PROFINET Network Design
PROFINET is easy!
PROFINET is 100% Ethernet

- Ethernet is the established standard in the IT world for fast exchange of data (IEEE 802.3)
- PROFINET is always full duplex → simultaneous communication in two directions
- PROFINET is always "switched Ethernet" → Distribution of network load can be influenced using topology

As comparison: PROFIBUS

- One line to which all nodes are connected
- Performance directly dependent on number of nodes

PROFINET completely uses all possibilities offered by Ethernet
Mechanisms for real-time communication in PROFINET

Separate channels for IO data and TCP/IP

- Performance and deterministic behavior through priority assignment of I/O data
- Openness for every type of Ethernet communication
  - TCP, UDP, IP, etc.
  - Integration of Ethernet devices in machines and systems (Webcam, network printer, etc.)

Time scheduling

Send cycle

IO data

TCP/IP

Next cycle

Real-time and standard on one cable = totally integrated uniformity
PROFINET technology at a glance: Ethernet

PROFINET is 100% switched Ethernet

PROFINET uses IT standards such as TCP/IP

PROFINET is real-time and deterministic
The Ethernet specification includes layer 1 and 2a of the ISO/OSI reference model.
Basics - 100 Mbps Fast Ethernet

Layer 2
Logical Link Control (LLC)
Ethernet Medium Access Control (MAC)

Layer 1
Physical

100 Base TX
Twisted pair

100 Base T4
Twisted pair

100 Base FX
Fiber-optic

Nomenclature:

<table>
<thead>
<tr>
<th>100</th>
<th>Data rate</th>
<th>100 Mbps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>Signaling</td>
<td>Baseband transmission</td>
</tr>
<tr>
<td>XX</td>
<td>Medium/length</td>
<td>T4 – Twisted pair with 4 wire pairs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TX – Twisted pair with 2 wire pairs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FX – Fiber-optic</td>
</tr>
</tbody>
</table>
Basics - 100 Base TX (Twisted Pair)

According to IEEE 802.3 Clause 25:
Shielded cable with two twisted wire pairs (in other words, 4 wires).
The nodes are connected via a switch that provides a port for each node.
According to IEEE 802.3 Clause 26:
Glass fiber cable for transmission of light/signals.
The nodes are connected via a switch that provides a port for each node.

Fiber-optic cable:
Distance depending on fiber type and network component

Examples:
• 3 km - multimode fiber (62.5/125 or 50/125 µm)
• 26 km - single mode fiber (10/125 or 9/125 µm)
• ...
Basics - 1000 Mbps gigabit Ethernet

Layer 1
- **1000 Base T**: Twisted pair
- **1000 Base CX**: Coax
- **1000 Base SX**: Fiber-optic
- **1000 Base LX**: Fiber-optic

**Layer 2**
- **Logical Link Control (LLC)**
- **Ethernet Medium Access Control (MAC)**

**Nomenclature**:

<table>
<thead>
<tr>
<th>1000</th>
<th>Data rate</th>
<th>1000 Mbps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>Signaling</td>
<td>Baseband transmission</td>
</tr>
</tbody>
</table>
| XX   | Medium/length | T – Twisted pair  
|      |            | C – Coaxial cable  
|      |            | S – Fiber-optic short wave  
|      |            | L – Fiber-optic long wave  |
## Transfer Media - Comparisons

<table>
<thead>
<tr>
<th></th>
<th>Twisted Pair Network</th>
<th>Fibre Optic Network</th>
<th>Wireless Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inter Building Networking</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Suitability for High Transmission Rates</td>
<td>Partly</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Max. Network Expansion</td>
<td>5000m</td>
<td>Upto 150km</td>
<td>1000m/segment</td>
</tr>
<tr>
<td>Max. Distance between Two Network Nodes</td>
<td>100m</td>
<td>50m POF 100 PCF 3000m Multi Mode 15km Single Mode</td>
<td>30m/segment (indoor) 100m/segment (outdoor)</td>
</tr>
<tr>
<td>Max. Connecting Cable Length</td>
<td>100m</td>
<td>50m POF 100 PCF 3000m Multi Mode 15km Single Mode</td>
<td>100m to AP</td>
</tr>
<tr>
<td>Assembly Onsite</td>
<td>Without Special Tool</td>
<td>With Special Tool</td>
<td>Specialist Personnel</td>
</tr>
<tr>
<td>Redundant Network Structures</td>
<td>Electrical Ring</td>
<td>Optical Ring</td>
<td>Use of Different Frequencies (2.4Ghz/5Ghz)</td>
</tr>
</tbody>
</table>
Design of the Industrial Twisted Pair cable
Current Connector Technology (Cu) - RJ45

RJ-XX  Acronym from FCC for Registered Jack

<table>
<thead>
<tr>
<th>Pin (DTE)</th>
<th>Signal (DTE)</th>
<th>PROFINET colour coding on cable connector</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TX+</td>
<td>yellow</td>
</tr>
<tr>
<td>2</td>
<td>TX-</td>
<td>orange</td>
</tr>
<tr>
<td>3</td>
<td>RX+</td>
<td>white</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>RX-</td>
<td>blue</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Current Connector Technology (Cu) - RJ45 Rugged

Industrial Ethernet connector-technology – RJ45 FC (Fast Connect)
- „Nose“ does not break-off…
Design of a Fibre Optic cable

- Hollow core
- Single-core sheath
- Outer sheath
- Optical fiber
- Strain relief using Aramid fibers

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Industry Sector
Industrial Ethernet Cable (FO) Classification

Fibre cross section  
Refractive index profile  
Fibre longitudinal section with typical steel propagation

Core dia.: 100-300µm  
Coating dia.: 200-1000µm  
e.g.: Plastic Optical Fibre (POF)

Core dia.: 50 / 62.5 / 85 / 100µm  
Coating dia.: 125 / 140µm  
e.g.: Glass Multi-Mode

Core dia.: 8-10µm  
Coating dia.: 125-140µm  
e.g.: Glass Mono-Mode
Latest Connector Technology (FO)

**ST Connector (Straight Tip)**
(ST = registered trademark of AT&T)
or
**BFOC Connector (Bayonet Fiber Optic Connector)**

Example: with 100 Base FX

**SC Connector (Subscriber Connector)**

Example: with 1000 Base SX and 1000 Base LX
Latest Connector Technology (FO)

Media Module for modular switches:
2 x 100/1000 Mbit/s SFP slot

SFP Plug (Small Form-factor Pluggable)
Also called „mini-GBIC“.
1 x 1000 Mbit/s LC Port optical

LC Plug (Lusent Connector)
developed from the company Lucent Technologies
Cable Installation (Cu)

**Category I (≥ 10cm from Cat.II and ≥ 20cm from Cat.III):**
- Fieldbus and LAN cables
- Shielded cables for digital data
- Shielded cables for analog and digital signals (≤ 25V)
- Low voltage cables (≤ 60V)

**Category II (≥ 10cm from Cat.I and ≥ 20cm from Cat.III):**
- Cable with DC voltage > 60V and ≤ 400V
- Cable with AC voltage > 25V and ≤ 400V

**Category III (≥ 20cm from Cat.I and Cat.II):**
- Cables with DC and AC voltage > 400V

**Category IV (≥ 50cm from all Categories):**
- All cables from I to III above ➔ Direct danger of lightning strike

**Grounding is the same as PROFIBUS!**

Please see the PROFINET Installation Guideline for more info
The Ethernet specification includes layer 1 and 2a of the ISO/OSI reference model.
Media Access Control (Layer 2a) defines the **formatting of the data (framing)** and the **medium access method**.

**Structure of the MAC frame:**

- **Preamble/SFD:** 8 bytes
- **Destination address:** 6 bytes
- **Source address:** 6 bytes
- **Length or type:** 2 bytes
- **User data:** 46 - 1500 bytes
- **FCS (Frame Check Sequence):** 4 bytes

- **Preamble:** For synchronizing the clock pulses of the station
- **SFD (Start Frame Delimiter):** Start pattern for the beginning of the frame
- **Destination / source address:** Ethernet destination/source address (MAC)
- **Length:** Number of bytes in the data field
- **Type:** Protocol type of the higher-level layer (e.g. IPv4 = 0x0800)
- **User data:** (>46 <= 1500 bytes)
- **FCS (Frame Check Sequence):** CRC checksum
In Ethernet, access to the cable is controlled using the method 
**Carrier Sense Multiple Access/Collision Detection (CSMA/CD)**

Function:

1st step – **CS** Carrier Sense:

2nd step – **MA** Multiple Access:

3rd step – **CD** Collision Detection:
Since the nodes share the medium, Ethernet is known as a **shared network**. Collisions are intended in the CSMA/CD method and therefore a **property** and not an error. Within a collision domain, all nodes share the network performance.
Basics - The ISO/OSI Reference Model

The Ethernet specification includes layer 1 and 2a of the ISO/OSI reference model.
TCP/IP is a network protocol

- **TCP**: Transmission Control Protocol, for secure transport of data
- **IP**: Internet Protocol, to send data across network segments

Most important declaration is the **IP address** e.g. **192.168.0.100**
The basic principle of Ethernet communication

The OSI layer model for structured communication

<table>
<thead>
<tr>
<th>Layer</th>
<th>Services</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 Application</td>
<td>HTTP, FTP, SMTP, SNMP, etc.</td>
<td>TCP header</td>
</tr>
<tr>
<td>6 Presentation</td>
<td>TCP, UDP</td>
<td>Application data</td>
</tr>
<tr>
<td>5 Session</td>
<td>IP</td>
<td>TCP header</td>
</tr>
<tr>
<td>4 Transport</td>
<td>Ethernet, LLDP</td>
<td>Application data</td>
</tr>
<tr>
<td>3 Network</td>
<td>IP</td>
<td>Ethernet header</td>
</tr>
<tr>
<td>2 Data link</td>
<td>Ethernet, LLDP</td>
<td>IP header</td>
</tr>
<tr>
<td>1 Physical</td>
<td>Ethernet, LLDP</td>
<td>TCP header</td>
</tr>
<tr>
<td></td>
<td>PROFINET</td>
<td>Application data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ethernet trailer</td>
</tr>
</tbody>
</table>

Web pages, mails, live pictures, network information, etc.

Maximum performance with retention of Ethernet standards

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Industry Sector
Comparison ➔ „Industry“ to „Office“

<table>
<thead>
<tr>
<th>Location</th>
<th>Industry: Rough environment</th>
<th>Office: Air-conditioned offices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation</td>
<td>Plant commissioning personnel</td>
<td>Network specialists</td>
</tr>
<tr>
<td>Topology</td>
<td>Plant-specific</td>
<td>Star</td>
</tr>
<tr>
<td>Availability</td>
<td>Network downtimes &lt; 300 ms</td>
<td>Second to minute range accepted</td>
</tr>
<tr>
<td>Device density</td>
<td>Low, switches with few ports</td>
<td>High, switches with a large number of ports</td>
</tr>
<tr>
<td>Network monitoring</td>
<td>Part of plant monitoring</td>
<td>By specially-trained person(s)</td>
</tr>
</tbody>
</table>
Open standard in practice

**Implementation in products**
- PROFINET is open for every type of standard Ethernet communication (e.g. TCP/IP)
- See also **Web tools**
- Openness of PROFINET for every manufacturer of automation equipment → large and continuously growing product portfolio
- Simple PROFINET integration using software stack for device manufacturer

**Example applications**
- Access to controllers per Web browser
- Standard Ethernet devices such as PCs for saving measured data and for quality assurance in a machine
- Expansion of an existing infrastructure by additional PROFINET networks
Structure of PROFINET Telegrams

Standardized telegram format according to IEEE 802.3
Ether type according to IEEE for PROFINET real-time telegrams
- 0x0800: IP telegram
- 0x8892: PROFINET real-time telegram

Allocation of the received data via the Frame-ID
- Cyclical transmission (process values) ➔ 8100 C000 hex
- Event triggered transmission (alarms and events) ➔ 8100 A000 hex

Status information

<table>
<thead>
<tr>
<th>Ethernet Frame</th>
<th>Ethernet-Standard</th>
<th>PROFINET specific</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-ambel</td>
<td>7 Byte</td>
<td></td>
</tr>
<tr>
<td>Sync</td>
<td>1 Byte</td>
<td></td>
</tr>
<tr>
<td>Source MAC</td>
<td>6 Byte</td>
<td></td>
</tr>
<tr>
<td>Dest. MAC</td>
<td>6 Byte</td>
<td></td>
</tr>
<tr>
<td>VLAN*</td>
<td>4 Byte</td>
<td></td>
</tr>
<tr>
<td>Ether-type ID</td>
<td>2 Byte</td>
<td>Prozess data up to 1440 Byte</td>
</tr>
<tr>
<td>Status Information</td>
<td>4 Byte</td>
<td></td>
</tr>
<tr>
<td>FCS</td>
<td>4 Byte</td>
<td></td>
</tr>
</tbody>
</table>

* According to 802.1 Q
Flexible topologies / Once cable for all purposes

**Topology based on machine design**
- Smaller cabling overhead and easier commissioning
- Line topology and redundant ring structures possible without additional network components
- Several controllers can be operated in one network → simultaneous access to one device with *Shared Device* and *I-Device*

**The right topology for every machine**
- Support of various topologies such as star, tree, line or ring
- Various media available for networking: Cat5 copper cable, glass and plastic fiber-optic cables, and IWLAN
- Access to machines and plants over a secure VPN connection, e.g. for remote maintenance purposes

Thanks to free selection of the topology, PROFINET enables flexible adaptation of the cabling to the machine or plant design.

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Industry Sector
Media redundancy

High performance with media redundancy
- Increase in plant and machine availability
- Media redundancy is integrated in PROFINET and can easily be utilized without added costs
- Diagnostics for fast troubleshooting also possible with network fault

Media redundancy integrated in PROFINET
- The media redundancy can be implemented both with the help of external switches and direct via integral PROFINET interfaces
- Device failures in the ring topology have no effect on the plant availability
- Troubleshooting is accelerated even with a network fault

High plant availability due to media redundancy
Example of Basic PROFINET Setup
### Overview of Redundancy Reconfiguration Time

<table>
<thead>
<tr>
<th>Downtime:</th>
<th>STP</th>
<th>RSTP</th>
<th>Big network support</th>
<th>MSTP</th>
<th>MRP/ HSR</th>
<th>Link Aggreg.</th>
<th>MRPD</th>
<th>PRP</th>
<th>HSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>seamless</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1ms to 100ms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100ms to 300ms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>300 ms to 10 sec</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 sec to 1 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 1 minute</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**The Future?**

- Not possible
- Possible
- Reliable
MRPD (Media Redundancy Protocol w/ Duplication)

**MRPD** is a PROFINET IO-specific protocol that allows seamless redundant linking of devices.

This is made possible by duplicating the frames and sending them in both directions in a ring structure (ERTEC required).
Parallel Redundancy Protocol (according to IEC 62439-3):

- Duplicate transfer of the frames in two separate networks (LAN A, LAN B)
- Sender end duplicates frames \( \rightarrow \) LAN A and LAN B
- The two LANs can be different (star, ring or tree structure)
- Receiver network access point (switch) forwards the first frame to arrive to the end device.
- The second frame from the second LAN is discarded.
**High-availability Seamless Redundancy** (HSR according to IEC 62439-3):
- Duplicate transfer of the frames **in two directions** in a ring-shaped network.
- Ring entry the switch duplicates via both ring ports.
- Ring exit the switch forwards the first frame to arrive to the addressee.
- Second frame is discarded.
Thank you for your attention!

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