over the uplink to the control system as a control cabinet switch. The integrated switch allows in distributed applications that the proxies can be connected in a linear structure.

Robot applications used in the automotive industry are an example of the use of the proxy technology. Communication within the robot cell is established via INTERBUS, whereas control cabinets are networked with one another via PROFINET.

2.2 PROFINET CBA

This section has been added for reasons of completion. Only PROFINET IO will be described in following sections. This also applies to related documents, see "PROFINET documentation" on page 1-1.

Distributed automation solution

The component-based architecture model, PROFINET CBA (Component Based Automation), supports the trend towards distributing automation functions to various intelligent subsystems, since it defines both plant engineering and communication between the subsystems and their devices.
PROFINET CBA means a function-oriented view of an automation system. The entire system is split into individual modules which are autonomously operating subsystems. Structure and function can be found identical or slightly modified in several systems. PROFINET CBA is used to implement a distributed automation solution based on pre-assembled components and part solutions.

Communication relationships are required for interaction of the part solutions during runtime. For this purpose, the data to be exchanged between the function units is described while the units are programmed via the programming system and a PROFINET CBA file. The parameter data of the individual subsystems is then imported to the link editor and the function units linked at the click of a mouse. The modular, intelligent components from PROFINET CBA are created in an engineering tool that may differ from one device manufacturer to another.

PROFINET CBA is an automation concept that focuses on the following:

– Implementation of modular applications
– Controller/controller communication

Horizontal communication

PROFINET CBA supports cyclic and acyclic communication with transmission cycles of up to 10 ms. These are very appropriate for communication between IO controllers. The TCP/IP protocol for PROFINET CBA is suitable for operating a system with response times in the range of 100 ms, see "PROFINET communication channels" on page 2-3.

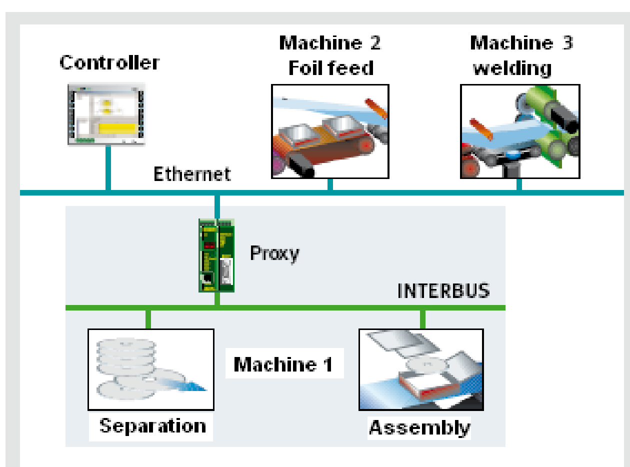

Figure 2-5 PROFINET CBA supports setting up modular, distributed machines and system concepts

3 PROFINET properties

Communication model

PROFINET IO features a very flexible but also detailed communication model. All demands of modern automation solutions can be met with PROFINET IO. At the same time, this model is so flexible that devices can only use those parts of the standard that are needed for this specific application.

In order to introduce you to the basic principles, the system will be described in the following in terms of communication phases (connection establishment/device parameterization) and realtime operation will be shown. Based on this basic knowledge, the contents of Section "Installing PROFINET IO devices and starting them with PC WorX" on page 4-1 will be easier to understand.

3.1 Connection establishment and start-up parameterization

To understand the connection establishment, you have to deal with some marginal conditions and the following questions:

– How is a device type identified?
– How is the device identified in the field?
– How does the device receive the communication and device-specified startup parameters?

3.1.1 Device type identification

Each PROFINET IO field device is characterized by a device identification (device ID). The IO controller transmits the device ID. During startup the IO device checks the device ID transmitted by the controller against the stored ID.

The device ID is structured as follows:

Vendor ID

The Vendor ID is a 16-bit identification being a unique reference to the manufacturer. It is assigned by the PNO to each manufacturer. A manufacturer needs this Vendor ID only once.

Device ID

The device ID is to be used for detailed differentiation between IO devices. It is specified manufacturer-specifically, for instance device class and device family.

Vendor ID	Device ID
Word (16 bits)	Word (16 bits)

Now every device has its own identification. It can be used, for instance, to read in a network structure and to link it automatically with a device description that has been uniquely assigned to this device ID. Normally, you do not have to observe this information. It is compared between IO controller and IO device during system startup. An error message is output and the connection establishment is aborted when the installed device does not match the device configured offline.

3.1.2 GSD file

Simple device description

To integrate the components needed in an automation solution, a range of information on the device must be provided in the various engineering steps. This is done with a device description. Each PROFINET device that has its own device ID is described by a General Station Description (GSD) file. This file contains all data that is important for engineering as well as for the data exchange with the IO device.

GSDML

In the engineering system, the GSD file operates as a basic for planning the configuration of a PROFINET I/O system. The manufacturer describes the IO device properties in a GSD file. The language used for this is **GSDML** (GSD Markup Language) - an XML-based language.

XML – eXtensible Markup Language

XML is nowadays the basis for many applications. This meta language is an abbreviated version of the international SGML standard (Standard Generalized Markup Language), on the basis of which one can develop such tagging languages as HTML oneself. Since SGML is very complex and parts of the standard are seldom used, the World Wide Web Consortium (W3C) created a simplified language in the form of XML. The basic idea of XML is that the documents generated follow certain basic patterns in their structure in order to make the data contained in them easier to reuse.

ISO 15745 standard

Each manufacturer of a PROFINET device must provide a GSD file. This file must also be available and checked during the certification test. The GSD file is based on the ISO 15745 standard.

Within the framework of the PROFINET system, this description is imported into the respective engineering system as a GSD file in XML format. Project planning and programming is carried out in the engineering tool and then transferred to the IO controller.

Compared to a keyword-based GSD for PROFIBUS devices, the XML-based version for PROFINET devices offers the following advantages:

– Due to the introduction of the term "submodule", it is possible to have a multi-dimensional description.
– Several device types may be described in a GSD file. This is due to the introduction of the DAP (**D**evice **A**ccess **P**oint).
– It is possible to integrate several languages (even languages that do not use the ASCII character set).
– All device-specific error texts are included in several languages in the GSD file.

GSD file name

The names of GSD files are standardized.

GSD-[GSD Schema Version]-[Manufacturer Name]-[Product Range Name]-[Date].xml

Example:

GSD-V1.5-CompanyX-IOdevice-20090701.xml

The keywords described in brackets have the following meaning:

[GSD-Schema Version]

The GSD schema version includes the version ID of the schema used, for example, V1.5. This version ID must correspond to the version ID in the file name of the gsd-DeviceDescription-[GSD-schema version].xsd.

[Manufacturer Name]

The manufacturer name is the name of the device manufacturer. Hyphens and spaces are permitted in the name.

[Product Range Name]

The name of the device range defines which device range is described in the GSD file. Hyphens and spaces are permitted in the name.

[Date]

The release date is entered in the yyyymmdd format. The manufacturer guarantees that there are no different GSD files with identical date for the same device range.

3.1.3 Device addressing in the field

MAC address

Like all other components in an Ethernet network, the PROFINET devices also have a MAC address. This address is used to identify the devices unambiguously.

It can be found on all devices. The MAC address is a worldwide unique address. It consists of twelve digits (hexadecimal). The first six digits of the MAC address represent the manufacturer. For Phoenix Contact it is the ID 00 a0 45.

PROFINET name

PROFINET communication requires that every device has a PROFINET name and can be assigned uniquely to a project. All devices in a PROFINET network can be identified with this name. The PROFINET name must only occur once in a network. The name is stored in a non-volatile way on the device and is available directly after power-up.

It is useful to assign a meaningful or user-friendly name to your device, since this name will be output in the diagnostic tools in the event of diagnostics. You may also derive the device name from the equipment identification of each device.

The IO controller searches only via the name for the IO device in the network. An error message is output and the startup is aborted when the name cannot be found or if, by mistake, there are two devices with an identical name in the network.

DNS syntax

Please note that the PROFINET device name is similar to the DNS syntax from the INTERNET URL. Only lower case letters are accepted. Special characters are limited to dot "." and hyphen "-". To facilitate readability some tools allow upper case letters. However, they will only be displayed in the project and will not be sent to the device.

Device naming

The IO device receives its name by the so-called device naming. An engineering tool identifies the terminal device using a flashing function or the MAC address. Afterwards, the device name is written to the device.

IP address

It is not necessary to assign an additional IP address since it is distributed automatically during startup using the project settings. Unlike the PROFINET name, the IP address is stored in a volatile memory on the device and newly assigned during every device start in comparison with the program.

3.1.4 Device parameterization during startup

After device identification the device is informed of its parameters over PROFINET. A terminal device is passive in the network until it is addressed with its name by an IO controller.

Communication parameters and device-specific startup parameters are transmitted to the device. Cyclic data exchange can only start after the device received this information, proved to be consistent and confirmed to agree with the actual hardware.

IP communication parameters

IP parameters are part of the communication parameters. The IP parameters include IP address, subnet mask and gateway address. Each IO device has a unique IP address. This IP address can be used to address the device, for example, using IT services such as FTP, HTTP provided that these functions are implemented in the device. A detailed description of these parameters can be found in the Appendix "Frequently used PROFINET terms" on page A-1.

Update rate and watchdog time

The consumer/provider communication model permits a separate update rate for both directions. You may also set a watchdog time for the device.

The update rate may have the following values. 1, 2, 4, 8, 16, 32, 64, 128, 256, 512 ms. The GDS file determines which update rate an IO device supports. The file also has a default update rate and a watchdog time integrated. These parameters will also be transmitted to the device during system startup.

Startup parameters

Depending on the device structure each device may have further device-specific startup parameters. If these parameters affect the IO device (e.g., activation of certain error classes) they will be addressed to slot 0. Each subordinated slot or subslot may have its own startup parameters.

This startup parameterization process takes place when an IO device is put into operation for the first time and after every connection abort. The IO device always receives the complete parameter record.

3.2 Realtime data exchange in the operating phase

Cyclic data exchange of PROFINET IO distinguishes between the two operating modes PROFINET IO-RT and PROFINET IO-IRT. IRT means Isochronous Real Time and RT means Real Time. IRT and RT can be operated in parallel in a network. Addressing and error handling are identical. Through special methods, IRT permits a high synchronism over the network. Therefore, PROFINET IO-IRT is used, for example, for high-deterministic positioning tasks.

3.2.1 Usual realtime communication with RT mechanisms

Cyclic data exchange starts once the device has acknowledged the connection establishment as positive. One Ethernet telegram is transmitted in each data direction for every IO device.

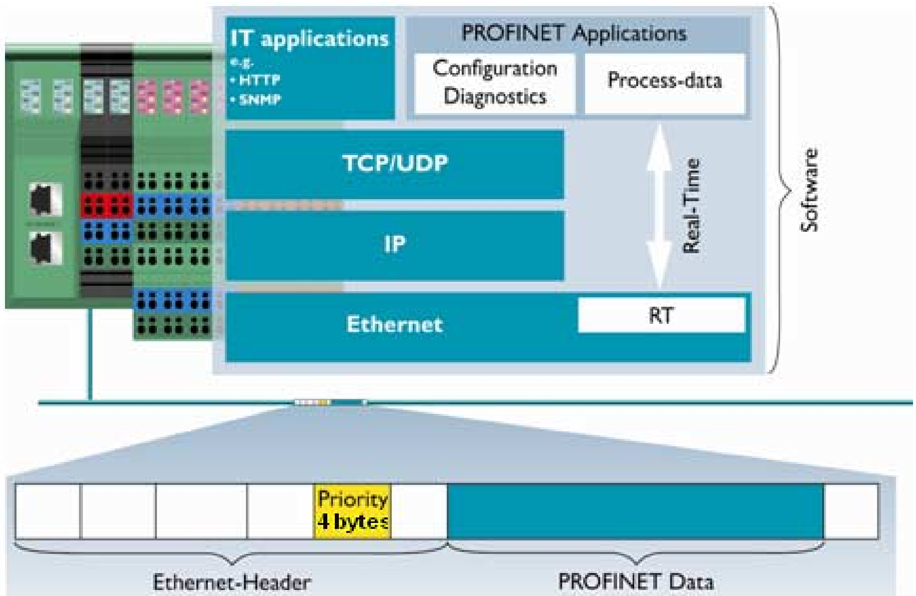

Figure 3-1 Realtime communication with RT mechanisms

Prioritization

This data telegram uses the VLAN tag defined in IEEE 802.x with its prioritization information. PROFINET sets the priority to the highest level 6. This flag is used in the switches available in the network to preferentially transmit the PROFINET telegram. That means when a PROFINET telegram and a non-PROFINET telegram with low priority arrive at a switch at the same time, the PROFINET telegram will be transmitted first.

The received values are transmitted over the process data channel to the application or the I/Os. This is done with the update rate set during the connection establishment. Each IO device may have its own update rate, see also "Defining update rates and estimating network loads" on page 4-4. There is no bus cycle time in the PROFINET system.

Status information

I/O data includes further status information. This status information shows whether the device has an error message or reports that data is valid. The controller and the drivers automatically evaluate this information. It will not be forwarded to the user. The validity of data is used, for example, for a parameterizable substitute value behavior of the I/O signals.

RT communication completely covers the communication requirements of modern fieldbus systems. Flexible startup parameterization, parallel IP communication and powerful acyclic communication can be used in parallel on one network.

3.2.2 Realtime communication with RT mechanisms

IRT networks (Isochronous Real Time) permits a deterministic data cycle that is exact down to a µs and additional synchronization information in particular for fast control processes. The communication model is identical with RT communication. For example, device addressing, startup parameterization and diagnostic mechanisms are also available.

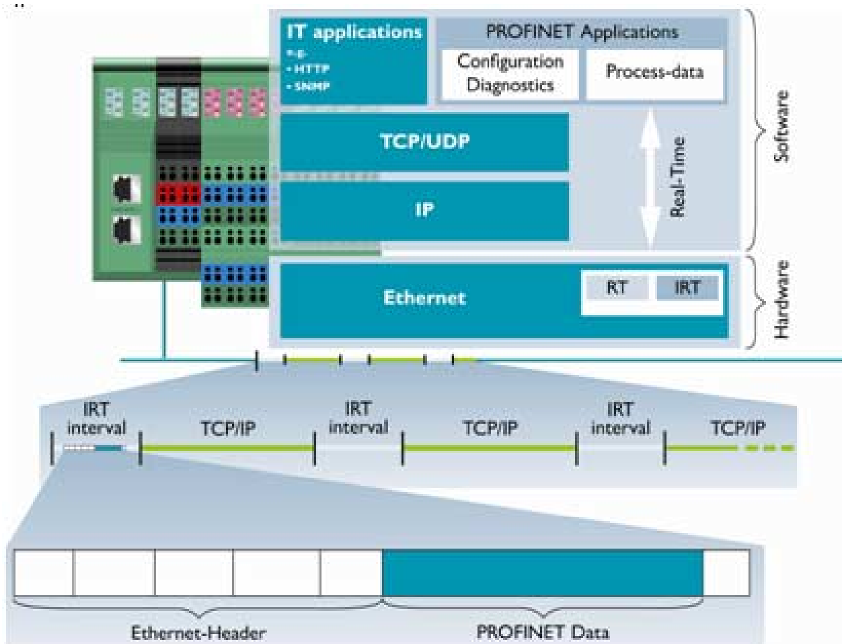

Figure 3-2 Realtime communication with RT mechanisms (Isochronous Real Time)

The high synchronization in an IRT network is achieved with a synchronous time slot method in the devices and switches. A clock pulse generator, the IRT-Sync-Master, defines the clock in the network. The telegram runtime is calculated with runtime measurements between the devices. In an IRT interval, realtime communication is carried out with each device.

IRT network and RT network differ in two major points. First, priotization in an IRT network is done using time slots. "Non-PROFINET data traffic" is only initiated or forwarded in the TCP/IP phase. If a "non-PROFINET telegram" has not reached its destination when the IRT phase starts, it is buffered in the device reached.

Second, every PROFINET telegram in the network is planned. For this, transmit lists are sent to every IRT device in the startup phase, so that the forwarding of the message is equally deterministic. Thus, PROFINET achieves a jitter accuracy of less than 1 µs.

> Since Phoenix Contact controllers do not yet support IRT, IRT will not be described further in this manual. Please check in the relevant data sheets whether I/O or infrastructure-components support IRT.

3.2.3 Integrated device and network diagnostics

The PROFINET system features comprehensive and standard device and network diagnostics. Apart from PROFINET diagnostic mechanisms, standards such as SNMP and HTTP can also be integrated into the diagnostics concept.

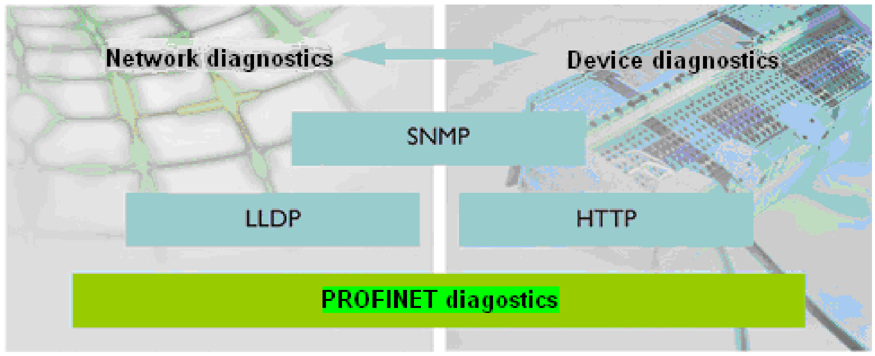

Figure 3-3 Device diagnostics and network diagnostics with PROFINET

http

Web-based diagnostics can be integrated into the device since every device has an IP address. The user can take a browser to go to the terminal device and perform local diagnostics. Web-based diagnostics is almost always available on infrastructure components. In the terminal devices it depends on the diagnostic depth the device can report. Web-based diagnostics is optional in a PROFINET network.

SNMP

SNMP (Simple Network Management Protocol) is a worldwide established Ethernet standard. Devices can send SNMP traps (alarms) to central stations, which in turn display messages or request devices to provide additional information via SNMP. PROFINET defines SNMP entries of MIB2 as mandatory, see also "Frequently used PROFINET terms" on page A-1.

3.2.4 PROFINET diagnostic mechanisms

Within the framework of PROFINET diagnostics, IO devices report an error cyclically using I/O transfer or acyclically using alarms. For example, in the event of undervoltage at the actuator supply of an IO device, an incoming alarm is sent to the control system. If the error has been eliminated, the control system is informed with a cleared alarm.

Diagnostic alarm and maintenance alarm

Alarms are divided into two groups to satisfy the ever increasing importance of preventive diagnostics:

- Usually, error states are transmitted as diagnostic alarms with corresponding parameters.
- Wear indication or similar information can be coded as maintenance alarms.

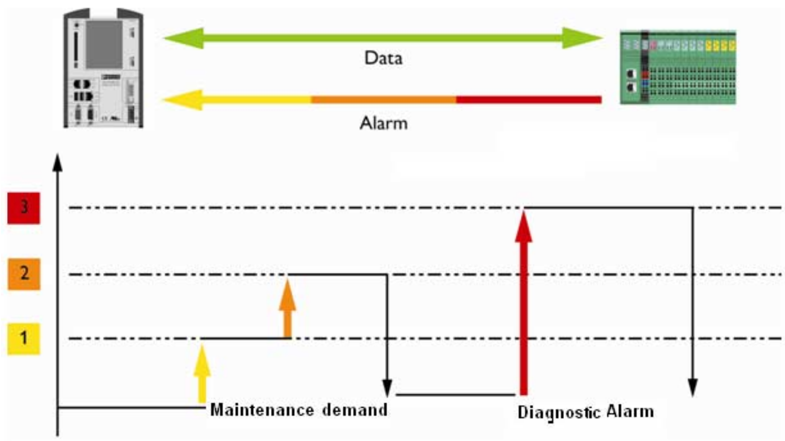

Figure 3-4 PROFINET diagnostic mechanisms

A PROFINET diagnostic tool only needs the manufacturer and device ID to find the file and display the error message in plain text. The more precise the error message given by the device, the more exact diagnostic locations can be displayed in the control or engineering system.

Diag+

In the automation solution from Phoenix Contact, the Diag+ software tool collects all diagnostic information, presents it clearly in a topology view or a tree structure and displays error causes in various languages in plain text. Diag+ is an integral part of the PC WorX programming environment. However, it can also be directly integrated into the visualization as an independent ActiveX solution.

3.2.5 Topology detection

LLDP

PROFINET uses the LLDP (Link Layer Discovery Protocol) to display the precise location of diagnostic messages in an open, flexibly cabled network. LLDP is a manufacturer-independent Layer 2 protocol, defined in accordance with the IEEE-802.1AB standard and can be used to exchange information between neighboring devices. Devices exchange their names and port numbers with the neighboring components via LLDP when the connection is being established. If all devices used in the network support the protocol, an accurate topology view can be presented in the diagnostic tool. This way, error messages can be displayed directly on the device or port.

A software component called LLDP agent runs on every device supporting LLDP. The LLDP agent transmits periodically information about itself and constantly receives information from neighboring devices. This happens independently and therefore the LLDP is called a "one-way-protocol" which does not establish communication to other protocols.

LLDP_EXT_MIB

Information received via LLDP is stored locally on every device in a data structure called Management Information Base (MIB). SNMP can be used to access this information in the LLDP_EXT_MIB.

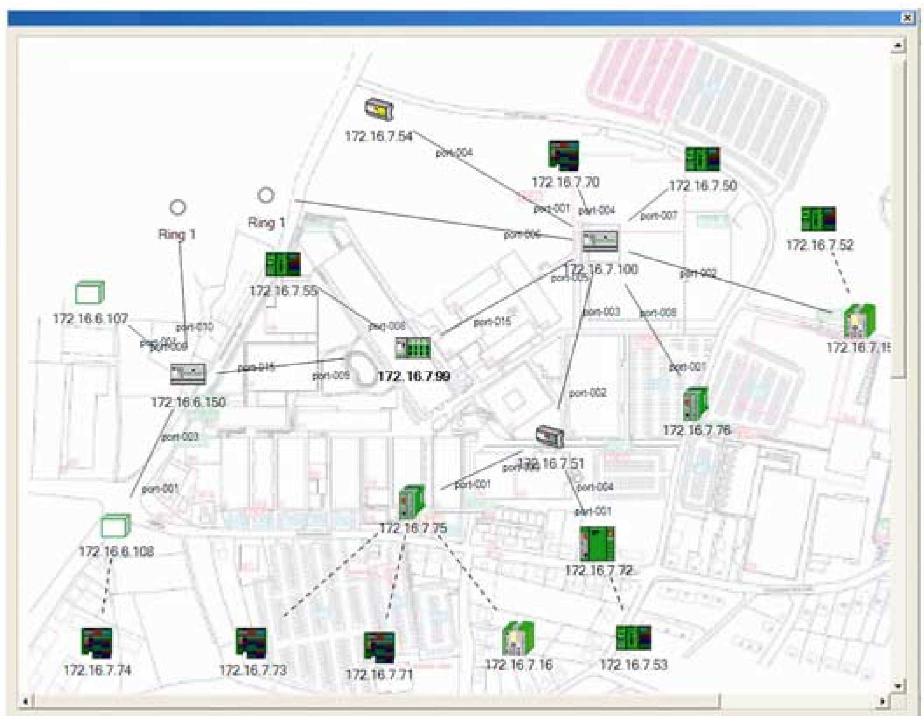

Figure 3-5 Topology detection

4 Installing PROFINET IO devices and starting them with PC WorX

This section describes the planning phase of your system and device replacement during operation.

To optimize your system startup, please proceed as described in the following.

4.1 Planning the PROFINET system

The PROFINET network is an open network which may also include Ethernet devices. Therefore, planning a PROFINET network is very important. This includes unambiguous IP addresses, definition of name assignment and a first estimation of the network load.

4.1.1 Planning the topology

Flexible network structures

PROFINET offers a flexible topology. The PROFINET installation follows the system which means that the topology is not specified by the technology. There is a point-to-point connection between the devices. The basic elements of the topology are always line structures or branches. You may create any topology using these basic elements. A special form of the line structure is the ring structure in which line from the last device is led back to the beginning of the line where it closes the ring. Topologies can be mixed at any time.

I/O devices with two ports permit to set up line structures. A switch with the corresponding number of ports is required when several devices are to be grouped together at one point.

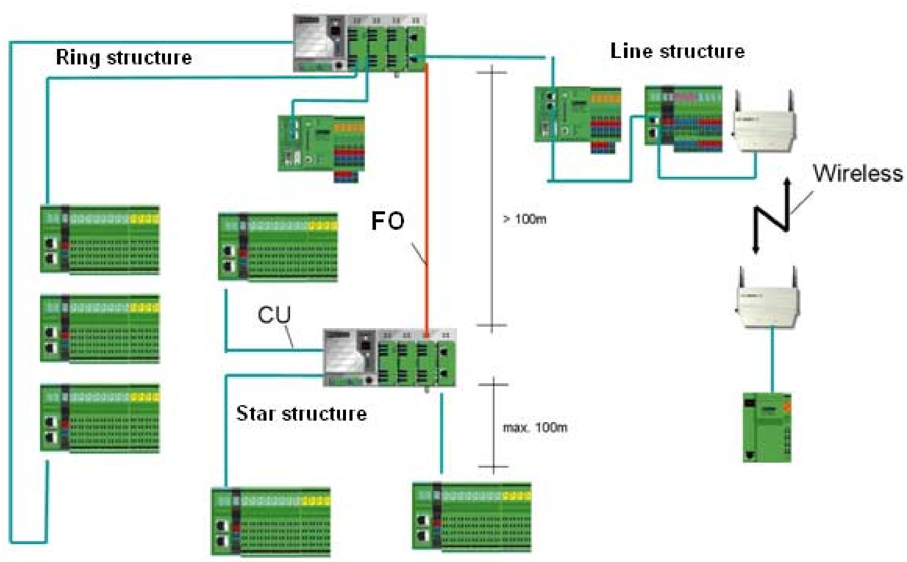

Figure 4-1 PROFINET topology example

4.1.2 Determining the transmission media

After you have planned the topology you determine the transmission media. PROFINET devices mostly use copper connections. This permits cable lengths up to 100 m. You may use optical transmission media when longer distances have to be covered. Fiber optics are resistant to electromagnetic interference and partly allow for larger network sizes than copper cables. The maximum segment length between two PROFINET devices is up to 14 km for fiber-optic cables.

If mobile devices are to be addressed using wireless technology, you have to design the wireless networks accordingly. For additional information, please refer to Section "Wireless transmission of PROFINET data" on page 5-1.

Transmission media

Depending on the requirement a PROFINET network permits to

- Communicate over present networks on the basis of copper cables
- Use fiber-optic cables that are resistant to EMI and permit larger network dimensions
- Switch - in the event of an error - the communication path to an intact branch of the ring structure using a standardized method
- Implement wireless data transmission over WLAN and Bluetooth

4.1.3 Using conformance classes for the planning

To aid your PROFINET network planning, the PROFINET user organization divided the PROFINET scope of functions into conformance classes (CC). The aim was to simplify the decision criteria for system operators when using PROFINET IO. By defining a conformance class you can may select field devices and bus components that feature clearly defined minimum properties. This is important to guarantee interoperability of all field devices involved in communication. All conformance classes include by default basic functions such as cyclic and acyclic data exchange or alarms.

The minimum requirements for three conformance classes (CC-A, CC-B, CC-C) have been defined from the system operator's point of view. In addition to the three application classes there are additional definitions for

- Device types
- Type of communication
- Transmission medium used
- Redundancy behavior

Conformance Class A (CC-A)

Uses the infrastructure of a present Ethernet network and integrates PROFINET basic functions. All IT services can be used without limitations. Typical applications can be found in production engineering, building or process automation. Only this class permits wireless communication.

Conformance Class B (CC-B)

In addition to CC-A, the CC-B scope of functions allow for an easy and convenient device replacement without engineering tool. A media redundancy protocol for TCP(UDP)/IP data is integrated to increase data security. Field devices of CC-B have and integrated 2-port switch. Typical applications are automation systems and higher-level machine control with low demands on a deterministic data cycle.

Conformance Class C (CC-C)

In addition to CC-B, the CC-C scope of functions allows for a high-precision, deterministic data transmission including synchronous applications. The integrated media redundancy allows for a bumpless switch-over of I/O data traffic when an error occurs. Typical applications can be found, for instance, in the field of motion control.

The following table provides an overview of the properties of the conformance classes.

Feature	CC-A	CC-B	CC-C
Realtime protocols	RT	RT	RT/IRT
Certified device types	IO controller IO device IO supervisor	IO controller IO device IO supervisor	IO controller IO device IO supervisor
Use of standard Ethernet infrastructure	Yes, no certification required – Switches acc. to 802.3 – WLAN and Bluetooth Access Point/Clients	Yes, but switches are also IO devices and therefore need to be certified	No, PROFINET IO-IRT-capable hardware required in all switch components
Transmission media	Copper (100 Mbps) FO (100 Mbps) Wireless (WLAN 2.4 GHz / 5 GHz, Bluetooth)	Copper (100 Mbps/s) FO (100 Mbps)	Copper (100 Mbps/s) FO (100 Mbps)
Bussynchronous applications	No	No	Yes
PROFINET cabling guideline valid	No	Yes	Yes
Functions			
– **Topology detection**	No	Yes	Yes
– **Representation in the network management via SNMP**	No	Yes	Yes
Redundancy mechanisms			
– **Media redundancy meshed with RSTP/switch-over 2 s**	Optional	Optional	No
– **Media redundancy MRP ring/ switch-over 200 ms**	Optional	Optional	No
– **Media redundancy MRP ring/ bumpless switch-over**	No	No	Optional

4.1.4 Specifying IP addresses

Every device in a PROFINET network has an IP address. The device receives this address from the control system when the system is started. That means that devices that should not be accessed over TCP/IP (e.g., a simple I/O station) also require an IP address. Other devices in the network (operating PCs, technology controllers, cameras,...) also have an IP address. Every IP address in a network must only be assigned once.

The IP parameters include the actual IP address, the subnet mask and the gateway address. These terms are explained in the Appendix "Frequently used PROFINET terms".

When you plan your PROFINET network you define the IP addresses of the devices on the network. If there are recurring structures, you may define IP addresses in the subnet according to your own rules. For example, I/Os in the network always have addresses 100 to 125 or the "Supply" system part has always addresses 50 to 59.

> When networking higher-level networks, the planner receives the IP parameters (gateway address, subnet mask and IP address range) directly from a responsible person for the network. Normally, the responsible person for automation can use any address of the IP address range.

4.1.5 Assigning the PROFINET device name

The PROFINET device name is an important information for the control system. The IO controller can find the end device only through its name. The name of the device output even in the event of diagnostics. It is therefore only useful to define a name space when you plan the system. For this you may use equipment identifications or device functions ("Motor1_Rotating_tower").

4.1.6 Defining update rates and estimating network loads

PROFINET distinguishes itself in one important point from other popular fieldbus systems. There is no bus cycle in which, for instance, the slowest device sets the transmission speed. For each device you may determine an individual update rate for the input and output direction.

Update rate and telegram length of a device determine the network load of this device. If you are not sure about the network load of your system, just calculate the network load for the busiest path on the network. In most cases this is the path to the controller. If additional network traffic on the control level and, for instance, additional network traffic for camera systems is to be expected, you have to estimate these paths separately.

The following table shows how much network load PROFINET devices with up to 40 bytes user data generate.

Number of devices	Update rate in ms									
	1	2	4	8	16	32	64	128	256	512
1	0.80%	0.40%	0.20%	0.10%	0.05%	0.025%	0.013%	0.006%	0.003%	0.002%
2	1.60%	0.80%	0.40%	0.20%	0.10%	0.050%	0.025%	0.013%	0.006%	0.003%
3	2.40%	1.20%	0.60%	0.30%	0.15%	0.075%	0.038%	0.019%	0.009%	0.005%
4	3.20%	1.60%	0.80%	0.40%	0.20%	0.100%	0.050%	0.025%	0.013%	0.006%
5	4.00%	2.00%	1.00%	0.50%	0.25%	0.125%	0.063%	0.031%	0.016%	0.008%
...										
10	8.00%	4.00%	2.00%	1.00%	0.50%	0.250%	0.125%	0.063%	0.031%	0.016%
...										
20	16.00%	8.00%	4.00%	2.00%	1.00%	0.500%	0.250%	0.125%	0.063%	0.031%
...										
30	24.00%	12.00%	6.00%	3.00%	1.50%	0.750%	0.375%	0.188%	0.094%	0.047%
...										
40	32.00%	16.00%	8.00%	4.00%	2.00%	1.000%	0.500%	0.250%	0.125%	0.063%
...										
50	40.00%	20.00%	10.00%	5.00%	2.50%	1.250%	0.625%	0.313%	0.156%	0.078%
...										
100	80.00%	40.00%	20.00%	10.00%	5.00%	2.500%	1.25%	0.625%	0.313%	0.156%

The following table shows how much network load PROFINET devices with up to 100 bytes user data generate.

Number of devices	Update rate in ms									
	1	**2**	**4**	**8**	**16**	**32**	**64**	**128**	**256**	**512**
1	1.60%	0.80%	0.40%	0.20%	0.10%	0.050%	0.025%	0.013%	0.006%	0.003%
2	3.20%	1.60%	0.80%	0.40%	0.20%	0.100%	0.050%	0.025%	0.013%	0.006%
3	4.80%	2.40%	1.20%	0.60%	0.30%	0.150%	0.075%	0.038%	0.019%	0.009%
4	6.40%	3.20%	1.60%	0.80%	0.40%	0.200%	0.100%	0.050%	0.025%	0.013%
5	8.00%	4.00%	2.00%	1.00%	0.50%	0.250%	0.125%	0.063%	0.031%	0.016%
...										
10	16.00%	8.00%	4.00%	2.00%	1.00%	0.500%	0.250%	0.125%	0.063%	0.031%
...										
20	32.00%	16.00%	8.00%	4.00%	2.00%	1.000%	0.500%	0.250%	0.125%	0.063%
...										
30	48.00%	24.00%	12.00%	6.00%	3.00%	1.500%	0.750%	0.375%	0.188%	0.094%
...										
40	64.00%	32.00%	16.00%	8.00%	4.00%	2.000%	1.000%	0.500%	0.250%	0.125%
...										
50	80.00%	40.00%	20.00%	10.00%	5.00%	2.500%	1.250%	0.625%	0.313%	0.156%
...										
100	-	80.00%	40.00%	20.00%	10.00%	5.000%	2.500%	1.250%	0.625%	0.313%

The resulting cumulated network load determines the performance of your controller. If the controller cannot process these network loads, reduce the devices update rates or use a more powerful controller. You can also distribute the controller program to several controllers.

The following table shows you guide values when using different controllers. If you need an exact result you can insert the number of devices in the PC WorX project. If the controller performance is exceeded, an error message is output when the project is compiled.

Controller	Network loads	Maximum number of devices
ILC 3xx	< 5%	100
RFC 4xx	< 10%	100
SMAX 4xx	< 15%	100

4.2 Configuring networks

Now transfer your planning results to the prepared project.

4.2.1 Preparations with PC WorX

Communication

In the "Extras/Profinet Configuration..." menu in PC WorX select the network card for your computer that is to be used for communication.

Creating a project

If a project does not yet exist, create it first under PC WorX. Select the "New Project..." command from the "File" menu.
Then select the IO controller.

Project parameters

In the bus configuration workspace you can adapt the project information to the project.

After you have selected the node for the IO controllers in the "Bus Structure" window, you can change, for instance, the IP settings in the "Device Details" window.

Also prepare the PC for communications by selecting its IP parameters in such a way that it can communicate with the connected network.

Importing third-party devices

Devices which are not yet included in the device catalog may be imported with the "Import GSD File" function (right-click). The device will then be added to the catalog with the company designation.

> For detailed information, please refer to the "Installing and starting up the starterkit 3.0" quick start guide UM QS EN PROFINET STARTERKIT 3.0. It can be downloaded at: www.phoenixcontact.net/download

4.2.2 Configuring PROFINET devices

In this step you drag PROFINET IO devices from the device catalog to the PROFINET node of the controller (double-click/return or drag & drop). The corresponding settings such as device name, IP address and update rate/monitoring time are automatically set with default values and should be changed to the planned name and address on the "PROFINET Settings" tab in the "Device Details" view.

In addition to the update rate you may set a monitoring time for each connection, so that a connection is aborted when this time is exceeded. A multiple of the transmission rate is set. The smallest setting is "3".

The following additional device parameters affect the system behavior of the controller and can be set separately for each IO device.

– Drive BF
– Log connection state
– Operate with differences in configuration

For detailed information, please refer to the "Installing and starting up the starterkit 3.0" quick start guide UM QS EN PROFINET STARTERKIT 3.0. It can be downloaded at: www.phoenixcontact.net/download

4.2.3 Integrating Ethernet devices into the project

To ensure that IP addresses are assigned only once in the network, Ethernet devices such as PCs or Ethernet infrastructure components may be integrated into the project as placeholders. To do so, you must drag these devices from the device catalog to the tree level in parallel to the controller. Ethernet and wireless infrastructure components from Phoenix Contact can be found directly under the FL (Factoryline) device range. You can use the Windows PC from the "Generic" folder as a placeholder for other Ethernet devices.

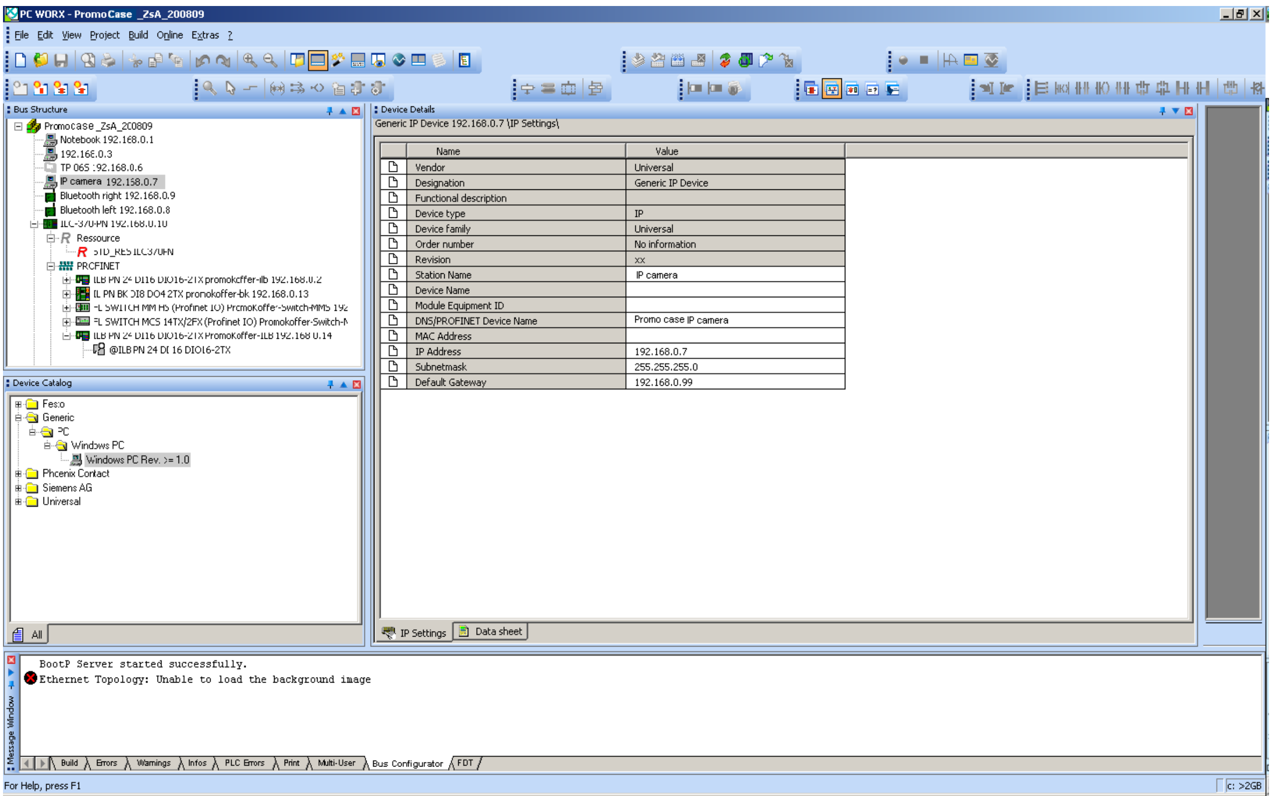

Figure 4-2 Placeholder: Windows PC device

4.2.4 Checking the controller performance

You have to compile the project once to check the performance of the selected controller. If no other error message than "Program missing" is output the basic specifications of the controller have not been exceeded.

4.3 Starting up the network

First, all device names have to be written to the devices to allow the controller to start up the network. This is called "device naming" and can be done from PC WorX or with other tools.

The device should be named when it is electrically installed. At this point there is a unique assignment to the device and you can name it without mixing it up with other devices.

You can use the MAC address printed on the device to identify the device unambiguously. Additional certainty is provided with the "Flashing". Single, addressed devices flash with their display instruments such as LEDs, when they are being searched with a PROFINET engineering tool in the system.

4.3.1 Assigning device names with Netnames+

The Netnames+ tool from the AUTOMATIONWORX Software Suite offers an easy option for naming a device.

You find the tool in the program menu under PHOENIX CONTACT-> AUTOMATIONWORX Software Suite ….-> Service programs. After you have selected the network card, this tool provides a fast overview of all PROFINET IO devices present in the subnetwork, even without a PCWorX project. You can set names and write several names simultaneously. You can also set IP addresses to address, for example, web pages of the device in the startup phase.

The import list offers a special function. With the help of an easy import list, Netnames+ can import all names from a planning tool. These names can be allocated to the identified devices using drag & drop. The device names no longer have to be entered manually.

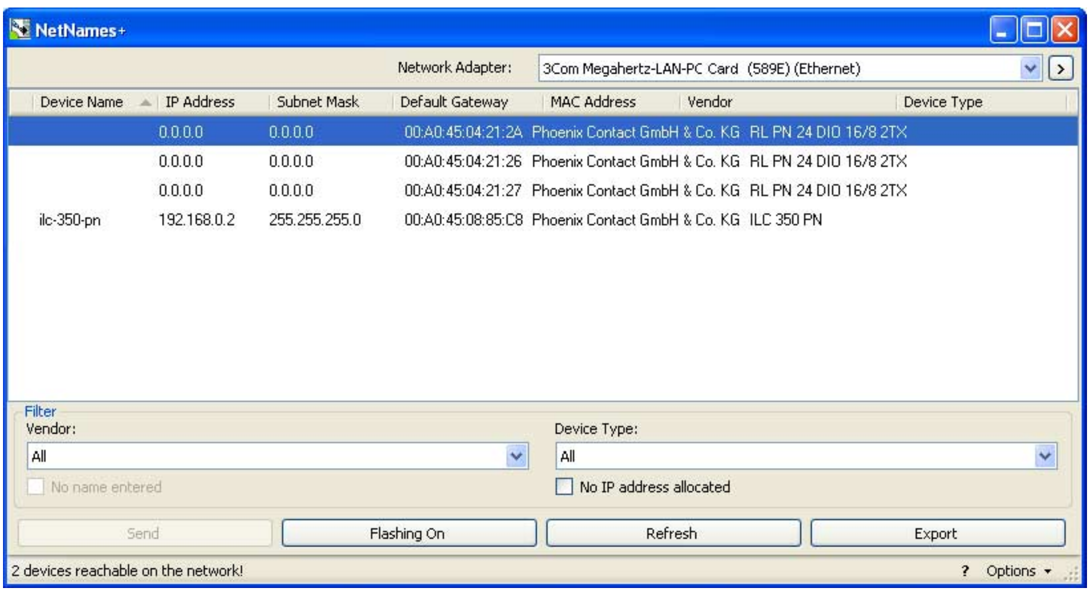

Figure 4-3 Changing device names

A detailed description of Netnames+ functions can be found in the online help.

Reading the configuration

Start PC WorX and create a new project or open an existing project, see "Preparations with PC WorX" on page 4-7. In the "Bus Structure" window of the bus configuration workspace select the PROFINET node for the control system. Select "Read PROFINET..." in the context menu. This function can be used to locate all PROFINET devices in the network.

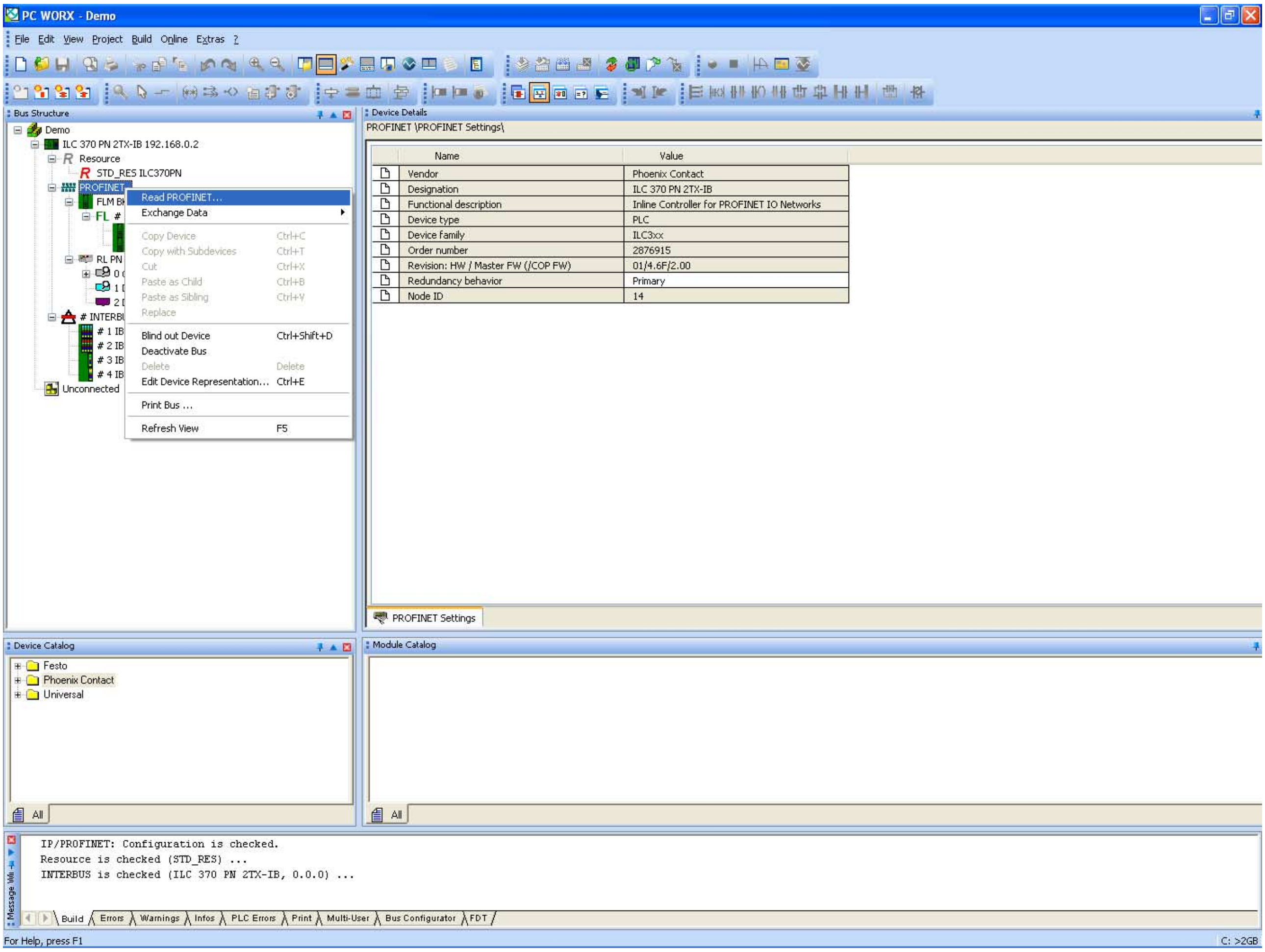

Figure 4-4 Read PROFINET

All the connected PROFINET devices are displayed.

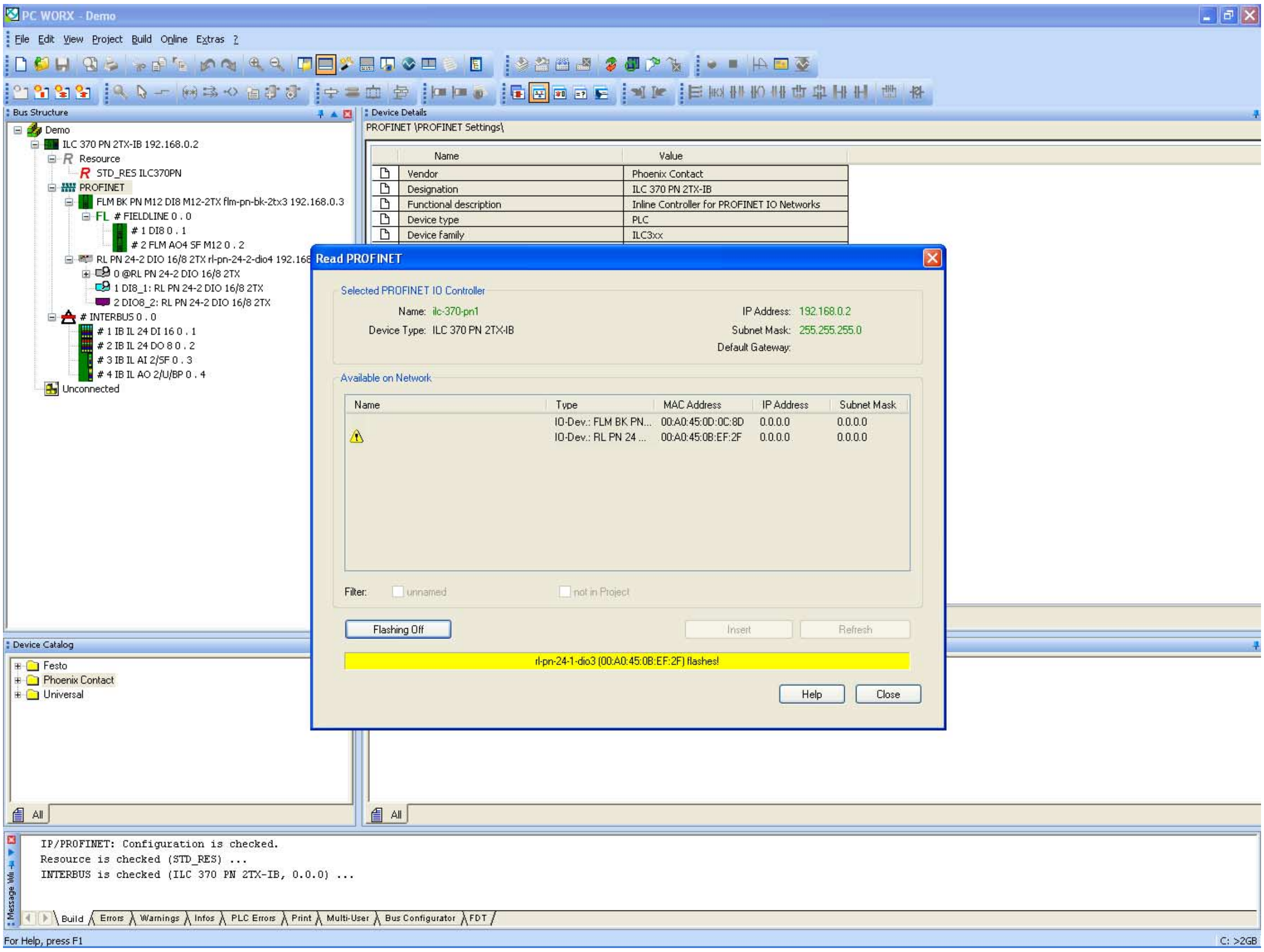

Figure 4-5 Inserting PROFINET devices

You can select devices from this list and insert them into the current project with the "Insert" button.

In order to limit the search results, different options are available:

No constraints	All devices that are available in the network are listed.
Unnamed	All those devices that do not yet have a PROFINET device name are listed.
Not in project	All those devices that are not included in the project are listed.

The devices are uniquely assigned with their MAC address. You also have the option of letting the LEDs flash for a selected device. To do so, select a device and click the "Flashing On" button.

A device name is created automatically when the device is transferred to the project and the device is named. You can also assign another, individual name.

Assigning a name manually

If a project has already been created, it includes all communication settings and device names. These must be assigned to the existing devices.

Select the node of the PROFINET device to which a device is to be assigned in the "Bus Structure" window. The "Device Details" window shows under "PROFINET Stationnames" all PROFINET devices available on the network.

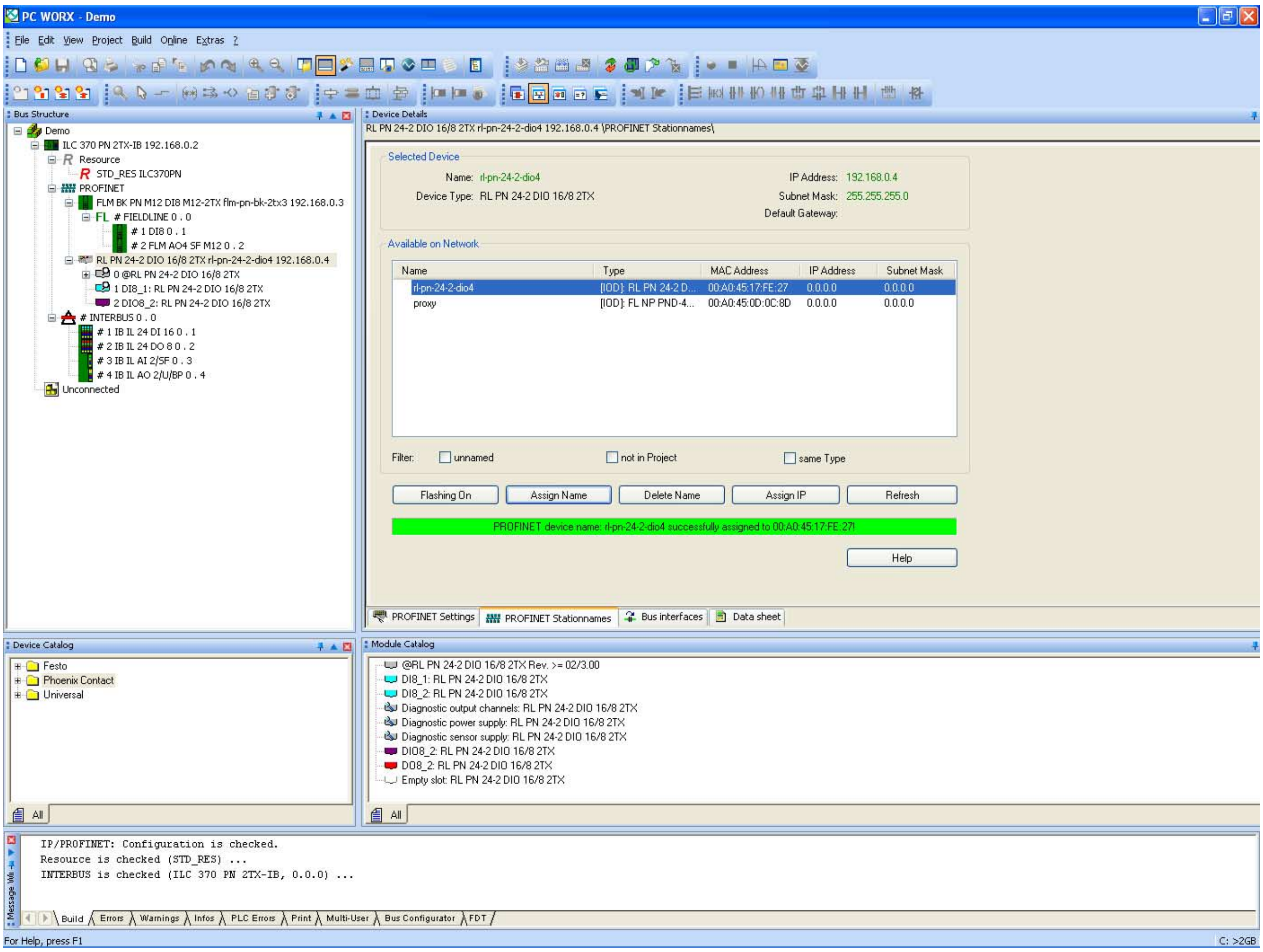

Figure 4-6 Display of PROFINET devices

In order to limit the search results, different options are available here too:

No constraints	All devices that are available in the network are listed.
Unnamed	All those devices that do not yet have a PROFINET device name are listed.
Not in project	All those devices that are not included in the project are listed.
Same type	Only devices that correspond to this device type are listed.

The MAC address is used to identify the devices in the network unambiguously. Select the desired device and click the "Assign Name" button. The device is named with the PROFINET name.

An other option to identify devices in a system is the "Flashing" function. To do so, select a device from the network and click the "Flashing On" button. You can now find the device in the system with help of the flashing LEDs.

You have to repeat these steps for every device in the project.

4.3.2 Observe startup behavior

Starting up the controller is the easiest way to check
- The controller is correctly parameterized
- The I/O devices have the right name
- There are double names or double IP addresses in the system.

Compile the project with the bus configuration. There will be a warning message if there is no application program. You can ignore this message.

Make sure that the controller has the IP address that was set in the project. Start the project control dialog via the menu bar.

If the message "Timeout" appears after 10 seconds, the project and device addresses do not match. It is also possible that the IP address of the computer has not been set correctly.

The controller can be reset from the project control dialog. Existing projects will be deleted. Start the download and perform a cold reset. Afterwards the BF LEDs must go out on all devices.

To access the network status from the program, the following system variables are mapped in the global variables of the programming environment. Activate the "Debug On" operating mode and the values of these variables will be displayed.

Global variable	Description
PNIO_CONFIG_STATUS_ACTIVE	Connection to these devices is being established or has been completed.
PNIO_CONFIG_STATUS_READY	The connection establishment to the devices has been completed.

If you need more detailed information, call the Diag+ diagnostic tool from PC WorX under View-> Diag+. Here you connect explicitly to a controller and receive further information, see Section 4.4.3 on page 4-19.

4.4 Network in operation

4.4.1 Automatic start after device replacement

PROFINET addresses each device with a name. If the device is exchanged, its name must be transferred to the new component In the PROFINET system, the control system detects the device replacement with the help of the topology information and automatically writes the name of the replaced component to the replacement device within seconds. However, using a memory card or starting a software for manual name assignment takes more time.

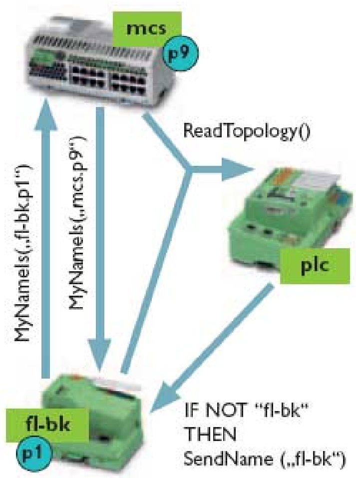

Figure 4-7 Automatic start after device replacement

However, some basic requirements must be met so that topology detection functions properly:

- It is mandatory that the PROFINET devices support LLDP.
- To be able to use the automatic name assignment when a device is replaced, the topology must not be changed by the replacement. That means that a defective device can only be replaced by an identical version and at the same spot.

It is important that IO controller operation is not interrupted after the device failure. If it is interrupted, information on neighborhood detection will be lost. Then you must name the device manually with the PROFINET name.

NOTE:
If devices of a system are replaced with one another, this will cause problems. All names are defined in the project, and so no device has been added and no device is missing. The system recognizes this status as a changed topology. PROFINET communication is started without having changed the device names.

4.4.2 Diagnostic variables in the controller

PROFINET IO offers very detailed diagnostic information about every device down to the channel.

Diagnostic states are important for system operation. If error messages occur, the process must be stopped in case of doubt. AUTOMATIONWORX controllers offer the following status information for the PROFINET network.

Global variable	Type	Description
PNIO_SYSTEM_BF	BOOL	An error occurred in the PROFINET network, that means, there is no connection to at least one configured device. This value is not set if the "Drive BF" parameter was set to FALSE for a device. This device is removed from connection monitoring.
PNIO_SYSTEM_SF	BOOL	At least one device reported a system error (diagnostic alarm or maintenance alarm).
PNIO_DIAG_AVAILABLE	BOOL	At least one device reported a diagnostic alarm with an active connection.
PNIO_MAINTENANCE_DEMANDED	BOOL	At least one device reported the "maintenance request" alarm with an active connection.
PNIO_MAINTENANCE_REQUIRED	BOOL	At least one device reported the "maintenance demand" alarm with an active connection.

If one of these values is set, it can be decided from the program now whether to continue or stop system operation. System errors of the type maintenance demand or maintenance request can, for example, only lead to a message to the service personnel. This message includes error location, error reason and priority.

If the application is to monitor every device for diagnostics, the automatically generated signals of the PNIO_DATA_STATE structure can be also be used.

Global variable	Description
PNIO_DATA_VALID	The application program must receive information on whether a PROFINET IO device is supplying valid data or not. For this reason, the "PNIO_DATA_VALID" process data item exists on every PROFINET IO device. Only if this bit is set does the PROFINET IO device supply valid data and all other process values are valid.
PNIO_DATA_DIAG	If this bit is set, no device diagnostics is present.

4.4.3 Diagnostics via alarm blocks

To display the error messages from the previous section in a reasonable way on the operating level, the error cause can be read from every device with the RALRM block.

This block needs the ADDRESS_TO_ID function to identify the terminal device. The RALRM block can retrieve the diagnostic message with the communication ID. Unlike Diag+ the block does not receive error texts. It outputs binary information only. This includes slot number, subslot number, channel number or error cause.

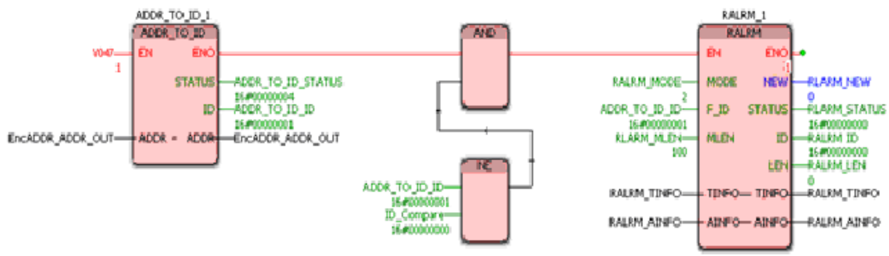

Figure 4-8 Alarm block

For more information on the alarm blocks, please refer to the PC WorX online help.

4.4.4 Diagnostics with Diag+

If an error occurs, the Diag+ tool can be started from PC WorX or from another program at any time. First, Diag+ must establish connection to the controller, then various diagnostic views can be called.

PROFINET diagnostics

PROFINET diagnostics displays all PROFINET devices in a tree structure. Devices shown in red have an error. If the device is accessed, all slots of the device will be displayed with the exact error location an type. The error cause will be given as text information when the GSDML file of the terminal device is available on this computer. This view displays the current error status. An error history can be found in the diagnostic archive.

Ethernet topology

The Ethernet topology displays the specified network status. PROFINET and Ethernet devices have equal rights. By switching to the "Show Accessibility" function you get an overview of the device connections.

Diagnostics archive

The diagnostic archive collects all error messages arriving on the controller - not only PROFINET. A time stamp and comprehensive filter criteria can be used to display certain processes at a later date. The archive is a ring buffer in which the oldest information is overwritten after the limits have been reached.

5 Wireless transmission of PROFINET data

Data transmission via cables is cost-effective, safe, and reliable if the cable installation is static. Industrial production features more and more movable components in production. Electromechanical installation solutions such as collector wires or drag chains are not only expensive, but they wear caused by constant strain. Communication errors may occur that reduce the availability of the system and require time-consuming maintenance work.

Cost-effective and reliable alternative

For many users, new options and considerable cost benefits can be achieved thanks to the transparent and reliable transmission of PROFINET via Bluetooth or WLAN. Wireless communication is a cost-effective and reliable alternative to this. Since most of the wireless standards have been developed for wireless Ethernet communication, PROFINET can also be transmitted easily and transparently. The PNO has specified Bluetooth (IEEE 802.15.1) and WLAN (IEEE 802.11) for PROFINET communication.

Wireless standard properties

Bluetooth and WLAN have different technical features. This is why they address different application fields.

WLAN

- Set-up of extensive networks with many devices
- High data throughput of up to 54 Mbps
- High mobility of the devices owing to fast roaming from access point to access point
- Good integration into IT network structures

Bluetooth

- Wireless connection of a small number of devices to local control systems
- Fast and efficient transmission of small data packets
- Reliable communication in rough industrial environment
- Excellent coexistence with WLAN networks
- Parallel operation of many Bluetooth networks is possible

5.1 PROFINET communication via WLAN

Since the signal is spread across about 22 MHz, WLAN proves to be very resistant against interferences. Data rates of up to 54 mbps (gross) can be attained depending on the quality of the transmission signal. A 2.4 GHz frequency band provides three WLAN channels, whereas the still rarely used 5 GHz frequency band provides 18 WLAN channels which can be used simultaneously. The WLAN Access Point from Phoenix Contact which has been specially developed for industrial automation offers quick roaming functions essential in mobile transport applications, among other things. Besides, data streams can be prioritized to give priority to the transmission of time-critical data.

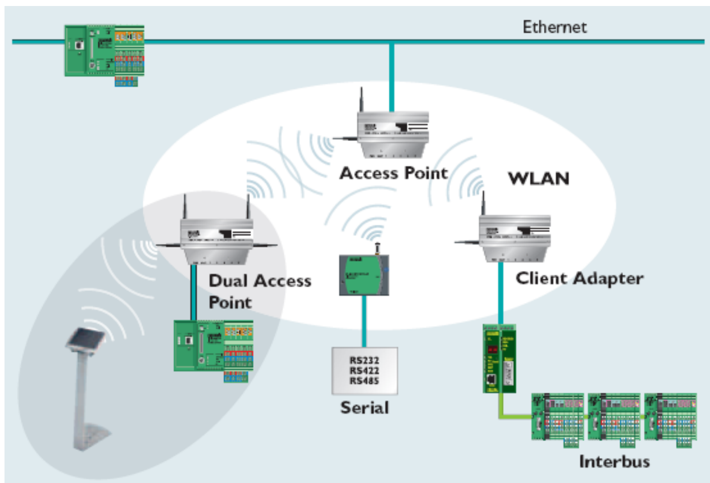

Figure 5-1 Communication via WLAN

WLAN (Wireless Local Area Network) standards operate on the Physical Layer of the ISO/OSI reference model, which means that PROFINET RT frames can be transmitted using a transparent protocol.

Although WLAN data rates are available in ranges up to 54 Mbps, the net data rate is only around 50 percent due to the large overhead. If, instead of large data packets of 1500 bytes, smaller, automation-typical packets are transmitted, the data throughput deteriorates considerably. However, this disadvantage is compensated by the benefits of standardization and low costs.

PROFINET is designed for a cable-based switch LAN with 100 Mbps full duplex transmission. WLAN is a shared LAN with a current maximum net data rate of 6 Mbps (WLAN 802.11b) and 25 Mbps (WLAN 802.11g) respectively for half duplex transmission. PROFINET RT frames can be transmitted transparently, however the realtime speed of a cable-based network cannot be achieved. If the WLAN network is available exclusively to only one device, short cyclic transmission times of 4 ms to 8 ms can be implemented with a low jitter. In the event of several devices, a maximum response time cannot be guaranteed due to the CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) access method used. With WLAN extension 802.11e, which is currently being specified, mechanisms will soon be available that will support a defined Quality of Service (QoS) for the wireless connection.

As a public medium is used to transmit data in wireless communication, a wide range of interference can occur. Since WLAN transmits in the 2.4 GHz range, transmission is not disturbed by interference fields, which occur in the kHz and MHz ranges, e.g., from arc welding, frequency inverters or switching operations. In addition, the signal is spread over a larger frequency range using the Direct Sequence Spread Spectrum (DSSS) method. However, a WLAN 802.11b/g system permanently occupies 22 MHz of the frequency range of just 83 MHz. Since there can be no overlapping frequencies for interference-free WLAN communication, only three of the 13 European WLAN channels can be used simultaneously. In the 5 GHz band, up to 12 channels are available.

5.2 PROFINET communication via Bluetooth

Bluetooth is a flexible wireless technology and is used, in particular, in small local networks with up to seven devices. The frequency hopping method in which the transmission channel switches up to 1600 times per second, makes the wireless standard extremely rugged. Bluetooth was designed for efficient transmission of small data packets so that control signals can be transmitted quickly and reliably. PROFINET update times of 8 ms or 16 ms are thus possible. Since WLAN channels can be hidden via configuration, Bluetooth components from Phoenix Contact can be operated simultaneously with WLAN networks without problems.

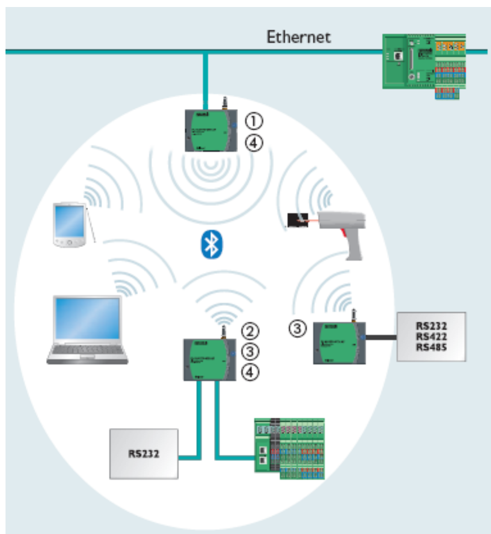

Figure 5-2 Communication via Bluetooth

Possible areas of application:

– As an access point for seven devices (1)
– As an Ethernet client adapter (2)
– As a serial port adapter (3)
– As a protocol-transparent point-to-point bridge (4)

Bluetooth is a universal wireless technology, which features a rugged and reliable transmission technology. This is mainly due to its use of broadband transmission over the entire 2.4 GHz frequency band using the Frequency Hopping Spread Spectrum (FHSS) method. Here, a total of 79 hopping channels are changed in a pseudo random sequence up to 1600 times per second. If necessary, faulty data telegrams are resent using another channel without a notable time delay. Thanks to the adaptive frequency hopping method of Bluetooth Version 1.2, channels that are occupied by other wireless systems or those that are frequently subject to interference are detected automatically and removed from the hopping sequence. This increases reliability and ensures interference-free coexistence with a WLAN 802.11b/g system.

Bluetooth offers various profiles and protocols for different applications. Thanks to the low protocol overhead, the available bandwidth is used effectively. With a gross data rate of 1 Mbps - which corresponds to a net rate of around 750 kbps - Bluetooth has a lower data throughput than WLAN. This is sufficient for the wireless connection of a small number of control systems or automation components, which usually only transmit a few bytes of data. If, for example, 100 bytes of data have to be exchanged cyclically in both directions after 16 ms, the required net data rate is only 100 kbps.

Bluetooth can use the frequency band efficiently thanks to the FHSS method. This is why Bluetooth systems can be operated in large numbers locally and in parallel, and can coexist with WLAN systems. However, in large industrial halls, a full coverage wireless signal can only reach several devices with good data throughput over WLAN with some difficulty. This is because the three WLAN channels limit the option of improving the wireless signal by increasing the density of access points. If roaming is not required between the access points, it is easier to create several small Bluetooth networks.

5.3 Planning of PROFINET in wireless networks

Wireless simulation tool

Every wireless network needs a wireless field simulation which takes into account not only the number of access points and devices but also building automation conditions. The Wireless Simulation Tool will help you in collecting the necessary information. The Wireless Simulation tool can be used for both the WLAN system (2.4/5 GHz) and the Bluetooth system. It allows to simulate walls, machines, control cabinets, as well as device positions with the antennas used. This simulation software for support when planning wireless systems in the industrial environment can be found at www.phoenixcontact.com.

IP address for wireless infrastructure

When planning the communication of a PROFINET network with integrated wireless paths, please note that access points and clients also have an IP address. This IP address must be taken from the planning phase of the system to be able to diagnose the devices with Web-Based Management.

Update rate

Due to the reduced net wireless data rate, devices after the wireless path cannot be operated with a 1 ms update rate. Typical values start with 8 ms for one device.

Please refer to the data sheets of the access points and clients for further information, in particular when using several devices.

5.4 Operating PROFINET in wireless networks

Connection monitoring

The wireless networks are transparent for the PROFINET connection monitoring. IO controller or IO device do not know that data is transferred over a wireless path.

If connection aborts occur, you should either change the update rate, increase the watchdog time, or check the web page of the wireless components for diagnostic information.

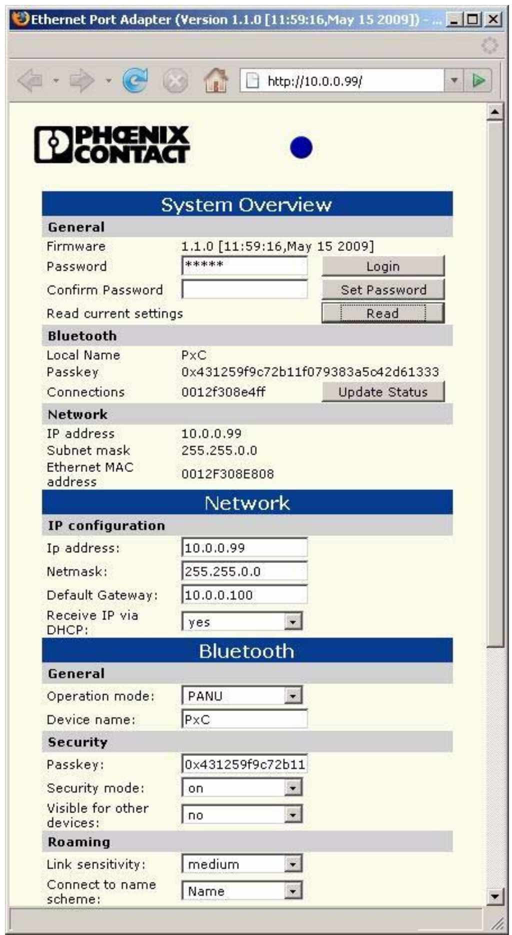

Figure 5-3 Bluetooth device web page

Topology information

If there is only one device after the access point, this wireless path is transparent and assessed like a cable. The topology information remains unique and the replacement of the PROFINET device after the wireless path still operates automatically.

If there are several devices after a wireless access point, the topology information is no longer unique. The "Automatic topology-based device replacement" function is no longer possible.

Device diagnostics

All error messages generated by the IO device regarding network status or device errors are still available. The diagnostic views in the tools, the diagnostic variables and blocks in the program must no be changed, since PROFINET diagnostic information is transmitted transparently with acyclic communication over the wireless path.

A Frequently used PROFINET terms

10BASE-T

Ethernet twisted pair cabling with a transmission speed of 10 Mbps. 10BASE-T uses four wires (two twisted pairs) of a CAT-3 or CAT-5 cable. The maximum segment length is 100 m.

100BASE-T

Fast Ethernet twisted pair cabling with a transmission speed of 100 Mbps. Like 10BASE-T, 100BASE-T uses twisted wire pairs for each direction but requires at least an unshielded Cat-5 cable. The maximum segment length is 100 m, just as with 10BASE-T.

ARP - Address Resolution Protocol

The Address Resolution Protocol (ARP) assigns network addresses to hardware addresses. Although not limited to Ethernet and IP protocols, it is used almost exclusively together with IP addressing in Ethernet networks.

Auto crossing

Autocrossing is a method where transmit and receive cables of a twisted pair interface are crossed automatically (if necessary). Autocrossing makes the differentiation between 1:1 and crossed cables superfluous. It prevents malfunctions if transmit and cables are mixed up.

Auto negotiation

In auto negotiation mode, an Ethernet device automatically sets itself to the data transmission rate of the device it is connected to (10 Mbps or 100 Mbps).
The transmission mode (full duplex/half duplex) is also agreed upon.

BOOTP - Bootstrap protocol

The Bootstrap Protocol (BootP) is used to assign an IP address and a range of other parameters in a TCP/IP network. BOOTP offers a whole range of parameters, so that the subnet mask, gateway, and boot server can also be determined.

DDI - Device Driver Interface

Interface between (Windows) operating system and device drivers. The Device Driver Interface (DDI) allows for the connection of various MonA modules and the FIBO agent to the internally used interface from the outside over TCP/IP (port 1962). The DDI supports two types of channels, the DDI Mailbox Interface (DDI-MXI) for the exchange of messages and the DDI Data Transfer Interface (DDI-DTI) for the cyclic exchange of process data.

Device model

A standard device model has been specified to structure PROFINET IO devices. It enables modeling of modular and compact field devices. The device model consists of slots and subslots. Slot 0 is always reserved for the bus interface.

DHCP - Dynamic Host Configuration Protocol

The Dynamic Host Configuration Protocol (DHCP) extends the BOOTP parameters. It makes dynamic IP address and other configuration parameter allocation possible on computers in a network (e.g., Internet or LAN) using an appropriate server.

DTM - Device Type Manager

FDT/DTM is a non-proprietary concept allowing parameterization of field devices from various manufacturers with only one program.

ERTEC - Enhanced Real Time Ethernet Controller

The Enhanced Real Time Ethernet Controller (ERTEC) is provided for implementing PROFINET devices with RT and IRT functions. With its integrated processor, the Ethernet switch with integrated PHYs and the option of connecting an external host processor system to a local bus interface, it offers all the requirements for implementing PROFINET devices with integrated switch functions.

FDT – Field Device Tool

FDT/DTM is a non-proprietary concept allowing parameterization of field devices from various manufacturers with only one program.

FTP
File Transfer Protocol

The File Transfer Protocol (FTP) is a network protocol for file transmission over TCP/IP networks that was specified in 1985. FTP is located in the Application Layer (Layer 7) of the OSI layer model. It is used to transfer files from server to client (download), from client to server (upload) or between two servers in a client-controlled way. With FTP you can also create and read directories, as well as rename or delete directories and files.

Gateway address

Address of the default gateway. All telegrams that are not addressed to devices in the same subnetwork are forwarded via the default gateway.

GSD
General Station Description

Each manufacturer of a PROFINET IO device must supply an associated GSD file. Similar to PROFIBUS DP this file describes the PROFINET IO device properties. However, unlike with PROFIBUS the file is not available in a keyword based text file but as XML file. The term Generic Station Description Markup Language (GSDML) is also used along with PROFINET IO.

HTTP - Hyper Text Transmission Protocol

The Hypertext Transfer Protocol (HTTP) is a protocol for data transmission over a network. It is mainly used to load web pages and data from the Internet into a web browser.

HTTP belongs to the Application Layer of established network models. The Application Layer is addressed by application programs. For HTTP it is usually a web browser. In the ISO/OSI layer model the Application Layer corresponds to Layers 5-7. In the TCP/IP reference model used on the Internet the Application Layer is in Layer 4.

Hub

A hub is a networking component that, being an Ethernet star coupler, regenerates Ethernet signals on Layer 1. The signals are transferred to all ports.

IO controller

An IO controller is a device that is addressed via the particular IO devices connected.

IO device

An IO device is a distributed field device that is assigned to one or more IO controllers and that transmits not only process and configuration data, but also alarms.

IO supervisor

An IO supervisor is a programming device or an industrial PC and has access to all process and parameter data like the I/O controller.

IP - Internet Protocol

The Internet-Protocol (IP) is a network protocol commonly used in computer networks. It is an implementation of the Internet Layer of the TCP/IP model, or the Network Layer of the OSI model.

The Internet Protocol is the first layer of the Internet protocol range that is independent of the transmission medium This means that the IP address and subnet mask can be used to group computers within a network into logical units, known as subnets. On this basis it is possible to address computers in larger networks and to establish connections to them, since logical addressing is the basis for routing (path selection and forwarding of network packets). The Internet Protocol is the basis for the Internet.

IP address - Internet Protocol Address

An Internet Protocol Address (IP address) is used for unique addressing of computers and other devices in an IP network. The number is technically a 32 or 128-position binary digit. The Internet is the most well-known network that uses IP addresses. For example, web servers are addressed with IP addresses (all computers on the Internet are addressed with an IP address). The IP address has the same function as the telephone number in a telephone network.

The IP address comprises four decimal numbers from the value range 0 to 255. They are separated by a dot. The IP address comprises the following:

– Address of the (sub) network
– Device address (generally known as host or network node).

IRT Protocol - Isochronous Real-Time Protocol

The Isochronous Real-Time Protocol (IRT protocol) is used for PROFINET IO applications with a cycle time of less than 10 ms.

LLDP - Link Layer Discovery Protocol

The Link Layer Discovery Protocol (LLDP) is defined according to IEEE-802.1AB. The own MAC address, the device name, and the port number are exchanged with the immediate neighbor via LLDP for neighborhood detection.

On each device supporting LLDP, there is an LLDP agent that transmits periodically information about itself and constantly receives information from neighboring devices. This happens independently and, therefore, LLDP is called a "one-way-protocol" which does not establish communication to other protocols.

Information received via LLDP-DUs (Data Units) is stored locally on every device in a data structure called Management Information Base (MIB). SNMP can be used to access this information.

LLDP messages are transmitted in a Layer-2 Frame (OSI) to the multicast address "01:80:C2:00:00:0E".

MAC
Media Access Control

Media Access Control is an extension of the Open Systems Interconnection Reference Model (OSI model) developed by the Institute of Electrical and Electronics Engineers (IEEE). IEEE divided the second lowest of the seven layers of the OSI model into the Media Access Control and Logical Link Control sublayers, MAC being the lower layer of the two.

The OSI model arranges hardware and software parts required in computer network into a total of seven layers with increasing complexity. The higher a layer, the less it is interested in the technical process of data transmission and the more it deals with the actual data contents. MAC is the second lowest layer and comprises network protocol and components that control how several computers share the physical transmission medium used together. It is required because a common medium cannot be used by several computers at the same time without having data collisions and therefore communication errors or data loss sooner or later. There had been no such a competition about the communication medium in the original OSI model. Therefore, MAC hat not yet been included.

MAC address - Media Access Control

The MAC address (Media Access Control, Ethernet-ID or called Airport-ID with Apple) is the hardware address of every single network adapter used for unique identification of the device in the network.

Each PROFINET device is assigned a worldwide unique device identification when it is manufactured. This 6-byte long device identification is called MAC address.

The MAC address is divided into:

– 3 bytes manufacturer ID
– 3 bytes device ID (consecutive number).

The MAC address is usually printed on the device.

The MAC address belongs to the Data Link Layer, i.e. Layer 2 of the OSI model. With Ethernet, for example, the Address Resolution Protocol is used to connect the Data Link Layer with the Network Layer.

Network devices need a MAC address if they are to be addressed explicitly at Layer 2 to offer services on higher layers. If the device only forwards network packets like a repeater or hub, it is not visible on the Data Link Layer and does not need a MAC address. Although bridges and switches check packets from the Data Link Layer in order to divide the network physically into several collision domains, they do not participate actively in the communication and, therefore, do not need MAC addresses.

A switch only needs MAC address if it is managed or offers monitoring services (e.g., via Telnet, SNMP o HTTP). Bridges us the MAC address for the Spanning Tree algorithm.

PDev
Physical Device Object

The Physical Device Object (PDev) represents the hardware of a device. There is exactly one PDev for an IO controller during runtime. PDev is accessible over the IP address of the device and is the first place for other applications for navigation through the device.

PHY

PHY is a special semi-conductor component or a functional groups of a circuit that is responsible for coding and decoding of data between a purely digital and a modulated system. PHY means physical interface. A PHY semiconductor is usually used in Ethernet devices. It is used for digital access (processor) to the modular operated channel (Ethernet).

PTCP - Precision Transparent Clock Protocol

According to IEC 61158, the Precision Transparent Clock Protocol (PTCP) is a method for exact time synchronization and is used with PROFINET IRT.

Synchronization takes place in increments which means that a clock master (usually the IO controller) determines the common clock and sends "Sync-Frames" for synchronization. The other IRT IO devices synchronize their local clock to this master clock. A clock master sends a synchronization frame to all clock slaves involved.

It is necessary to determine the "line delay" between neighboring devices and the actual synchronization to synchronized the devices to a common clock.

RARP - Reverse Address Resolution Protocol

The Reverse Address Resolution Protocol (RARP) enables assignment of hardware addresses to Internet addresses. It is part of the Network Layer of the TCP/IP protocol range. RARP is used when the IP address of a computer is unknown.

RSTP - Rapid Spanning Tree Protocol

The Rapid Spanning Tree Protocol (RSTP) is commonly used even outside of PROFINET applications. It does not provide guaranteed switch-over times. But it supports complex network structures far beyond simple ring structures.

Only a single corrupted Spanning Tree frame can cause a reorganization and disable the entire network for 30 seconds or more. To avoid this scenario, the downward-compatible RSTP, also called Fast Spanning Tree, was developed under IEEE 802.1w. In the event of a connection failure, the existing network structure will be used further until an alternative path has been calculated. Then a new logical tree is created and afterwards the switch-over takes place within a second.

Since 2004 efforts are made to translate RSTP to IEEE 802.1d. There have been further improvements, for instance the support of up to 160 switches and reconfiguration times of < 500 ms.

RT - Real Time Protocol

The Real Time Protocol (RT) is used for PROFINET IO applications with a cycle time of more than 10 ms.

Slot

A slot describes the structure of the components or functions, for example, hardware modules or logical units within a PROFINET IO device. A slot may have several subslots.

SNMP - Simple Network Management Protocol

The Simple Network Management Protocol (SNMP) is a network protocol that was developed for monitoring and controlling network elements (e.g. routers, servers, switches, printers, computers, etc.) from a central station. The protocol controls communication between the monitored devices and the monitoring station. SNMP describes both the structure of the data packets that can be sent and the communication sequence. SNMP was designed in such a way that each network-capable device can be monitored. SNMP enables the following network management tasks:

– Monitoring of network components
– Remote control and remote configuration of network components
– Error detection and error notification

STP - Spanning Tree Protocol

The Spanning Tree Protocol (STP) is commonly used even outside of PROFINET applications. It does not provide guaranteed switch-over times. But it supports complex network structures far beyond simple ring structures.

The Spanning Tree Protocol is specified for the MAC layer in the IEEE 802.1d standard. It should prevent double frames in a switched Ethernet network. Double frames occur when there are two or more parallel connections between two switches. Frames that arrive more than once at the receiver may cause errors. Spanning Tree spans the physical network to a logical tree in which there is only one single path to every destination. In a network the switches or bridges communicate with the help of BPDUs (Bridge Protocol Data Unit). These configuration packets are sent as multi-cast frames to MAC address 01-80-C2-00-00-10. Every two seconds, these frames are transferred to the next lower station (bridge or switch). In this way, parallel paths will be detected and the optimum path be determined. This is referred to as priority or path cost that take data rate and distance into account. Ports with non-preferred paths will be deactivated. If the preferred path fails, no BPDU frame arrives and this leads to a network reorganization. When there are complex nestings, the Spanning Tree is recalculated which can cause a delay of up to 30 seconds or more. Only then can transmission continue on the redundant path.

Subnet mask

The subnet mask specifies which part of the IP address is used as the subnet address. Example: In a Class A network (subnet mask 255.0.0.0) the first field is the IP address of the subnetwork. The IP address is 207.142.2.1, which means the subnet address is 207.0.0.0 and the device address is 142.2.1.

Subslot

A subslot describes the structure of the components or functions, for example, hardware modules or logical units within a slot.

Switch

A switch is a network components that generally routes Ethernet data packets only to those ports on which the destination device is registered. Addresses are evaluated on Layer 2. Switches increase the data throughput and simplify the design of various topologies.

TCP - Transmission Control Protocol

The Transmission Control Protocol (TCP) defines how data is to be exchanged between computers. All operating systems of modern computers know TCP and use it to exchange data with other computers. The protocol is a reliable, connection-oriented transport protocol in computer networks. It is part of the Internet protocol range, the basis of the Internet.

Unlike the connectionless User Datagram Protocol (UDP), TCP creates a virtual channel between two end points of a network connection (sockets). Data can be transmitted in both directions on this channel. In most cases, TCP is based on the Internet protocol. Therefore, it is often referred to as "TCP/IP protocol". It is located in Layer 4 of the OSI reference model.

TCP/IP - Transmission Control Protocol/Internet Protocol

The Transmission Control Protocol/Internet Protocol (TCP/IP) is a network protocol and because it is so important for the Internet it is just called Internet protocol. Protocol structure and integration into the OSI layer model are described in the TCP/IP reference model. Computers are identified with IP addresses.

TCP/IP reference model

Networks are divided into functional levels, also called layers, to classify the communication tasks. The TCP/IP reference model applies for the Internet protocol range. It describes structure and interaction of the network protocols from the Internet protocol range and divides them into four layers built on one other:

TCP/IP layer	OSI layer	Example
Application Layer	5-7	HTTP, FTP, SMTP
Transport Layer	4	TCP, UDP
Network Layer	3	IPv4,IPv6
Network Layer	1-2	Ethernet, token ring, FDDI

TFTP - Trivial File Transfer Protocol

The Trivial File Transfer Protocol (TFTP) is suitable for transmission of complete files. It uses a minimum number of commands and the connectionless UDP protocol as the transmission medium.

**UDP
User Datagram Protocol**

The User Datagram Protocol (UDP) is a minimum, connectionless network protocol, which belongs to the Transport Layer of the Internet protocol range. The task of UDP is to transmit data that is transmitted over the Internet to the right application without securing the transmission process.

Web server function

Device interface for configuration and diagnostics with a standard browser (device homepage).

XML – eXtensible Markup Language

The Extensible Markup Language (XML) is a tagging language for displaying hierarchically structured data in text files. XML is preferably used for data exchange between different IT systems. An XML document consists of letters, in the simplest case ASCII, and is human-readable - it does not include binary data per definition.