EtherCAT for Factory Networking
EtherCAT Automation Protocol (EAP)
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   - Process Data Structure

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   - Mailbox Data Structure
   - Object Dictionaries
EtherCAT Automation Protocol

- **Factory Level**
  - MES

- **Process Control Level**
  - SCADA
  - Central Computer

- **System / Cell Level**
  - HMI
  - Configuration / Diagnosis
  - WiFi

- **Field Level (Control)**
  - PLC

- **Sensor / Actuator Level**

**EtherCAT Device Protocol** (processed on the fly)
Fieldbus Network Requirements

- **Hard Real-Time**
  - Fast Cycle Times within µs
  - Precise Synchronization

- **Flexible Topology**
  - Line, Tree, Star, Daisy Chain...

- **Standard Ethernet Cabling, Cost Effective Components**

- **Master-Slave & Slave-Slave Communication**

**EtherCAT Device Protocol** (processed on the fly)
**Fieldbus | EtherCAT Device Protocol**

- Well known „EtherCAT“ Protocol
- Used at field level within machines e.g. for I/O, Motion, Measurement, Robotics
- Outstanding Features, e.g.:
  - **Hard Real-Time**
    - Protocol is processed in hardware (ESC)
  - **Fast Cycle Times** (<100µs)
  - **Precise Synchronization** (<100ns)
  - **Flexible Topologies**
  - **Standard Ethernet Cabling, Cost Effective Components**
- **EtherCAT Frame Type = 1**

<table>
<thead>
<tr>
<th>Ethernet Header</th>
<th>Ethernet Data = EtherCAT Frame</th>
<th>FCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dest.</td>
<td>Src.</td>
<td>EtherType</td>
</tr>
<tr>
<td>0x88A4</td>
<td>1</td>
<td>Length</td>
</tr>
</tbody>
</table>

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Factory Network Requirements

EtherCAT Automation Protocol

- Connection to MES
- Configuration/Diagnosis, also Wireless
- Control/Visualization
- Standard Ethernet Infrastructure Components
- Vehicles/Logistics
- Master-Master Communication
Factory Network Requirements

• Constraints:
  – Standard Ethernet interfaces and infrastructure devices
  – Diagnosis and Configuration
  – No strict requirements regarding cycle time and synchronization
  – Cycle time in the range of milliseconds
Factory Network Requirements

- Communication between:
  - EtherCAT Master Devices (Master-Master Communication)
  - EtherCAT Master and Visualization, Configuration Tool (also via Remote Access)

- Access to devices in underlying EtherCAT segments from the control level

- Access from configuration tools:
  - Configuration of the Master-Master communication
  - Configuration of underlying sub-devices (e.g. Drives, Gateways,…)
  - Routing through EtherCAT Master
## Factory Network Requirements | Services

<table>
<thead>
<tr>
<th>Service</th>
<th>Required Mechanism</th>
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</thead>
<tbody>
<tr>
<td>Master-Master Communication</td>
<td>×</td>
</tr>
<tr>
<td>External Configuration and Diagnosis</td>
<td>× × × ×</td>
</tr>
<tr>
<td>Connection to Main Computer / Controller and MES / ERP Systems</td>
<td>× ×</td>
</tr>
<tr>
<td>Connection to Visualization including Status and Monitoring</td>
<td>× ×</td>
</tr>
</tbody>
</table>

**Abbreviations:**
- **PD**: Process Data Communication (cyclic)
- **MBX**: Mailbox Communication (acyclic)
- **R**: Routing
- **OD**: Object Dictionary
EtherCAT Automation Protocol

✔ EtherCAT Automation Protocol (EAP) achieves all these requirements

✔ EAP is an enhancement of the EtherCAT technology

IEC61158, Part 12:
EtherCAT Specification

ETG.1005:
EAP Specification

• Protocols
• Frame Structure
• Configuration Structure
• Network Management Functions

✔ EAP offers services for communication at control level and thus for complete factory networking
EAP | Example Application

Je Verbindung: 10 ms cycle
IN 1kByte
OUT 1kByte

10 ms cycle
to Controller and all Stations

Ethernet Connection
EtherCAT Segment
EtherCAT Automation Protocol
OPC

IN 600 Byte
OUT 600 Byte

Stations-Master
Einschleusen
Prozess-Kammer
Ausschleusen

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### EAP | Protocol Transmission

#### Flexible Protocol Transmission:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>EtherType</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ECAT</td>
<td>Dest</td>
<td>Src</td>
<td>0x88A4</td>
</tr>
<tr>
<td>2</td>
<td>UDP</td>
<td>Dest</td>
<td>Src</td>
<td>0x800</td>
</tr>
<tr>
<td>3</td>
<td>TCP</td>
<td>Dest</td>
<td>Src</td>
<td>0x800</td>
</tr>
</tbody>
</table>

- **Type 1** EtherCAT Device Protocol
- **Type 4** EAP Process Data
- **Type 5** EAP Mailbox Data

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- **Standard** EtherCAT Frame Header
- **Standard** Frame Structure
EAP | Process Data Communication

- EAP Process Data communication is used for cyclic data exchange

- An EtherCAT Master can publish information and can receive information from other Master devices

- Two transfer modes
  - Pushed Data Exchange (Broadcast)
  - Polled Data Exchange
Process Data | Pushed Data Exchange

- **Pushed Data Exchange (Broadcast)**
  - each node can send information with its own cycle
  - all nodes are able to receive information from each other
Process Data | Polled Data Exchange

- **Polled Data Exchange (1:1 Connection)**
  - One device sends cyclically its information (Client)
  - Each addressed device (Server) responses with its telegram

![Diagram of Polled Data Exchange](image)

Machine A

Machine B

Machine C
Process Data | Polled Data Exchange

- **Polled Data Exchange (1:n Connection)**
  - One device sends cyclically its information (Client)
  - One or many devices (Server) response with their telegram
  - Soft Synchronization of devices
**Process Data | Frame Structure**

- EtherCAT Header: *EtherCAT Frame Type* = 4
- *Telegram* consists of one or several *Process Data*
- *Process Data* consist of one or several *PDOs*
- *Publisher ID* = AoE NetID of Publisher
- Each *PDO* consists of one or several *Variables*
- *Variable ID* identifies Process Data → Connectionless
- Cyclic Frames are *configured in advance*
EAP | Mailbox Communication

- EAP Mailbox Communication is used for asynchronous access to the devices
  - Configuration of Process Data
  - Configuration of Device Specific Parameters
  - Diagnosis Information of EtherCAT Slaves

- Standard Mailbox Protocol in Ethernet telegram (Type: 0x88A4) or UDP/TCP Telegram
Mailbox Data | Frame Structure

- EtherCAT Header: *EtherCAT Frame Type* = 5
  - Indicates mailbox communication
- Telegram consists of a *Mailbox Header* and *Mailbox (Protocol) Data*
- For EAP: *Mailbox Header Type* = 1 (AoE)
  - Routable protocol to access several object dictionaries
  - *AoE Header Type*: Mapping of other Mailbox protocols possible

```
Ethernet / UDP / TCP | Length | 5 | Mailbox | CRC
```

```
<table>
<thead>
<tr>
<th>Mailbox Header</th>
<th>AoE Header</th>
<th>Mailbox Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>AoE</td>
<td>Mailbox Data</td>
</tr>
<tr>
<td>Type 3</td>
<td>CoE</td>
<td>Mailbox Data</td>
</tr>
<tr>
<td>Type 4</td>
<td>FoE</td>
<td>Mailbox Data</td>
</tr>
<tr>
<td>Type 5</td>
<td>SoE</td>
<td>Mailbox Data</td>
</tr>
</tbody>
</table>
```
Object Dictionaries within EtherCAT Master for Configuration and Routing

- Configuration of EAP
  - Process Data
- Address Information of available Ethernet Ports:
  - IP Addresses, AoE NetID
- Information about EtherCAT Segment
- Ethernet Port 1
  - EAP
    - IP Address
    - AoE Address
    - Object Dictionary Type 1000
  - EtherCAT Router Information
    - AoE Address
    - Object Dictionary Type 9000
  - EtherCAT Master
    - Optional: IP
    - AoE Address
    - Object Dictionary Type 1100
- Ethernet Port 2
  - EtherCAT Master
    - Object Dictionary Type 1100
- Ethernet Port x
  - EAP
    - Object Dictionary Type 1000
- Ethernet Port y
  - EtherCAT Master
    - Object Dictionary Type 1100

EtherCAT for Factory Networking
Access to EtherCAT Slave

1. AoE NetID of EAP Device → AoE Router Information
   - EAP
     - IP Address
     - AoE Address
     - Object Dictionary Type 1000

2. AoE NetID of EtherCAT Masters → List of EtherCAT Slaves
   - EtherCAT Router Information
     - AoE Address
     - Object Dictionary Type 9000

3. e.g. CoE Access via AoE to Slave
   - EtherCAT Master
     - Optional: IP AoE Address
     - Object Dictionary Type 1100
Conclusion of EAP

- Master-Master Communication
- Remote Configuration / Diagnosis
- Exchange of Process Data and Parameter Data
- Routing to any device connected
- Easy vertical integration
- Integration of wireless device
- Data Structure equal to EtherCAT Device Protocol
- IP Addresses only for Control Level – not for Fieldbus Level

→ EtherCAT is factory networking!
Please visit

www.ethercat.org

for more information

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