



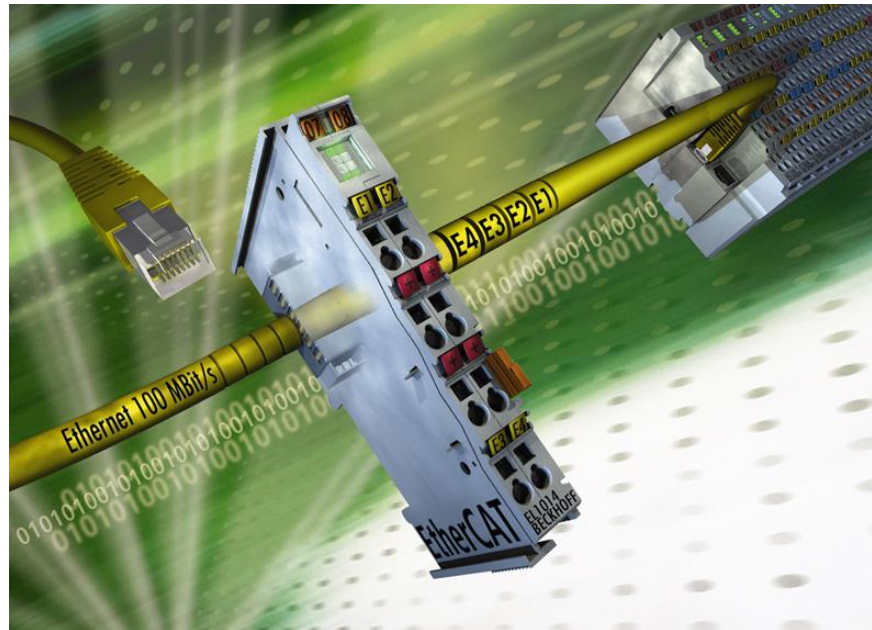
# EtherCAT<sup>®</sup>

The Ethernet Fieldbus.

**EtherCAT is:**

- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

- EtherCAT is real time down to the I/O level
- No underlying sub-systems any more

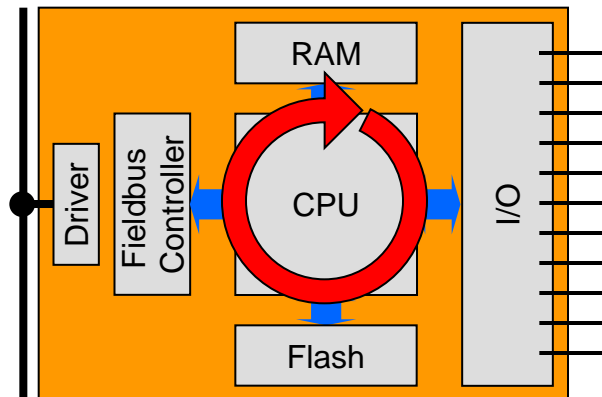
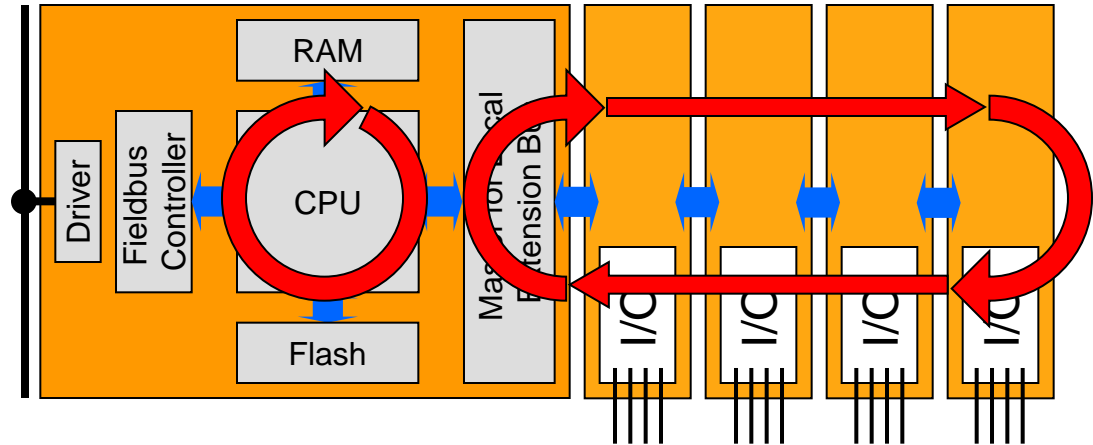


# EtherCAT - The Ethernet Fieldbus.

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- Other technologies need local I/O cycles + gateways

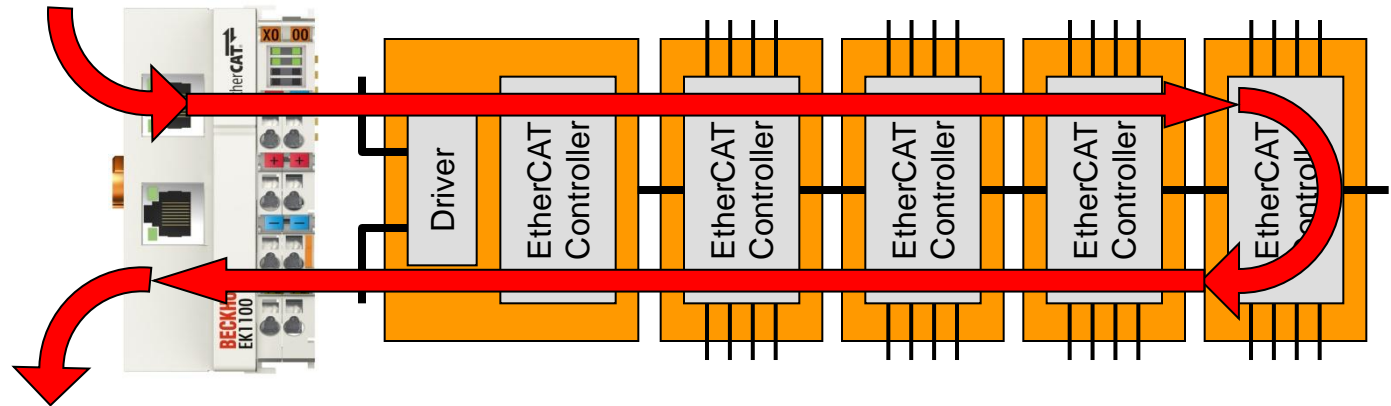


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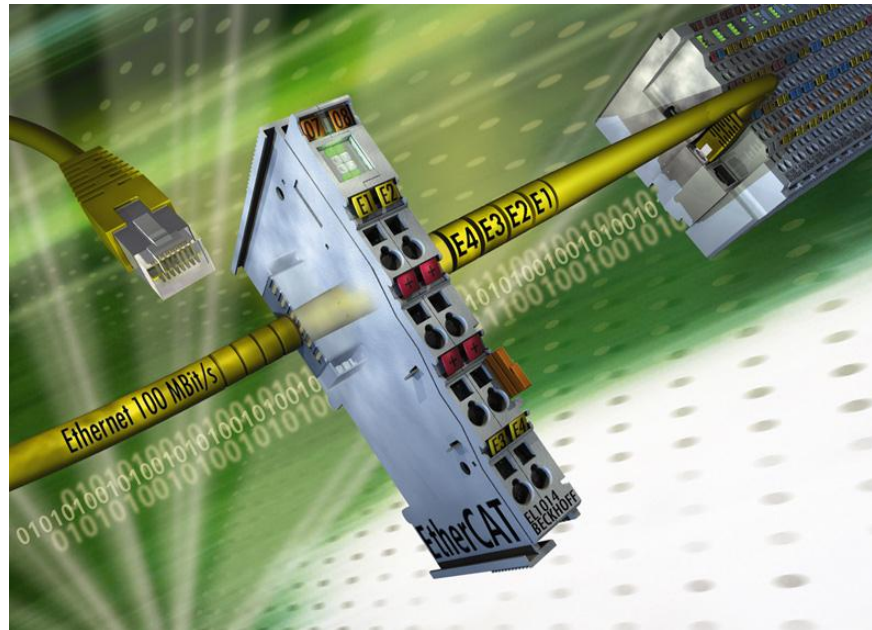
- EtherCAT: Real time down to the I/O



## EtherCAT is:

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- EtherCAT is real time down to the I/O level
- No underlying sub-systems any more
- No delays in gateways
- In- and outputs, sensors, actuators, drives, displays:  
**everything in one system!**



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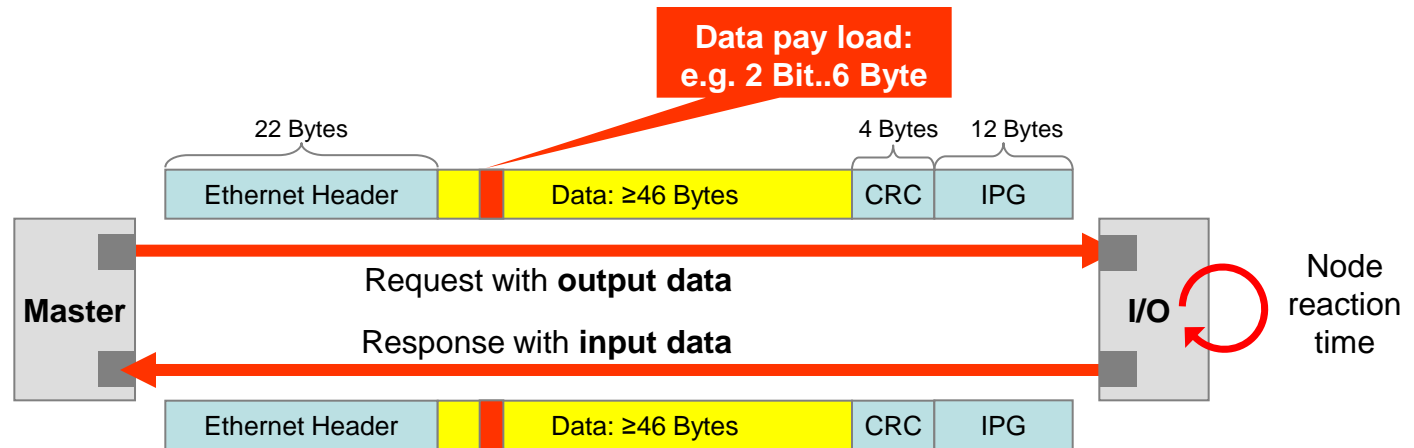
- Transmission Rate:
  - 2 x 100 Mbit/s (Fast Ethernet, Full-Duplex)
- Update Times:
  - 256 digital I/O in 11  $\mu$ s
  - **1000 digital I/O distributed to 100 nodes in 30  $\mu$ s = 0.03 ms**
  - 200 analog I/O (16 bit) in 50  $\mu$ s, 20 kHz Sampling Rate
  - **100 Servo-Axis (each 8 Byte In + Out) in 100  $\mu$ s = 0.1 ms**
  - 12000 digital I/O in 350  $\mu$ s

# EtherCAT is faster

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- Bandwidth Usage of Ethernet for I/O and Drives:
  - Ethernet Frame:  $\geq 84$  Bytes  
incl. Preamble + IPG (interpacket gap)

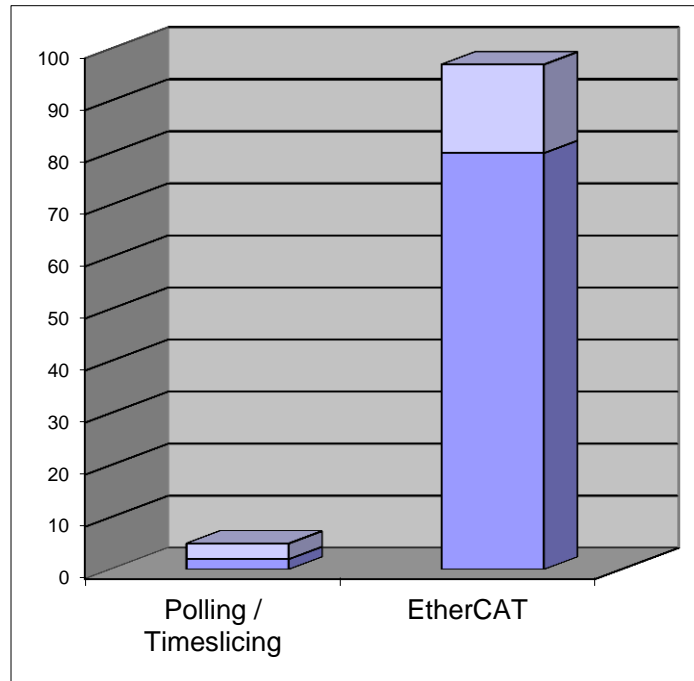


- with 4 Byte input + 4 Byte output per node:
  - **4,75%** application data ratio at **0  $\mu$ s** reaction time/node
  - **1,9%** application data ratio at **10  $\mu$ s** reaction time/node

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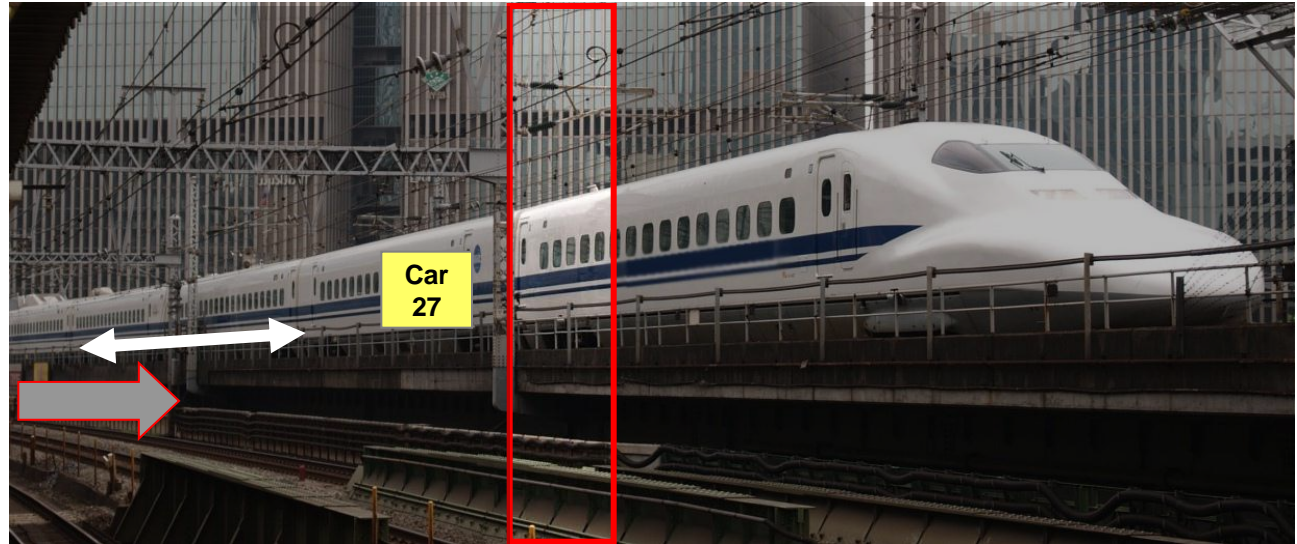
- Bandwidth Usage Comparison:
  - At 4 Byte user data per node:
    - Polling / Timeslicing: ~ 2..5 %
  - From 2 Bit user data per node:
    - **EtherCAT: ~ 80..97 % (Full Duplex, 2 x 100 MBit/s)**





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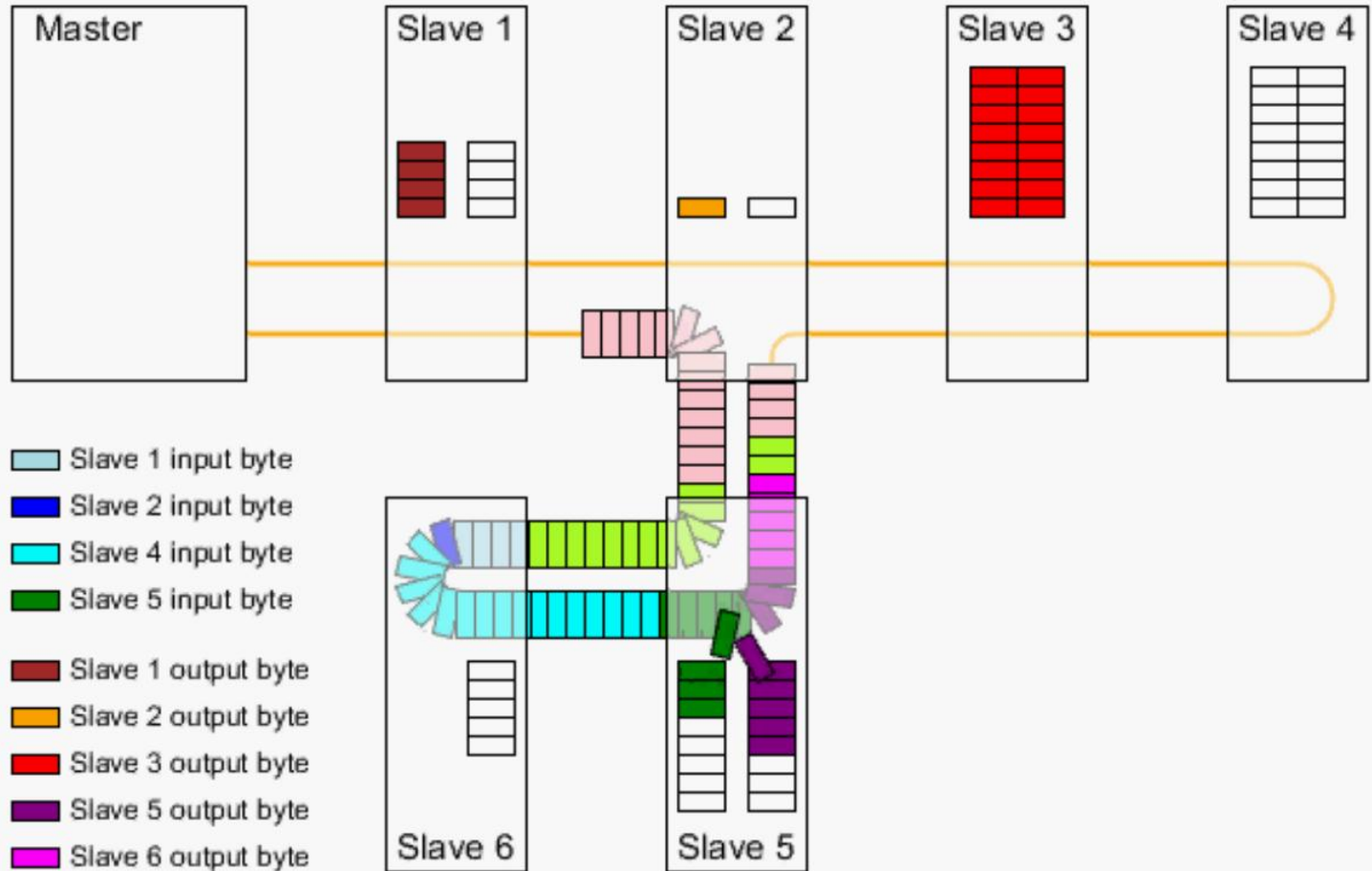


- Analogy Fast Train:
  - “Train” (Ethernet Frame) does not stop
  - Even when watching “Train” through narrow window one sees the entire “Train”
  - “Car” (Sub-Telegram) has variable length
  - One can “extract” or “insert” single “persons” (Bits) or entire “groups” (Bytes) – even multiple groups per train

# Functional Principle: Ethernet “on the Fly”

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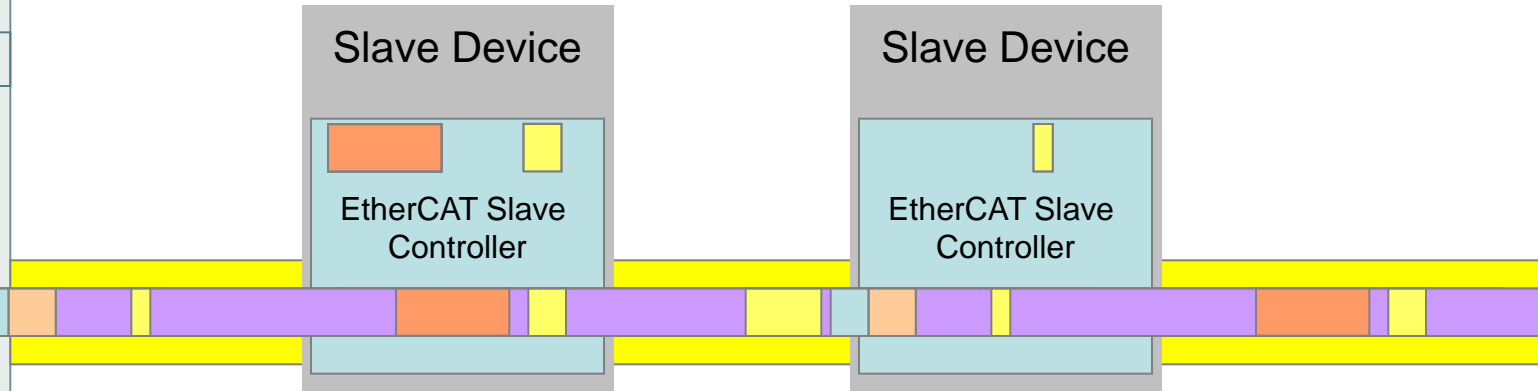


- Efficient: Typically only one Ethernet Frame per Cycle
- Ideal Bandwidth Utilization for maximum Performance

# Functional Principle: Ethernet „on the fly“

## EtherCAT is:

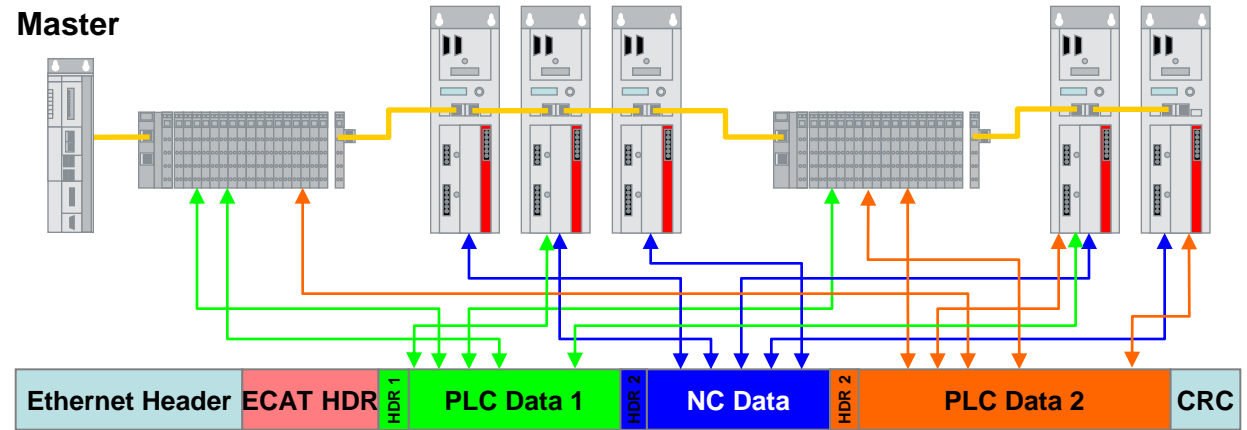
- Faster
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- Process data is extracted and inserted on the fly:
  - Process data size per slave almost unlimited (1 Bit...60 Kbyte, if needed using several frames)
  - Compilation of process data can change in each cycle, e.g. ultra short cycle time for axis, and longer cycles for I/O update possible
  - in addition asynchronous, event triggered communication

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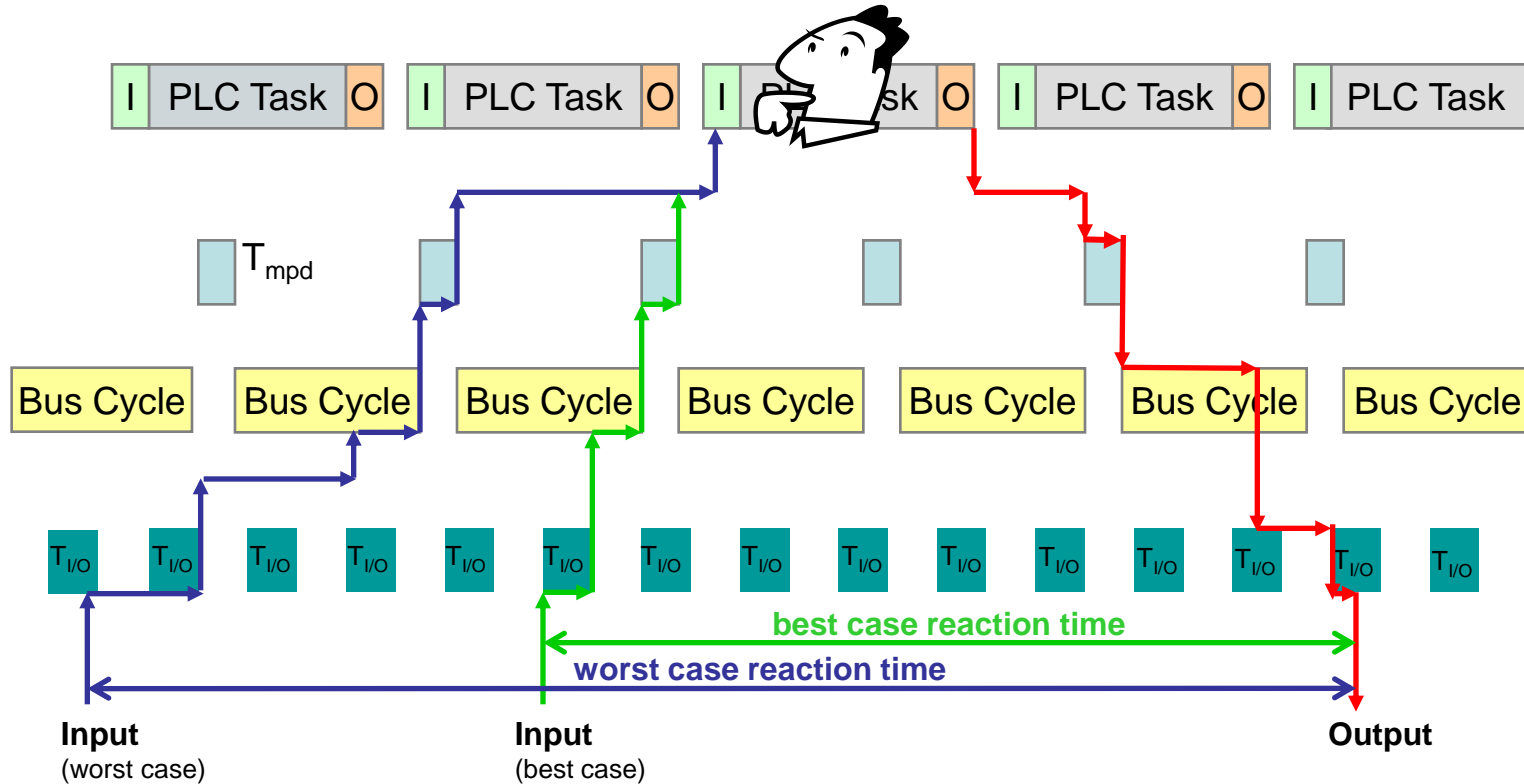
- Minimal protocol overhead via implicit addressing
  - Optimized telegram structure for decentralized I/O
  - Communication completely in hardware: maximum (+ predictable!) performance
  - No switches needed if only EtherCAT devices in the network
  - Outstanding diagnostic features
  - Ethernet-compatibility maintained

# 'Slow' Control Systems benefit, too

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## Reaction time with legacy fieldbus I/O:



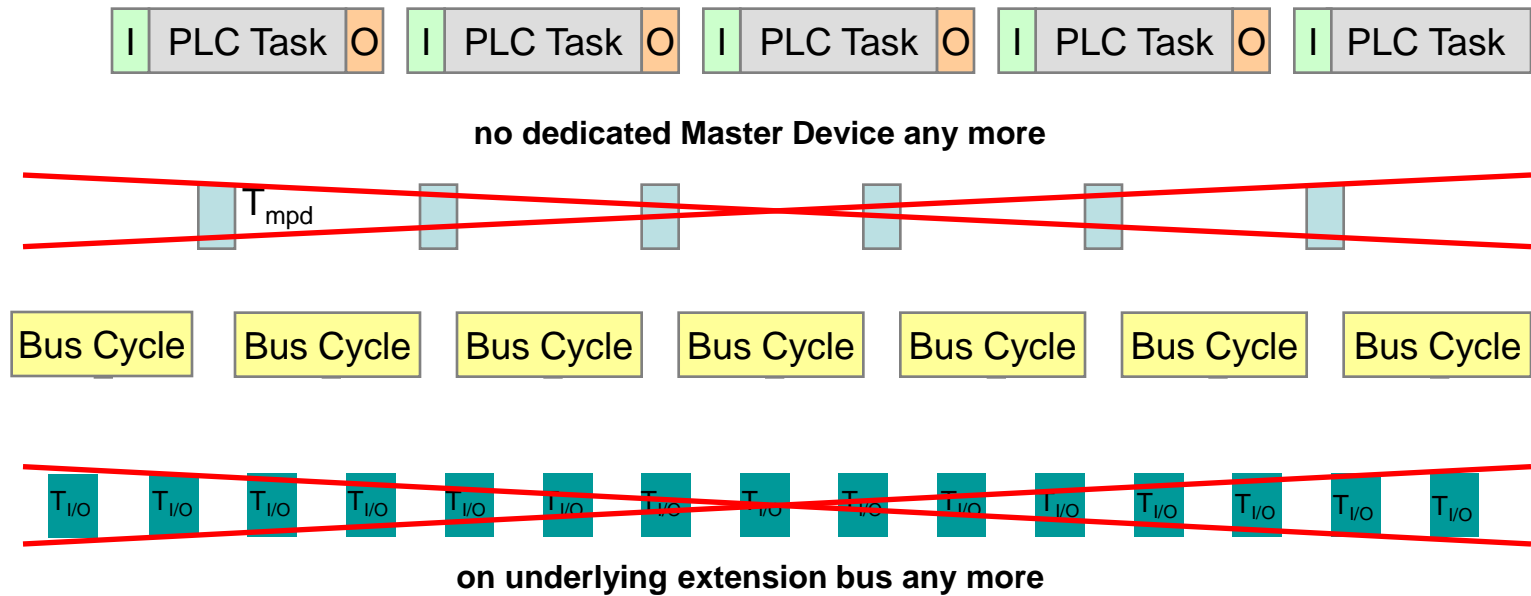
$T_{mpd}$ : Master Processing Delay  
 $T_{I/O}$ : Local I/O Update Time  
 (local Extension Bus + Firmware)

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## System Architecture with EtherCAT:

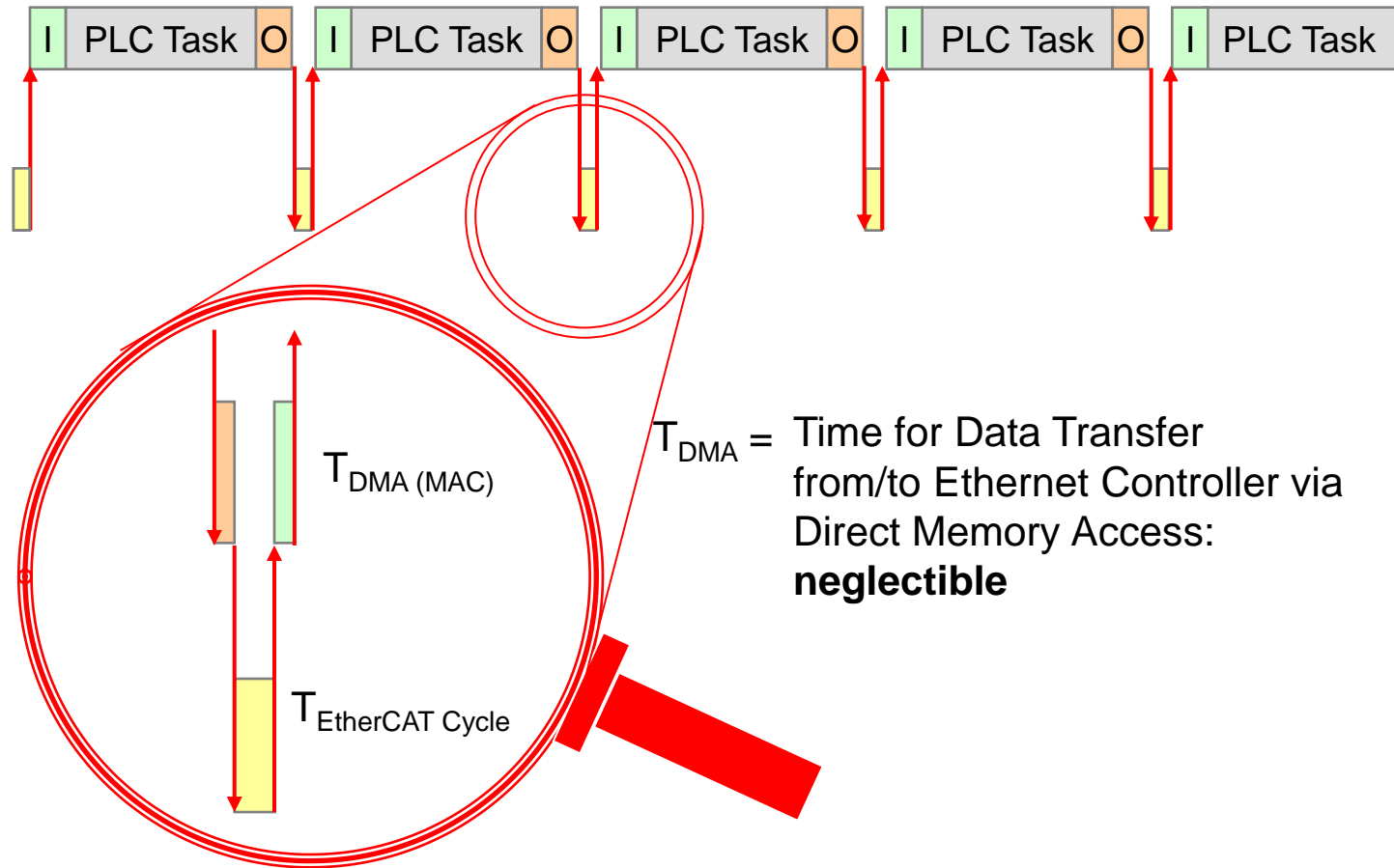


# 'Slow' Control Systems benefit, too

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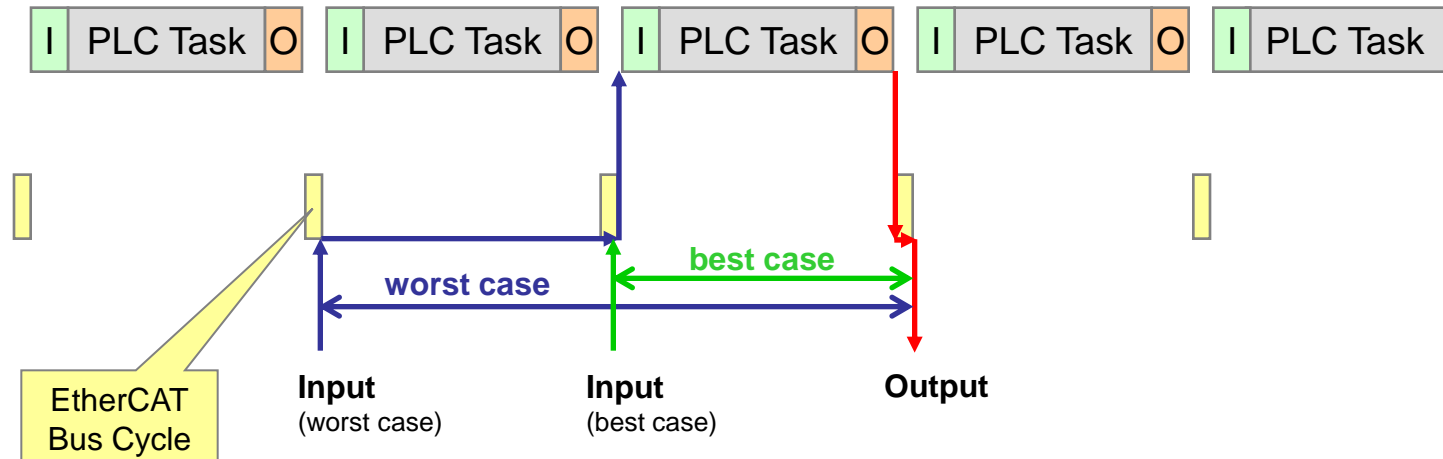


# 'Slow' Control Systems benefit, too

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## Reaction Time with EtherCAT:



- Reaction time reduced significantly with the same controller performance
- no underlying local I/O cycles and extension bus delays any more
- Due to the very simple protocol no dedicated master systems (e.g. plug-in cards) required

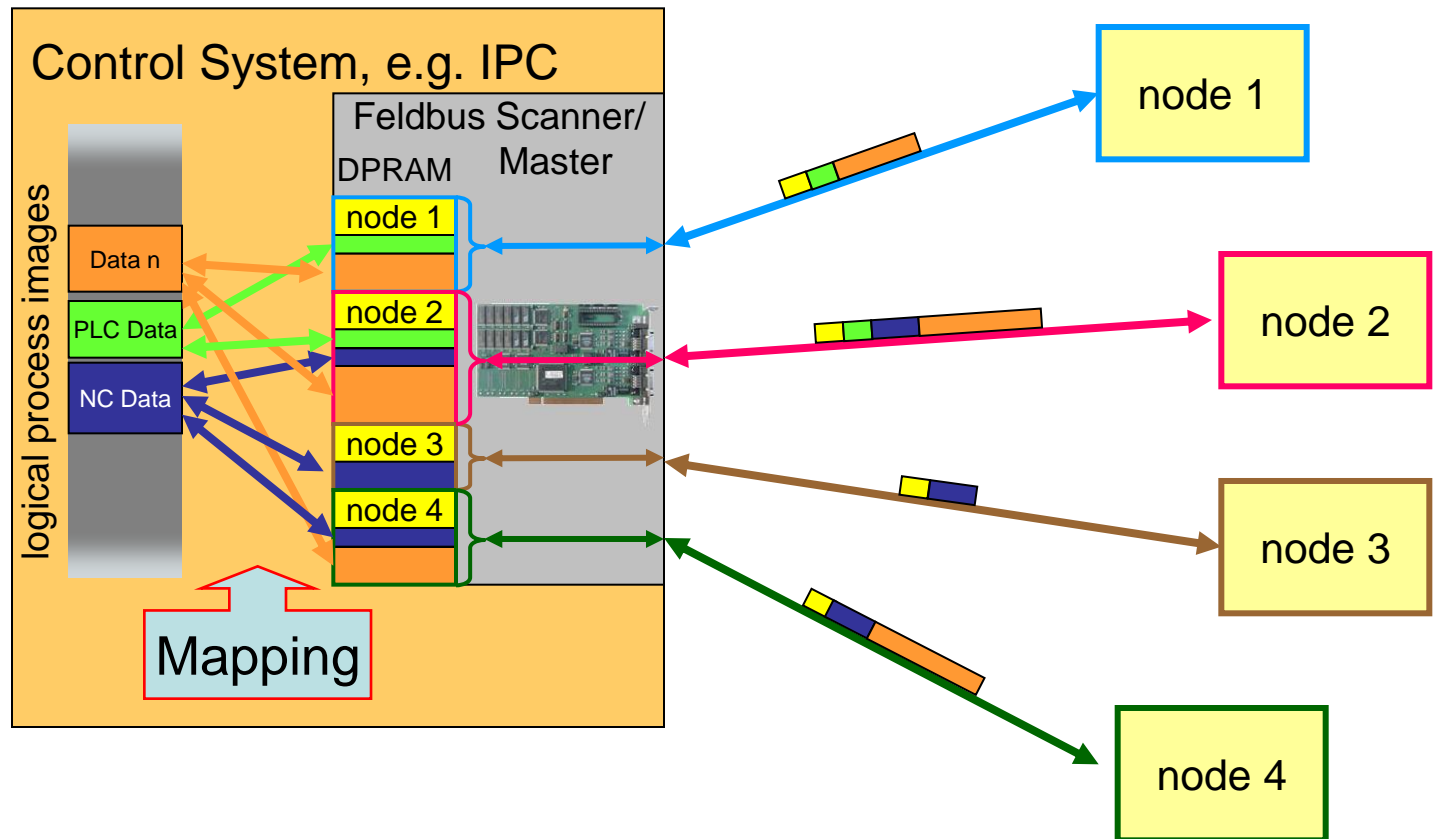


# Fieldbus: requires Mapping in Control System

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- Traditional fieldbus system generate *physical* process image
- This has to be mapped to *logical* process image(s)

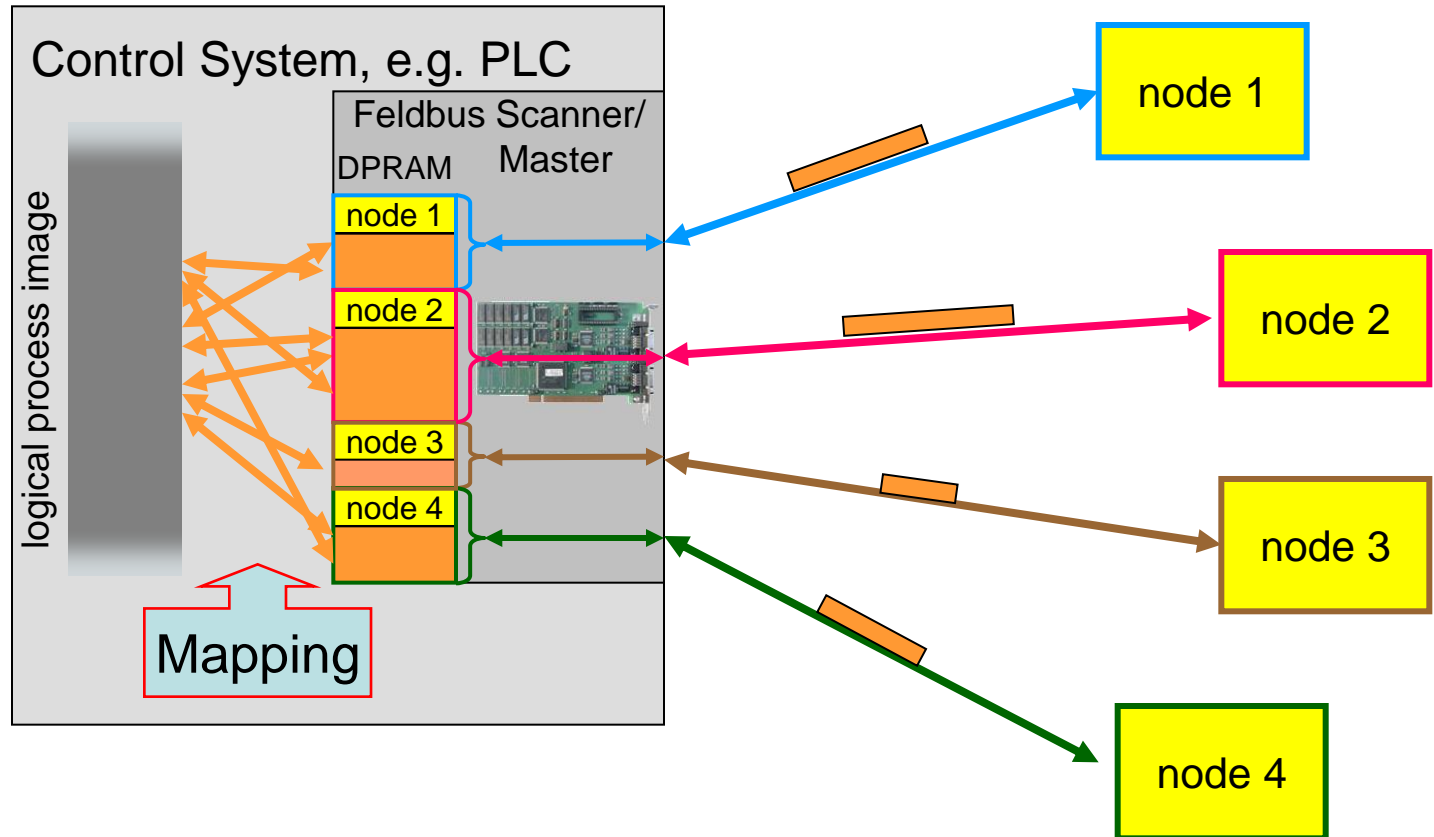


# Fieldbus: requires Mapping in Control System

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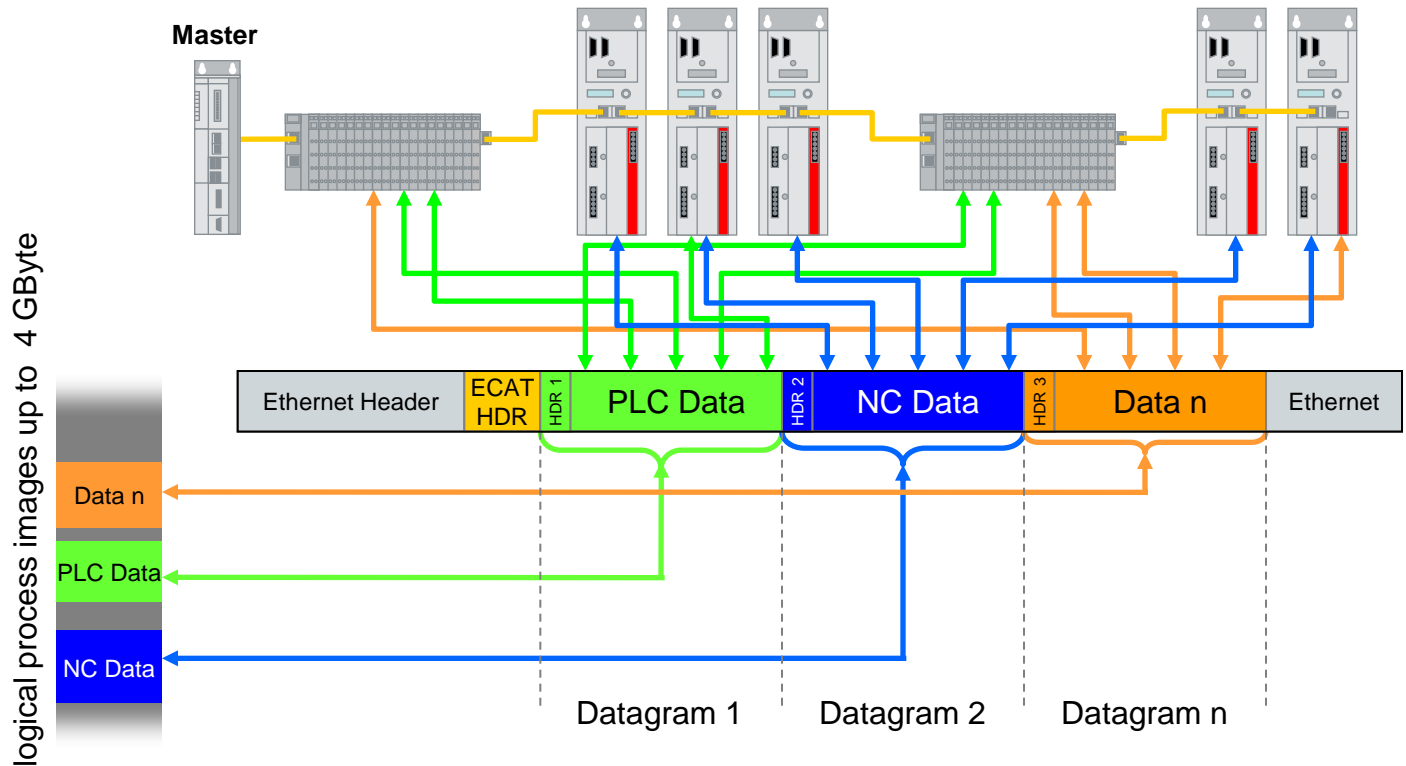
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- The same applies to system with just one process image
- Resorting of process data (“Mapping”) is required, too



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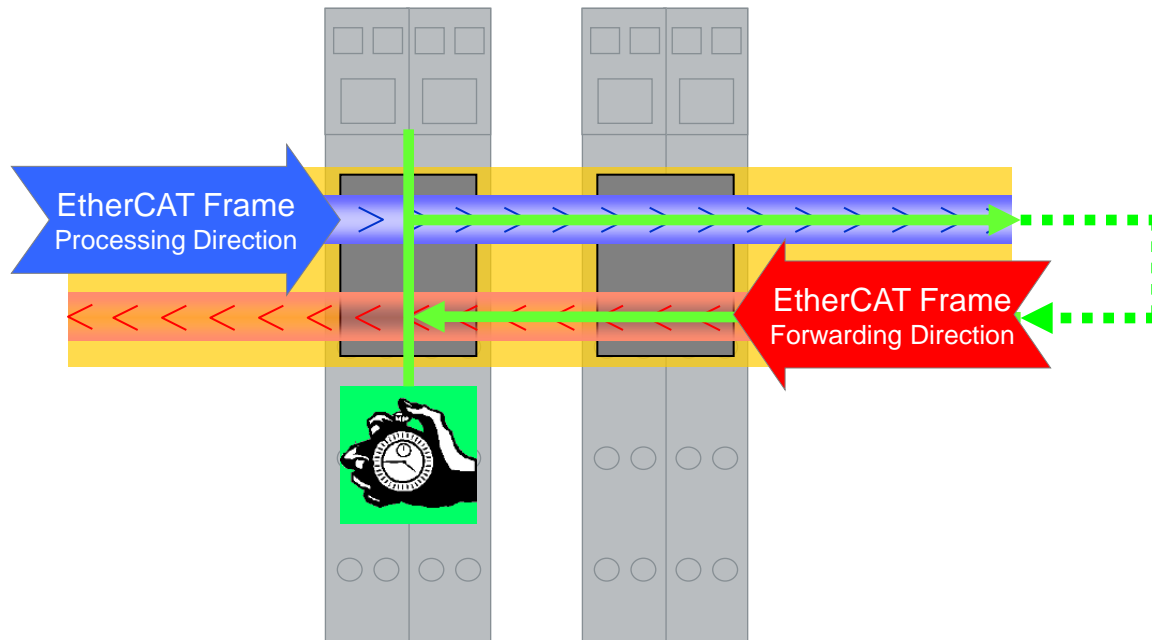


- Control System is unburdened, master becomes very simple
- Data is transmitted according to the application requirements: extremely fast, flexibly and efficiently

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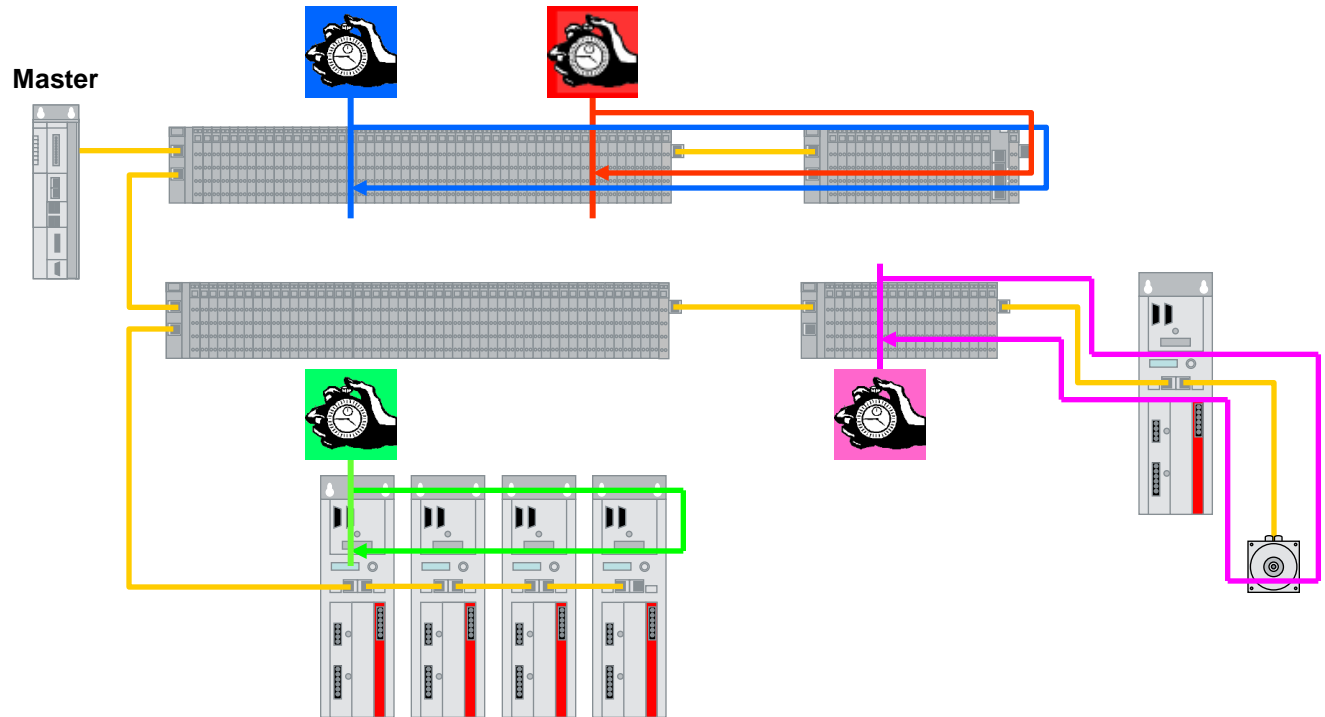
- EtherCAT Node measures time difference between leaving and returning frame



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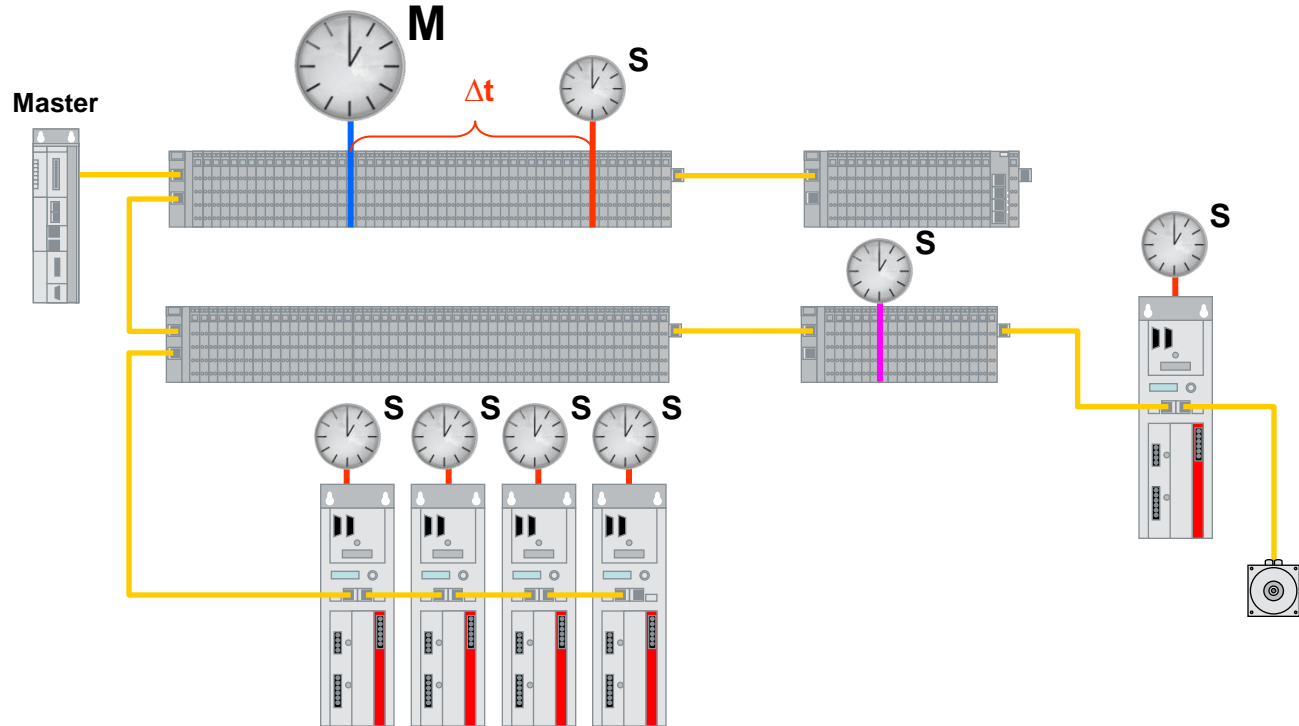


# Distributed Clocks

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- Precise Synchronization ( $\ll 1 \mu\text{s}$ !) by exact adjustment of Distributed Clocks

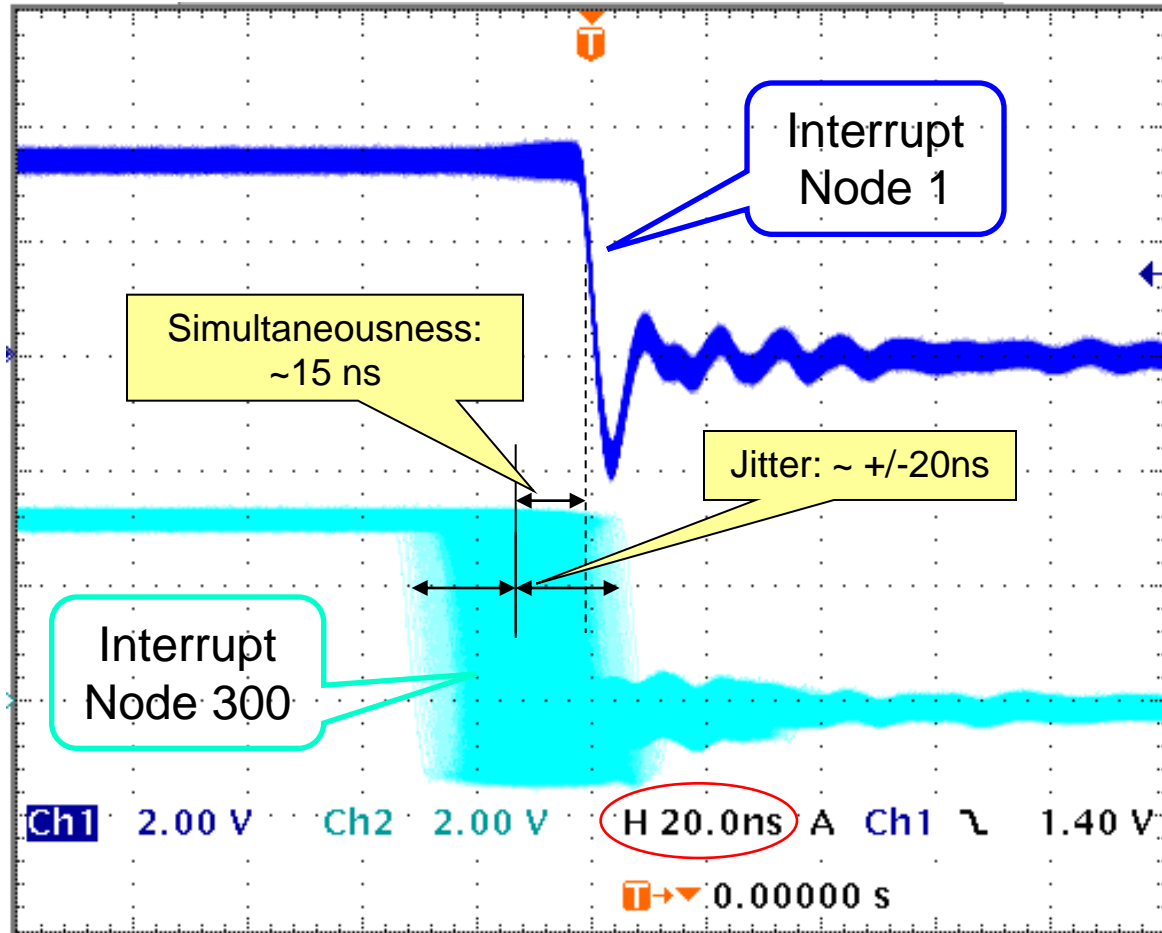


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- Long Term Scope View of two separated devices
- 300 Nodes in between, 120m Cable Length

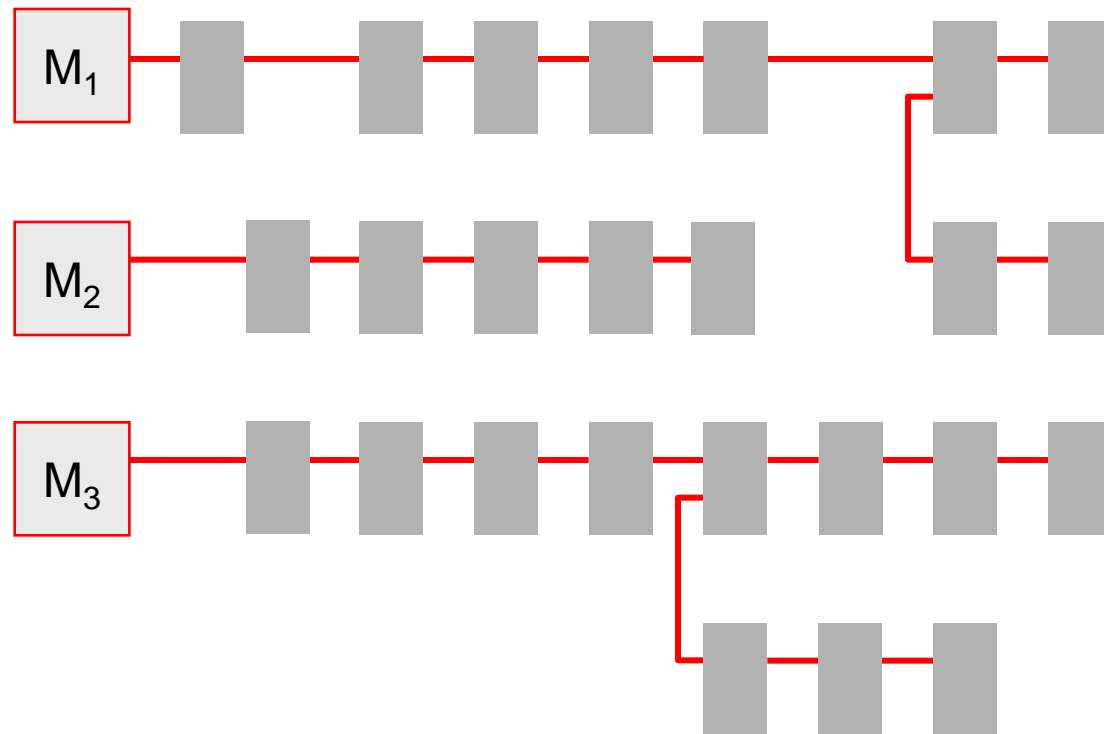


# Synchronization of multiple Networks

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- EtherCAT networks can be coupled via EtherCAT Bridge
- Bridge provides hardware synchronization of several networks



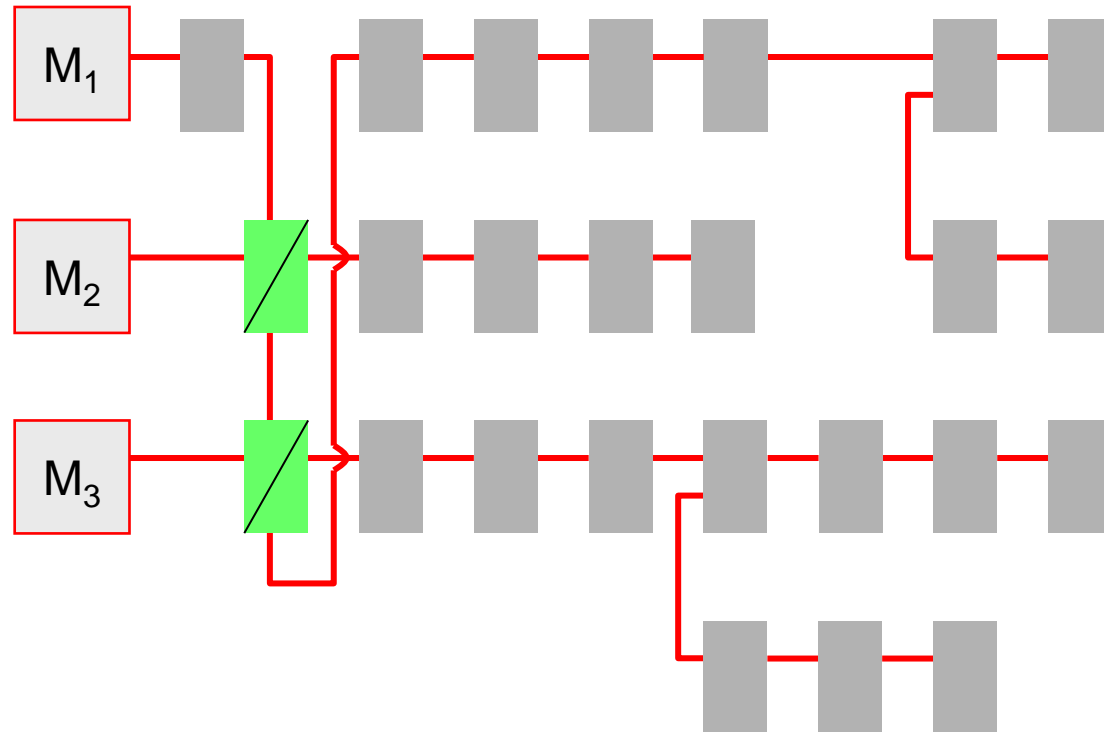


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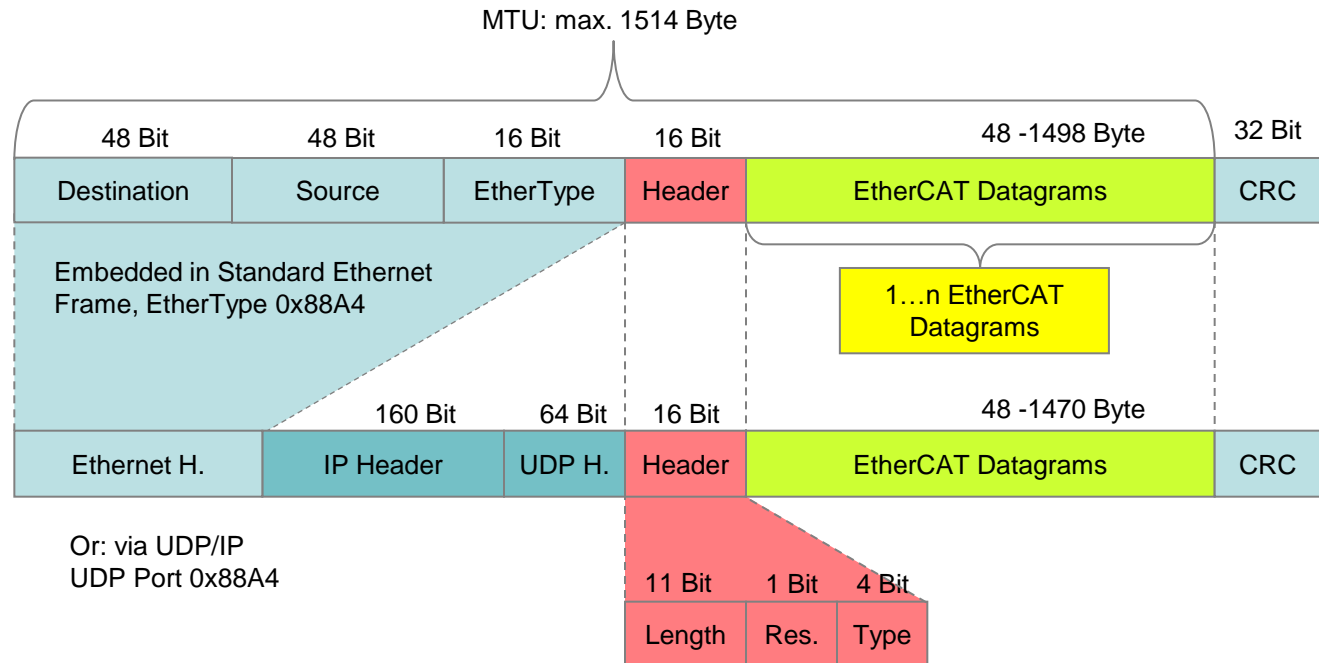


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- EtherCAT uses Standard Ethernet Frames: IEEE 802.3
- Alternatively via UDP/IP (if IP Routing is needed)
- no shortened frames

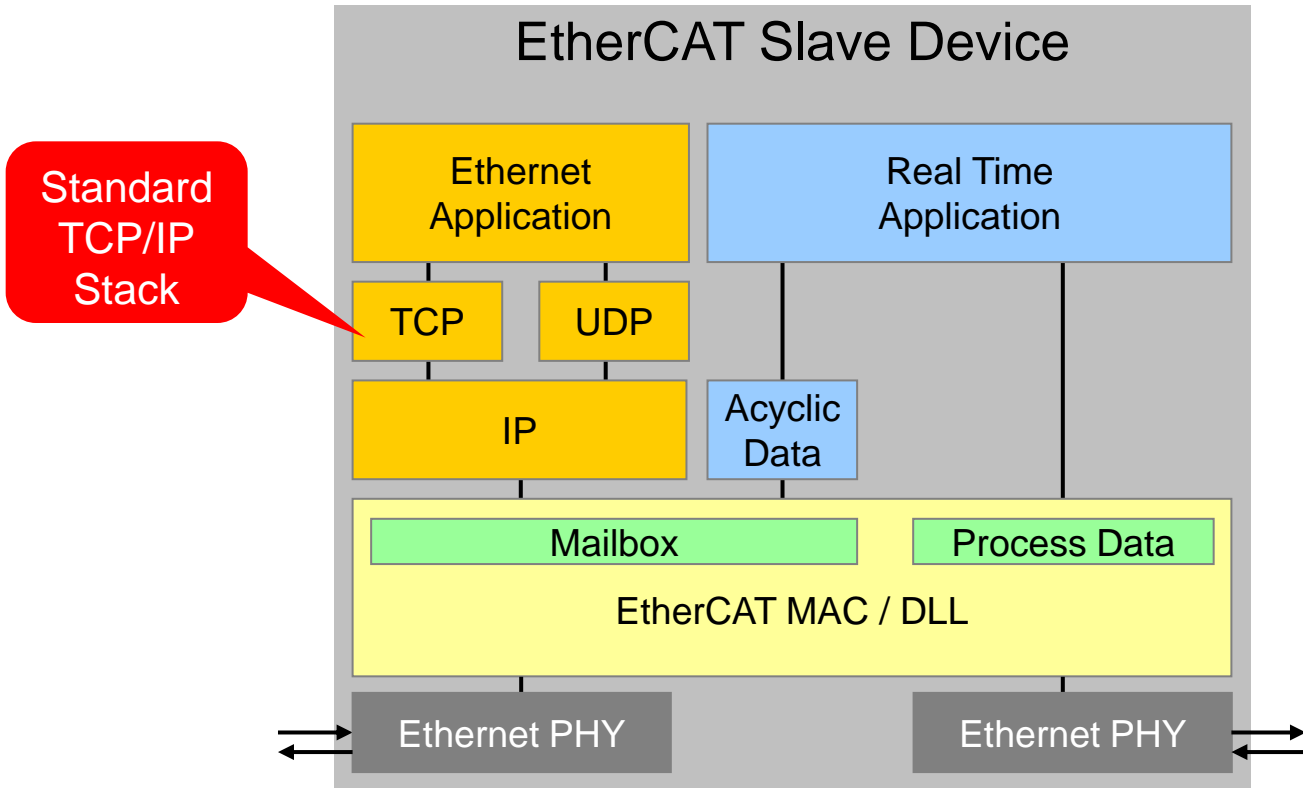


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- fully transparent for TCP/IP
- all Internet technologies (HTTP, FTP, Webserver,...) available without restricting the real time capabilities!



# EtherCAT is Industrial Ethernet!

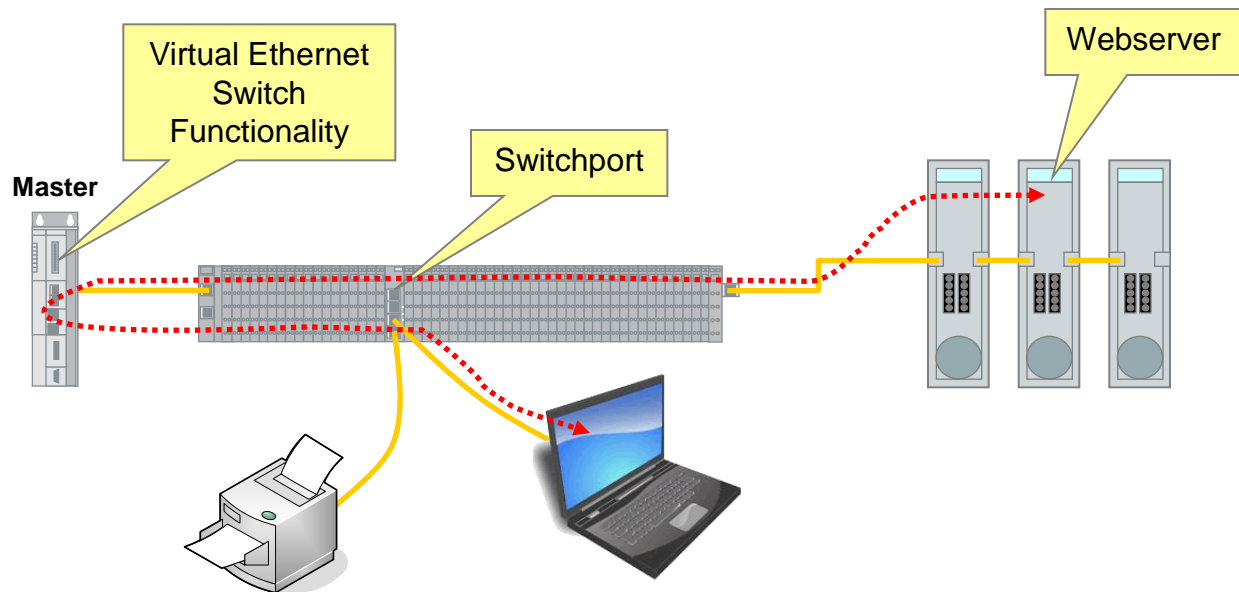
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- Any Ethernet Device can be connected to Switchport
- Access to Webserver with Standard Browser

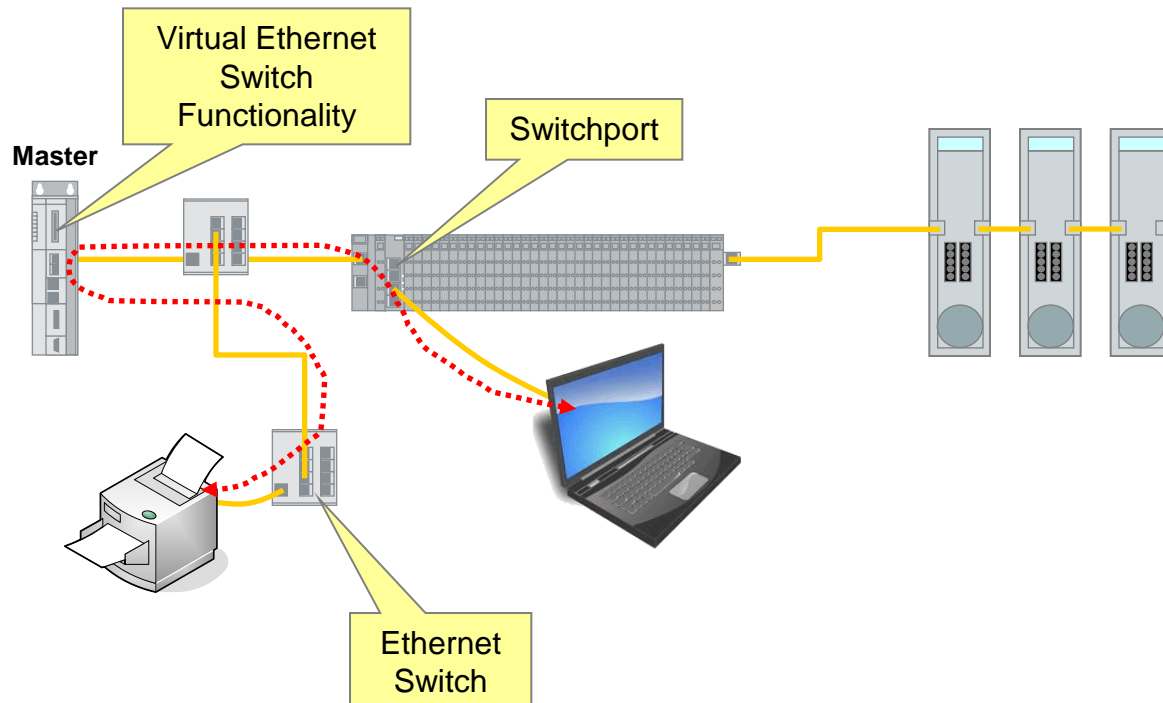


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- Virtual Ethernet Switch routes any Ethernet Frame
- From inside as well as from outside the segment

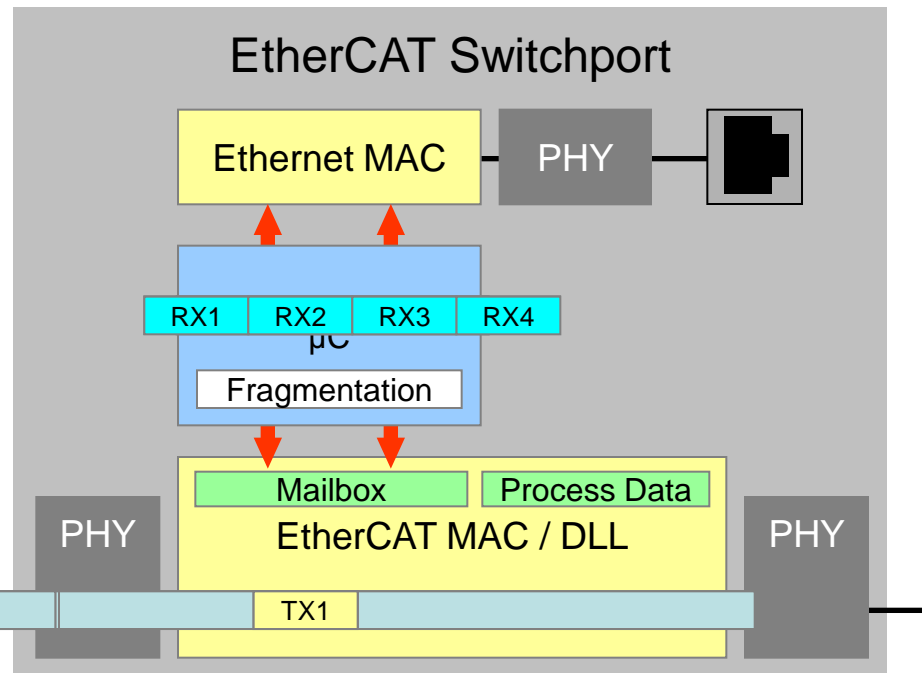


# Switchport: Any Ethernet Protocol

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- Interface to any Ethernet Device or Network
- Ethernet Frames are inserted into EtherCAT Protocol:
  - 'Ethernet over EtherCAT'

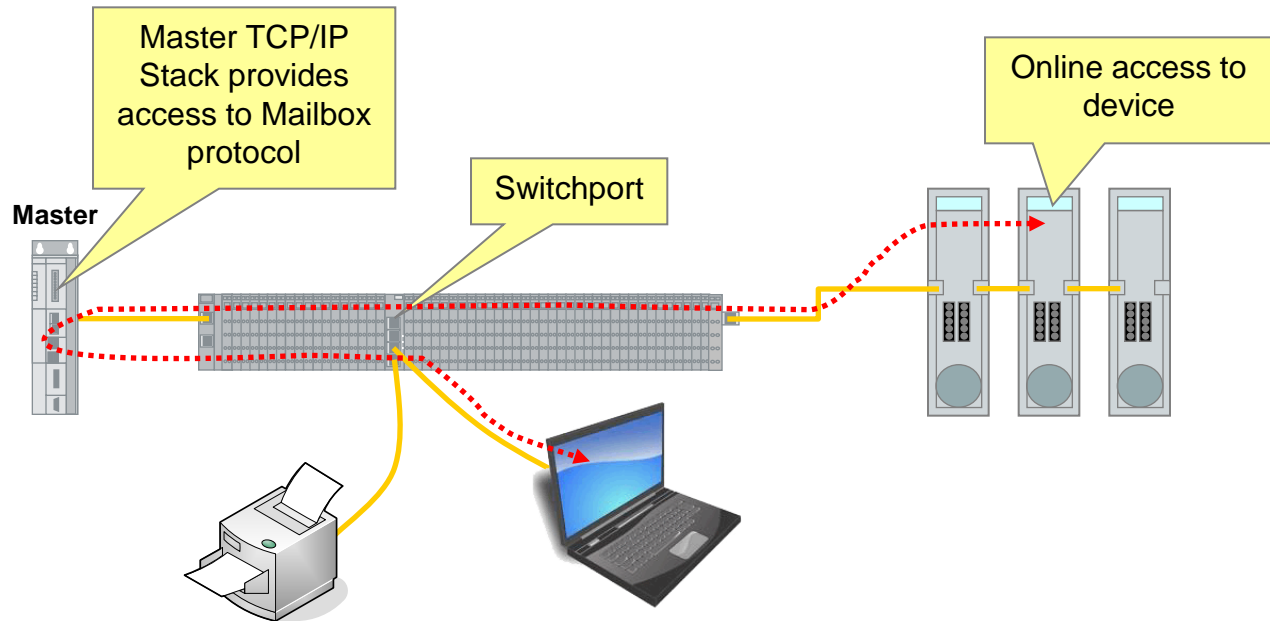


# EtherCAT is Industrial Ethernet!

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- Master TCP/IP Stack can provide remote Mailbox access via TCP/IP to any EtherCAT device – ideal for tools.
- No need for TCP/IP stack in each device: cost reduction

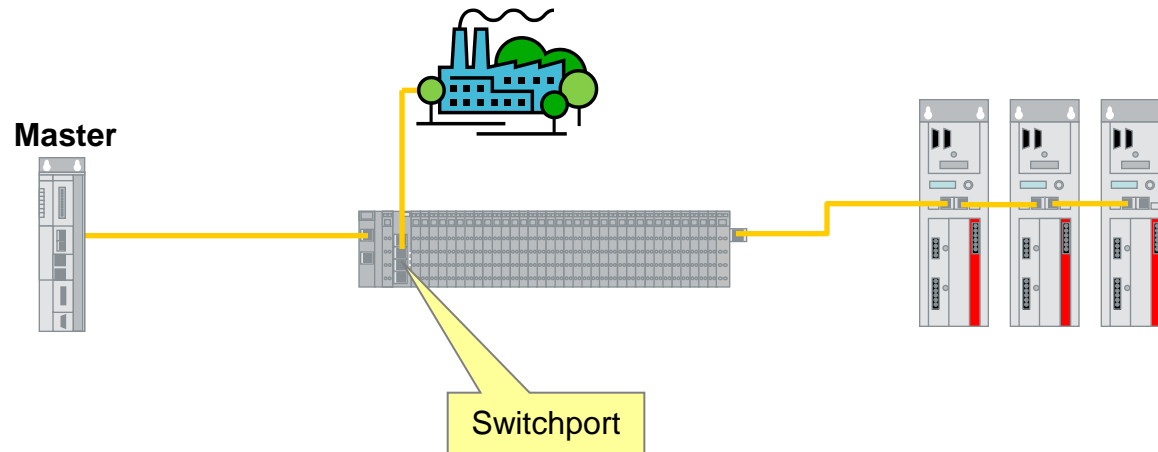


# Vertical Integration (1)

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...via Switchport



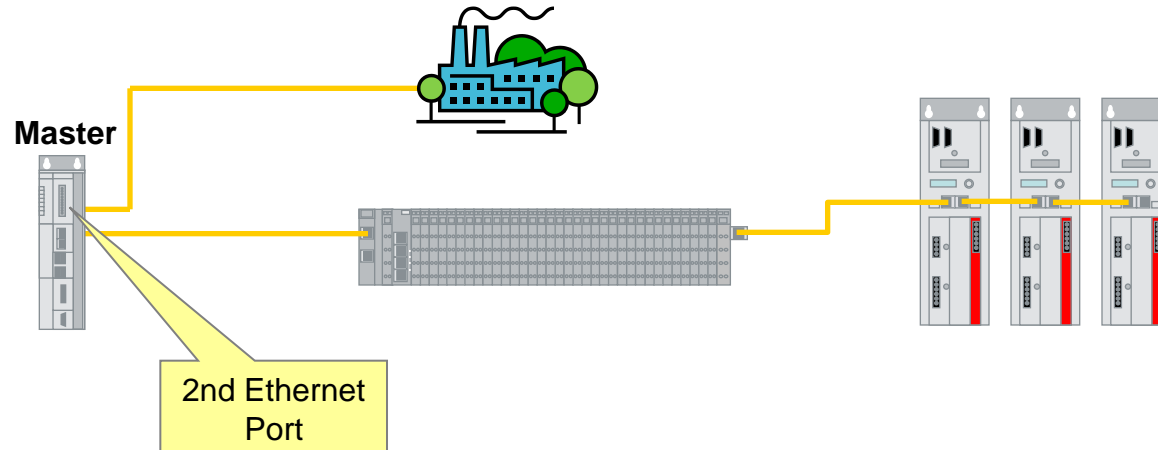
- + any Ethernet Protocol can be used
- + requires only one Ethernet Port (at IPC/Controller)
- + EtherCAT performance is not limited



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...via 2. Ethernet Port

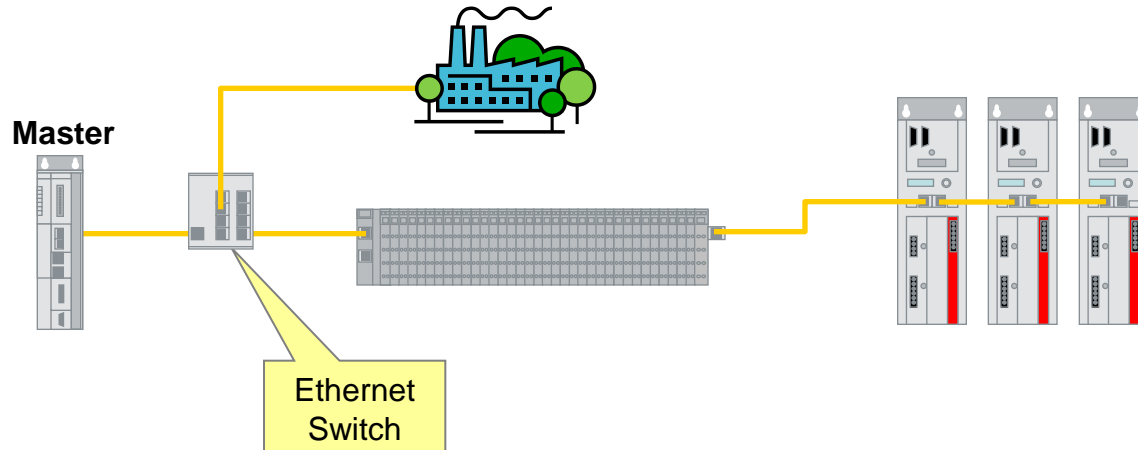


- + any Ethernet Protocol can be used
- + EtherCAT performance is not limited
- but: requires second Ethernet Port (at IPC/Controller)

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## ...via Switch



- + any Ethernet Protocol can be used
- + requires only one Ethernet Port (at IPC/Controller)
- but: performance reduced by switch delay (and generic Ethernet traffic)

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- Standard Ethernet Topology: Star

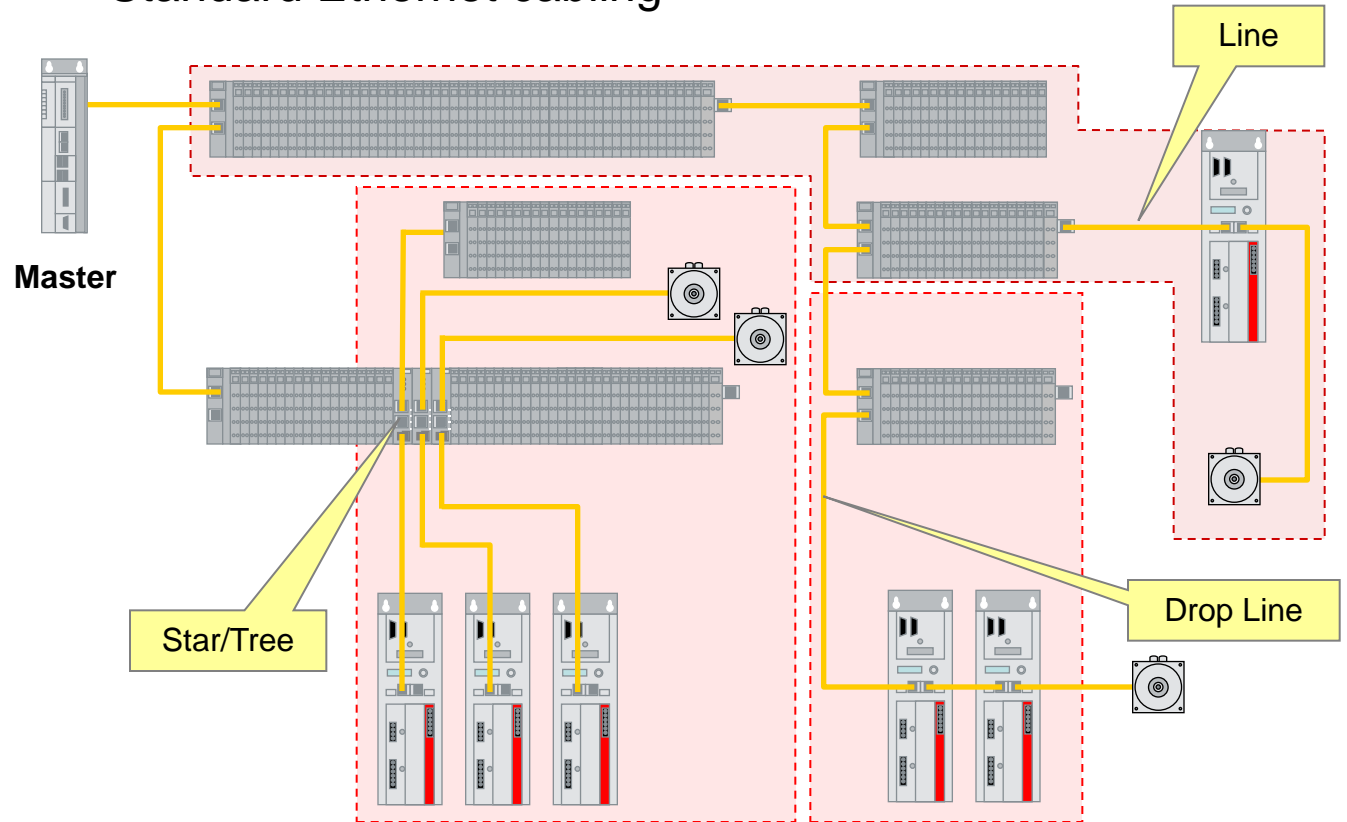


# EtherCAT wiring is more flexible

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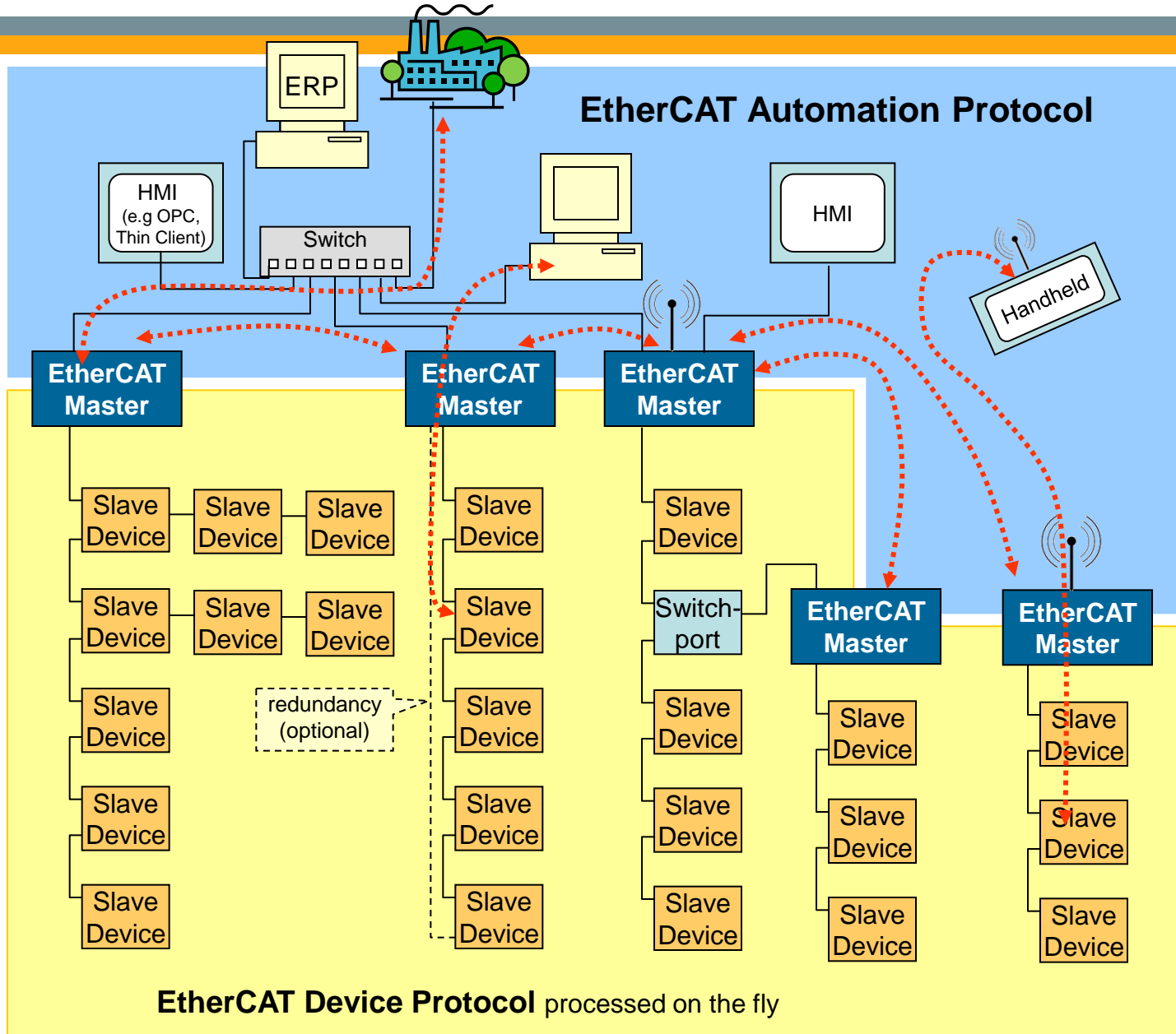
- Flexible topologies – arbitrarily extendable
  - Topology variants like Line, Star, Tree, Daisy Chain + Drop Lines possible; can be used in any combination!
  - Up to 65.535 nodes for each EtherCAT segment
  - Standard Ethernet cabling



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**10.056  
EtherCAT Nodes**

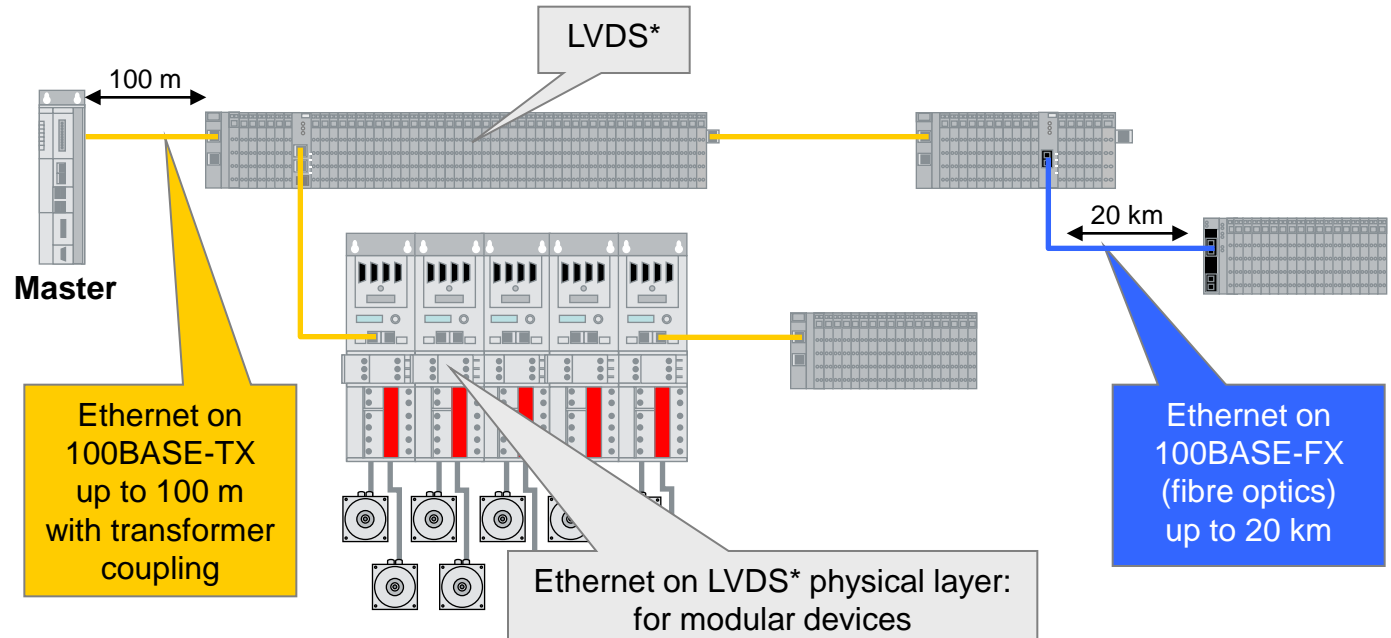
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• Ethernet Signal Variants of EtherCAT:

- 100BASE-TX (up to 100 m between 2 nodes)
- 100BASE-FX (up to 20 km between 2 nodes (single mode fibre) )
- LVDS (for modular devices)



• Any number of physical layer changes allowed

\*LVDS: Low Voltage Differential Signaling according to ANSI/TIA/EIA-644, also used in IEEE 802.3ae (10 Gigabit Ethernet)

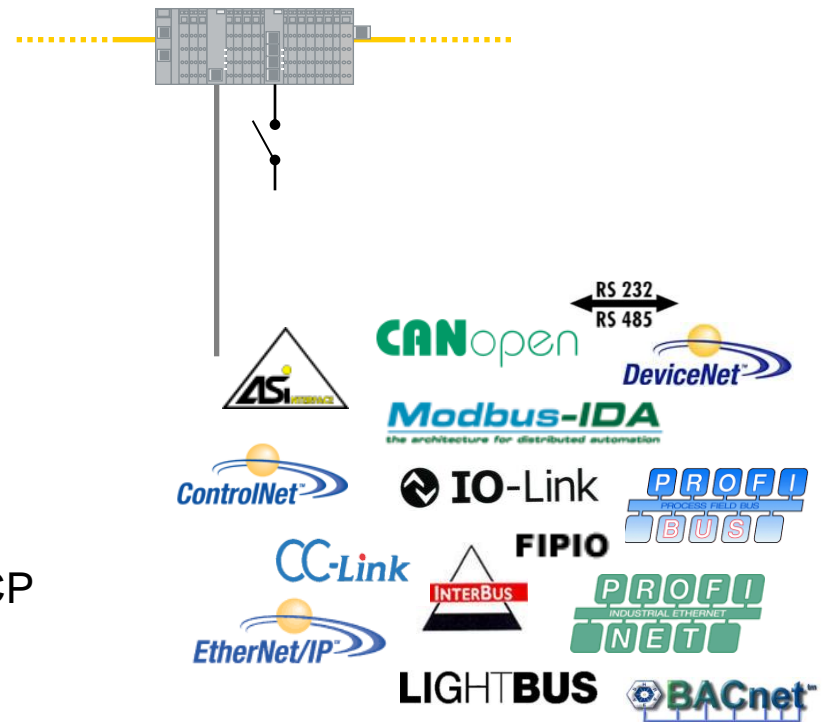
# EtherCAT instead of PCI

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- Protection of your investment
- smooth migration path from legacy fieldbus to EtherCAT
- seamless integration of existing fieldbus devices, e.g.:

- AS-Interface
- BACnet MS/TP
- CANopen
- CC-Link
- ControlNet
- DeviceNet
- Ethernet/IP
- FIPIO
- Interbus
- IO-Link
- Lightbus
- LonWorks
- Modbus Plus, RTU, TCP
- PROFIBUS
- PROFINET IO
- ...



- maximum system expandability with low cost fieldbus gateways



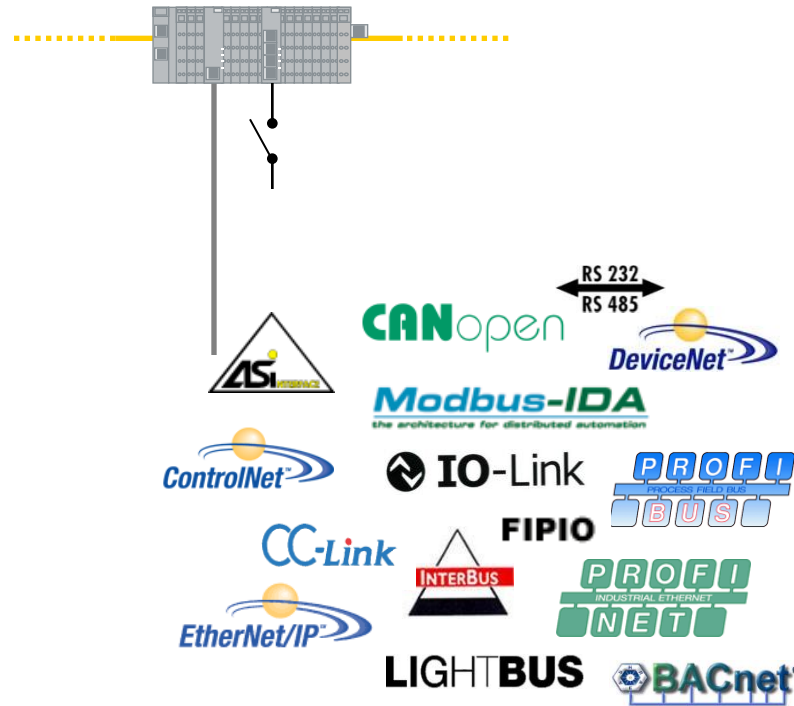
# EtherCAT instead of PCI

**EtherCAT is:**

- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

• Update Times:

- Process image update-time via PCI (**500 Bytes** input and output data each): **400 μs**
- Process image update-time via EtherCAT (**1.500 Bytes** input and output data): **150 μs**

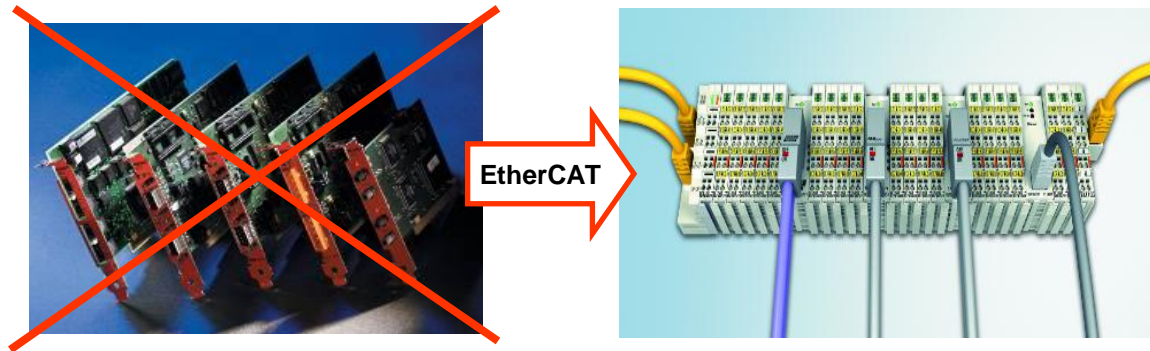


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- No Slots in Control System (IPC or PLC) required any more
- Nevertheless maximum expandability





**EtherCAT is:**

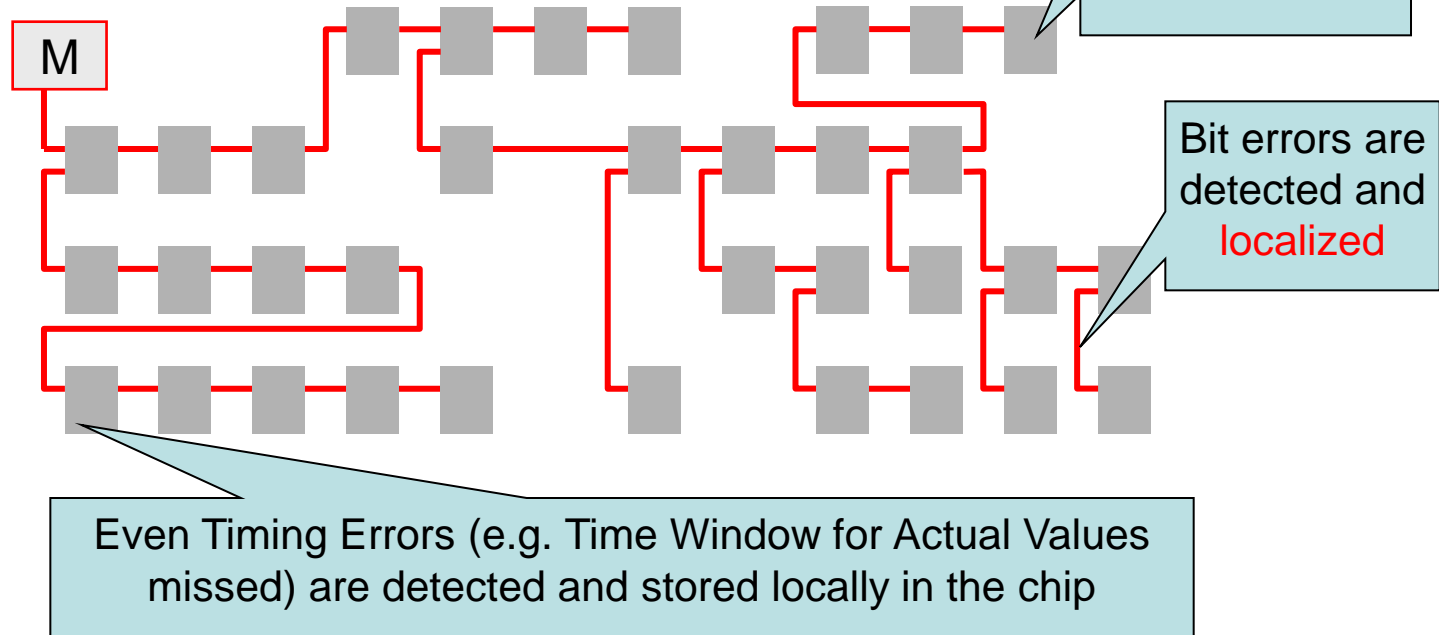
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• **Topology:**

- Automatic Topology Expected/Actual Comparison

• **Diagnosis:**

- Diagnosis with exact Localization





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- Network planning:
  - Performance independent of:
    - Slave implementation  
(no Stacks involved in Process Data Communication)
    - Topology (no Switches/Hubs)
- Addressing
  - No manual address setting required
  - No IP- or MAC-Address Handling Required
  - Addresses can be assigned automatically
  - Addresses can be kept
    - no new addressing if nodes are added



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1. Select + Plan Topology according to System Limitations
2. Configure Node Address at Slave Device
3. Select and Configure Baudrate, depending on:
  - Network Length + Topology
  - EMI-Environment
  - Application Requirements
4. Select Device Description Files (GSD, EDS) in Configuration Tool
5. Select and Configure Communication Parameters, such as:
  - cyclic Polling
  - event driven Communication
  - synchronized or free running
6. Allocate physical to logical Process Image (Mapping)



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- ~~1. Select + Plan Topology according to System Limitations~~
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- **Less effort for Network planning:**
  - Simplified configuration
  - Default settings will work, no network tuning
- **Improved Diagnosis:**
  - Faster error handling leads to less downtime
- **Faster Setup:**
  - No address setting required
- **Implementation / Tools:**
  - Standard Network Monitor Tools, e.g. MS Network Monitor or Wireshark: free of charge
  - Parser Software: free of charge



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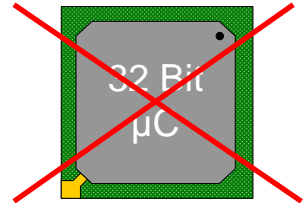
- **Master:**

- no dedicated plug in card (co-processor)
- on-board Ethernet Port is fine



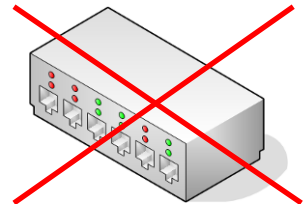
- **Slave:**

- low cost Slave Controller
  - FPGA or ASIC
- for simple devices: no  $\mu$ C needed
- no powerful  $\mu$ C needed



- **Infrastructure:**

- no Switches/Hubs required
- Standard Ethernet Cabling + Connectors





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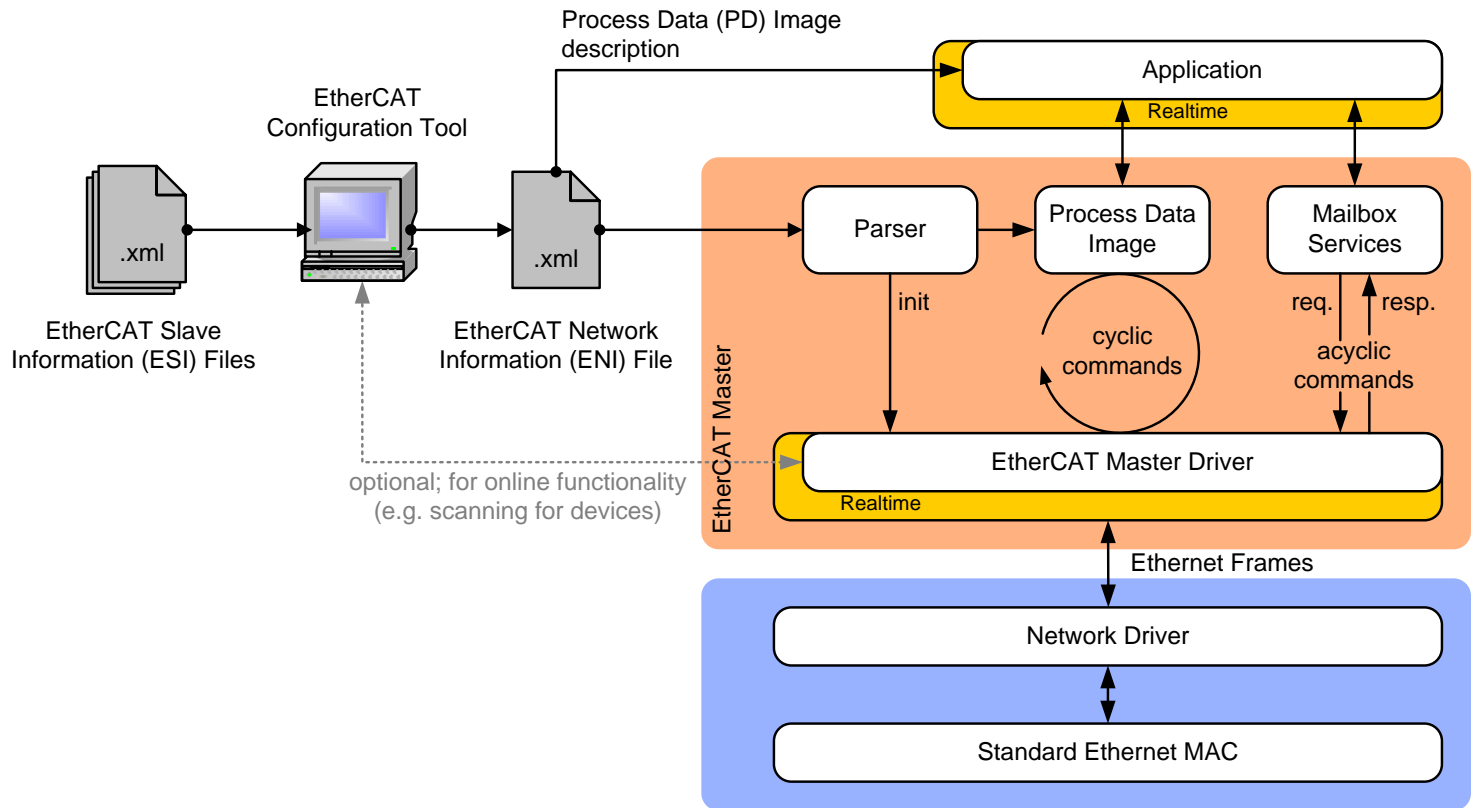
- **Slave Implementation:**
  - All time critical functions implemented on ASIC or FPGA
    - ESC handles Real-time Protocol in Hardware
  - Integrated Communication State Machine
  - Network Performance independent of
    - Slave- $\mu$ C Performance
    - Protocol Stack
  - For usage with or without  $\mu$ C (Host CPU)
  - Integrated DPRAM (1...8kByte)
  - Integrated Distributed Clock Handling
  - Ultra precise interrupts to  $\mu$ C

# EtherCAT is easier to implement: Master

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- Master Implementation:
  - e.g. with Master Sample Code (Source)
  - EtherCAT Configuration Tool
  - XML Data format of ESI and ENI



# EtherCAT is well proven

**EtherCAT is:**

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  - Flexible Topology ✓
  - Easier to configure ✓
  - Cost effective ✓
  - Easier to implement ✓
- 
- Well proven
  - Open
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  - Safety
  - Redundancy
  - Versatile

In Series Production since 2003, outstanding Product Variety



# EtherCAT is an open technology

## EtherCAT is:

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- Cost effective ✓
- Easier to implement ✓
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- Protocol is disclosed completely:
  - EtherCAT is IEC, ISO and SEMI Standard (IEC 61158, IEC 61784, ISO 15745, SEMI E54.20)



Commission Electrotechnique Internationale  
International Electrotechnical Commission  
Международная Электротехническая Комиссия



- Slave Controller from several sources available
- Slave Controller provides interoperability
- ETG organizes Interoperability Testing („Plug Fests“), Workshops and Seminars
- Conformance Testing + Certificates

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• EtherCAT Masters implemented on wide range of RTOS\*

- eCos
- Integrity
- INtime
- Linux with RT-Preempt
- Microware® OS-9
- MQXTM
- On Time RTOS-32
- Oracle® Solaris (SunOS)
- PikeOS
- Proconos OS
- QNX®
- Real-Time Java™
- RMOS
- RTKernel
- RT-Linux
- RTX
- RTXC
- RTAI Linux
- SCALE-RT
- TKernel
- VxWin® + CeWin®+ RTOS32Win®+LxWin
- VxWorks®
- Windows® CE
- Windows Embedded mit IntervalZero RTX
- Windows® XP/XPE mit CoDeSys SP RTE
- Windows® XP/XPE mit TwinCAT RT-Extension
- Windows® Vista, 7
- XOberon
- XENOMAI Linux
- µC/OS-IITM

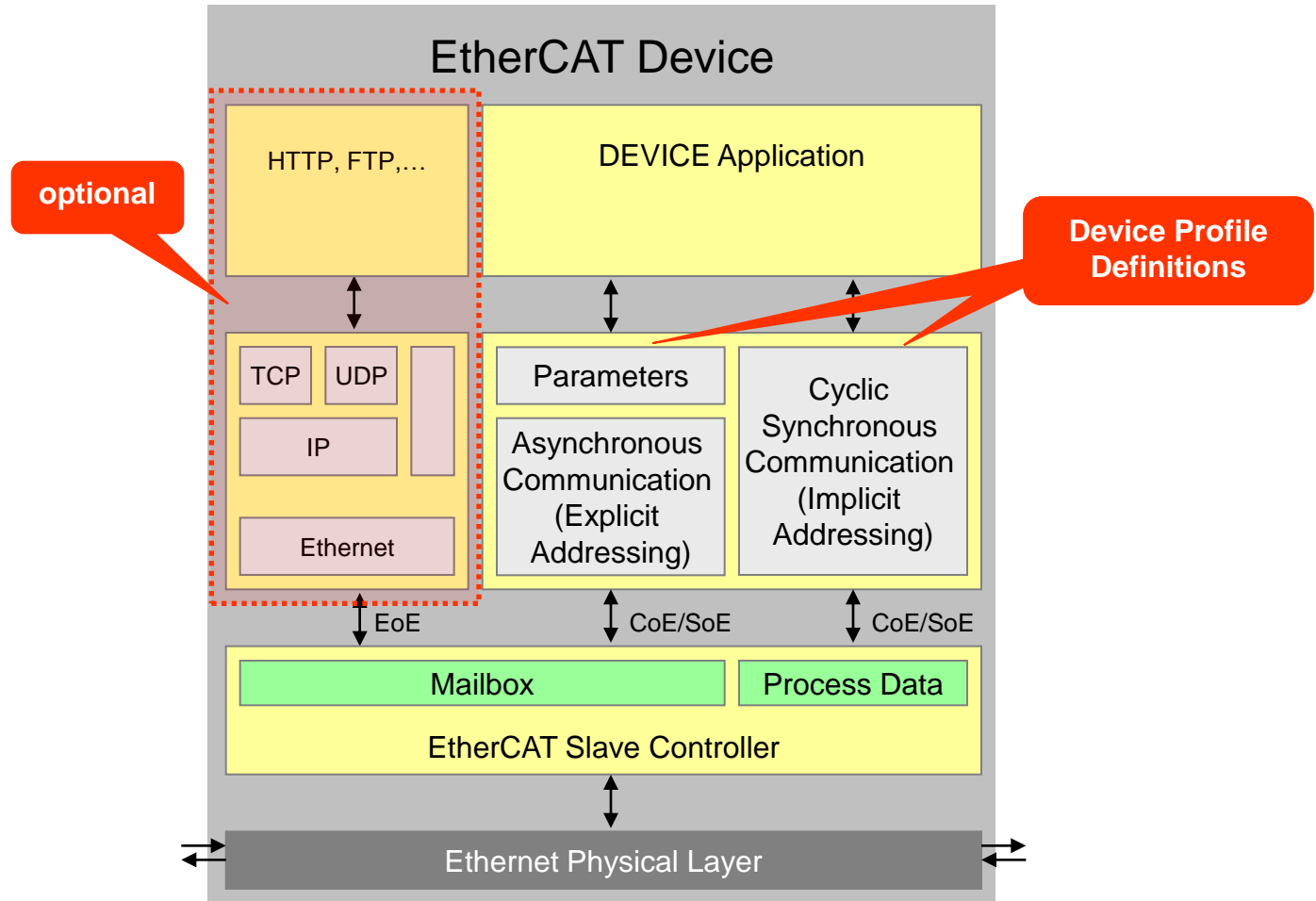


\*as of July 2012

# Typical EtherCAT Device Architecture

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- Foundation: November 2003
- Tasks: Support, Advancement and Promotion of EtherCAT
- The worlds largest fieldbus organization
- More than 2100\* member companies from 55 countries in 6 continents:
  - Device Manufacturers
  - End Users
  - Technology Providers
- Membership is open to everybody

# ETG Team Worldwide

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|  |   |  |  |   |  |  |  |   |
|--|---|--|--|---|--|--|--|---|
| Dr. Guido Beckmann, GER<br> | Andrea Bock, GER<br>             | Geng Cheng, CHN<br>     | Bin (Beryl) Fan, CHN<br> | Oliver Fels, GER<br>   | Florian Hammel, GER<br> | Florian Häfele, GER<br>   | Rainer Hoffmann, GER<br>    | Liliane Hügel, GER<br> |
| Dr. YanQiang Liu, CHN<br>   | Prof Dr. Yong-Seon Moon, KOR<br> | Masanori Obata, JPN<br> | Thomas Rettig, GER<br>   | Martin Rostan, GER<br> | Makiko Hori, JPN<br>    | Joseph P. Stubbs, USA<br> | Fengjiao (Jojo) Fu, CHN<br> | Key Yoo, KOR<br>       |

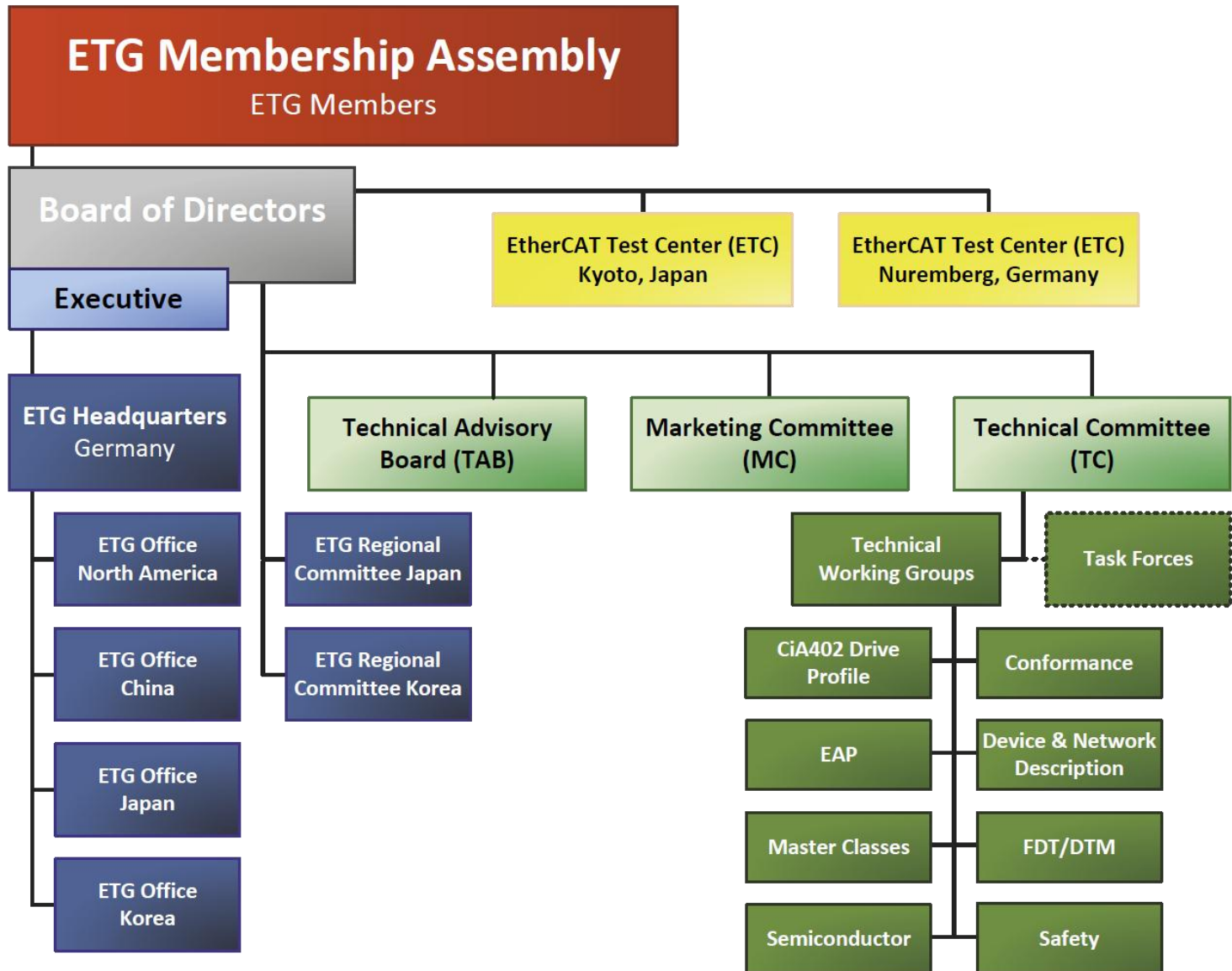




# EtherCAT Technology Group Structure

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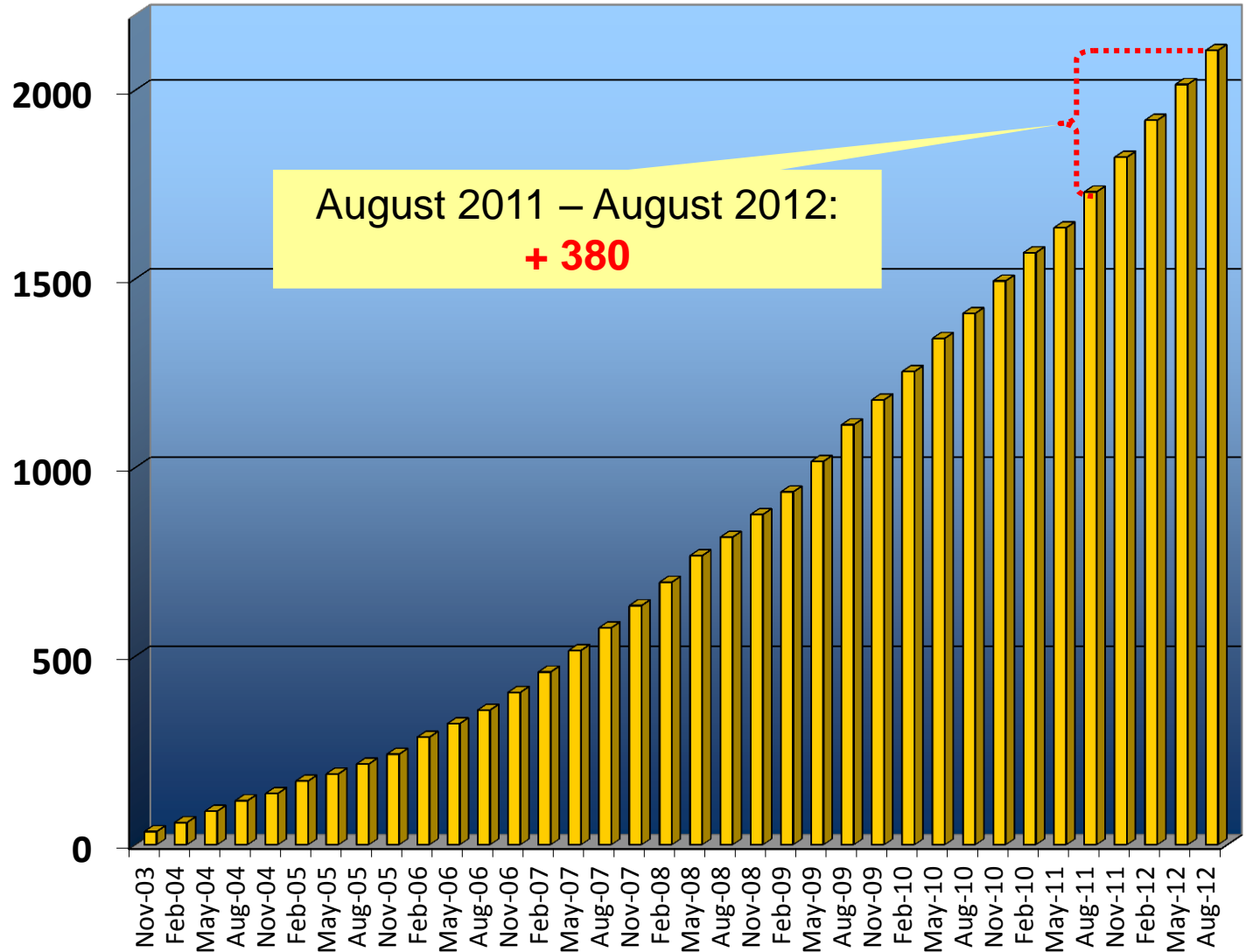


# ETG Membership Development

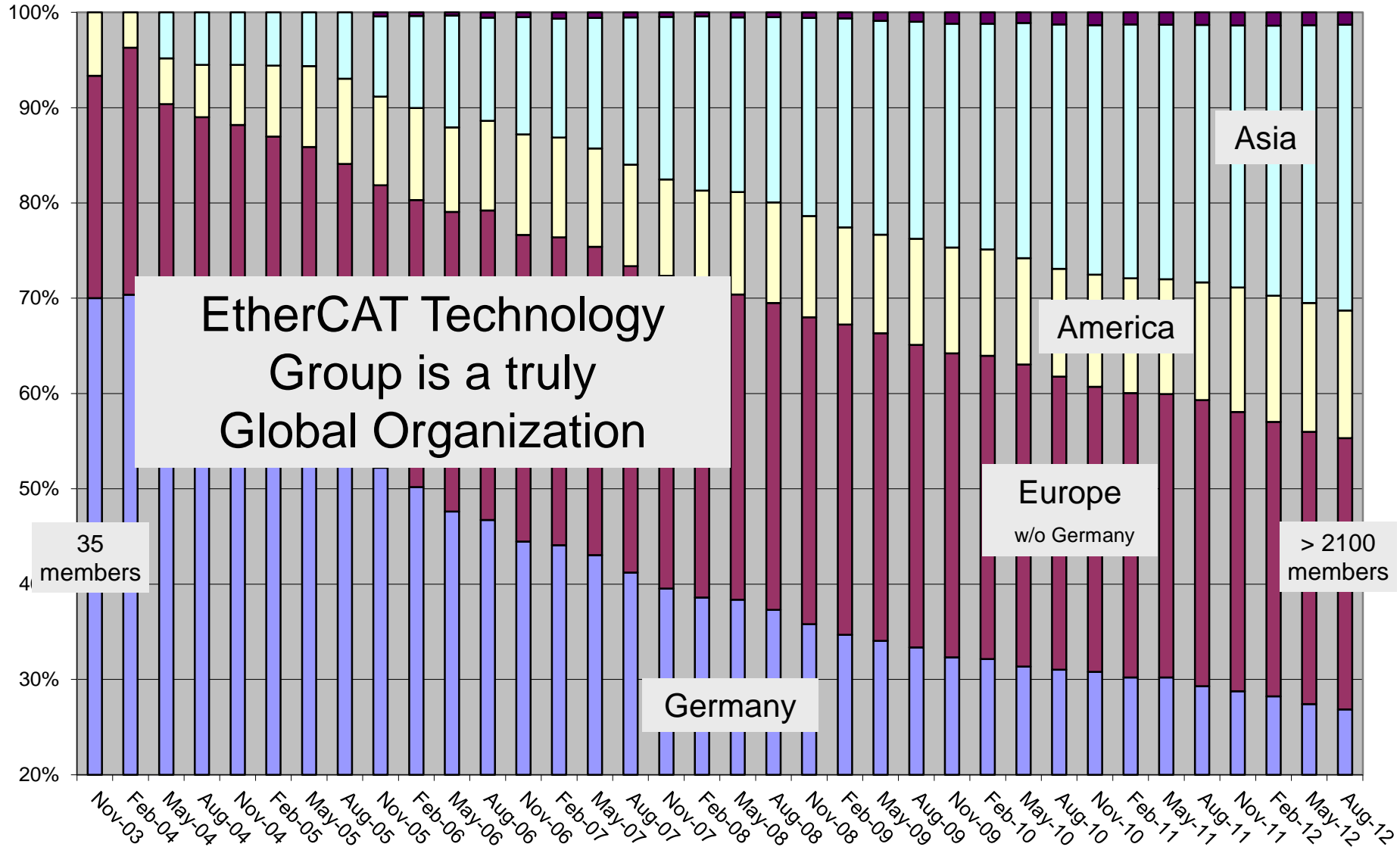
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As of August 31<sup>st</sup>, 2012: 2105 Members



# ETG Membership Distribution

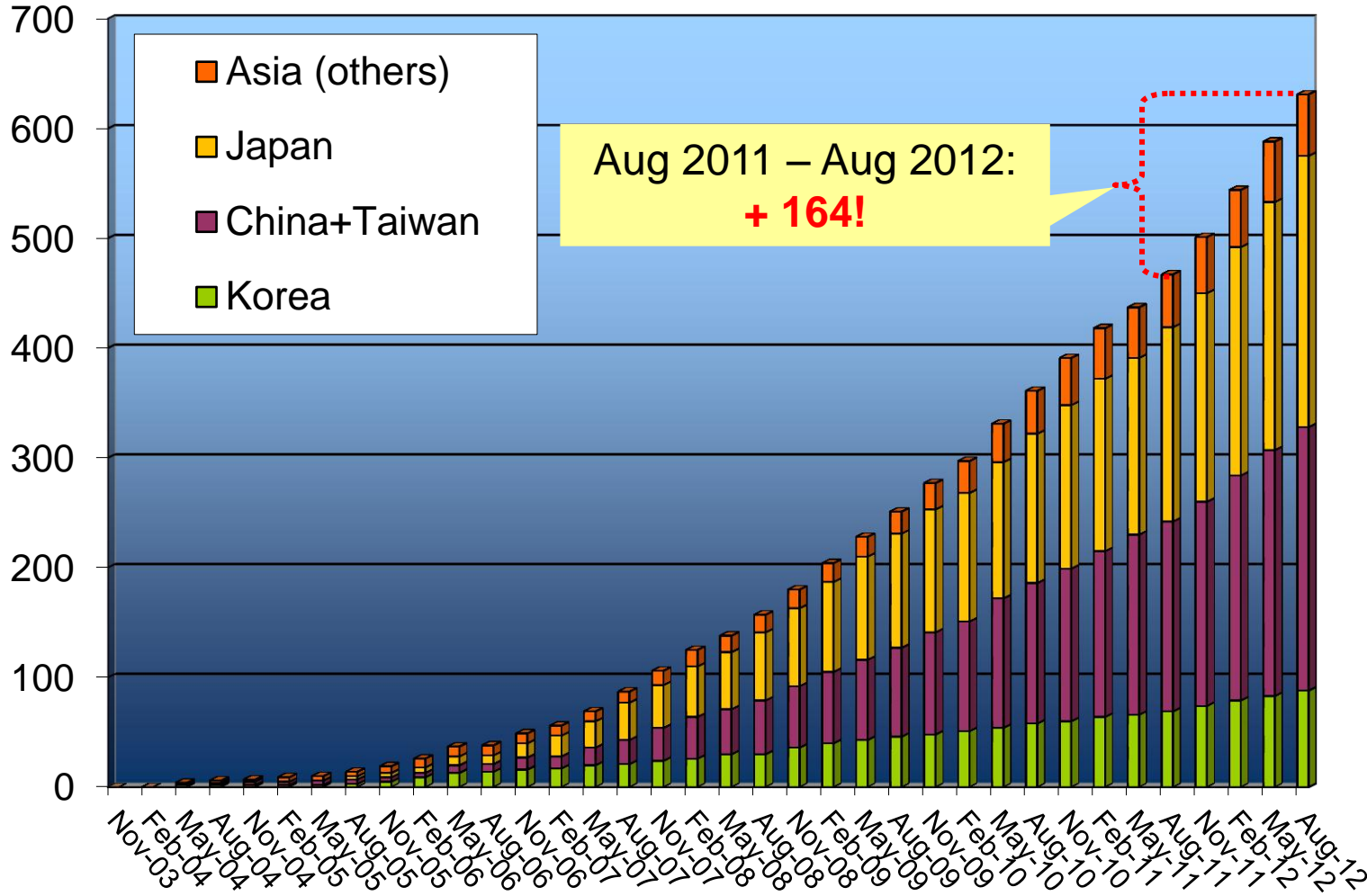


# ETG Members Asia

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August 31<sup>st</sup> 2012:  
631 Asian Members



# Members from 55\* Countries, 6 Continents

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# How many members invest in the technology?

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- One indicator: implementation kits sold.
- Until now, Beckhoff alone has sold over 1400 kits (78% slave kits, 22%(!) master kits)
- + there are slave implementation kits + master stacks from many other vendors\*, such as

- Slave**
- Beck IPC
  - Deutschmann
  - EBV Elektronik
  - Hilscher
  - HMS anybus
  - IXXAT Automation
  - koenig-pa
  - port
  - Red one
  - Soft Servo Systems
  - ST Microelectronics
  - Terasic Technologies
  - Tetra
  - Xilinx
  - ...

- Master**
- acontis
  - esd
  - igH
  - IXXAT Automation
  - Kithara
  - Koenig-PA
  - MicroSys
  - Profimatics
  - Sybera
  - ...

\* Only those listed that have entered their offering in the EtherCAT Product Guide

# ETG: Active Members

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- Hannovermesse 2012: 65 Vendors with over 280 different EtherCAT Devices at ETG booth:
  - 35 different drives from 24 manufacturers jointly operating in one network
  - 25 different functional Masters in one setup, using 10 different operating systems
  - Safety devices (master + slave devices) from several manufacturers operating in one system



# EtherCAT: Large Product Selection

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I/O, Controller, HMI, Servo Drives, Variable Speed Drives  
Sensors, Slave + Master Development Kits  
Control Panels, Hydraulic Valves  
and Pneumatic Valves,  
...





**EtherCAT is:**

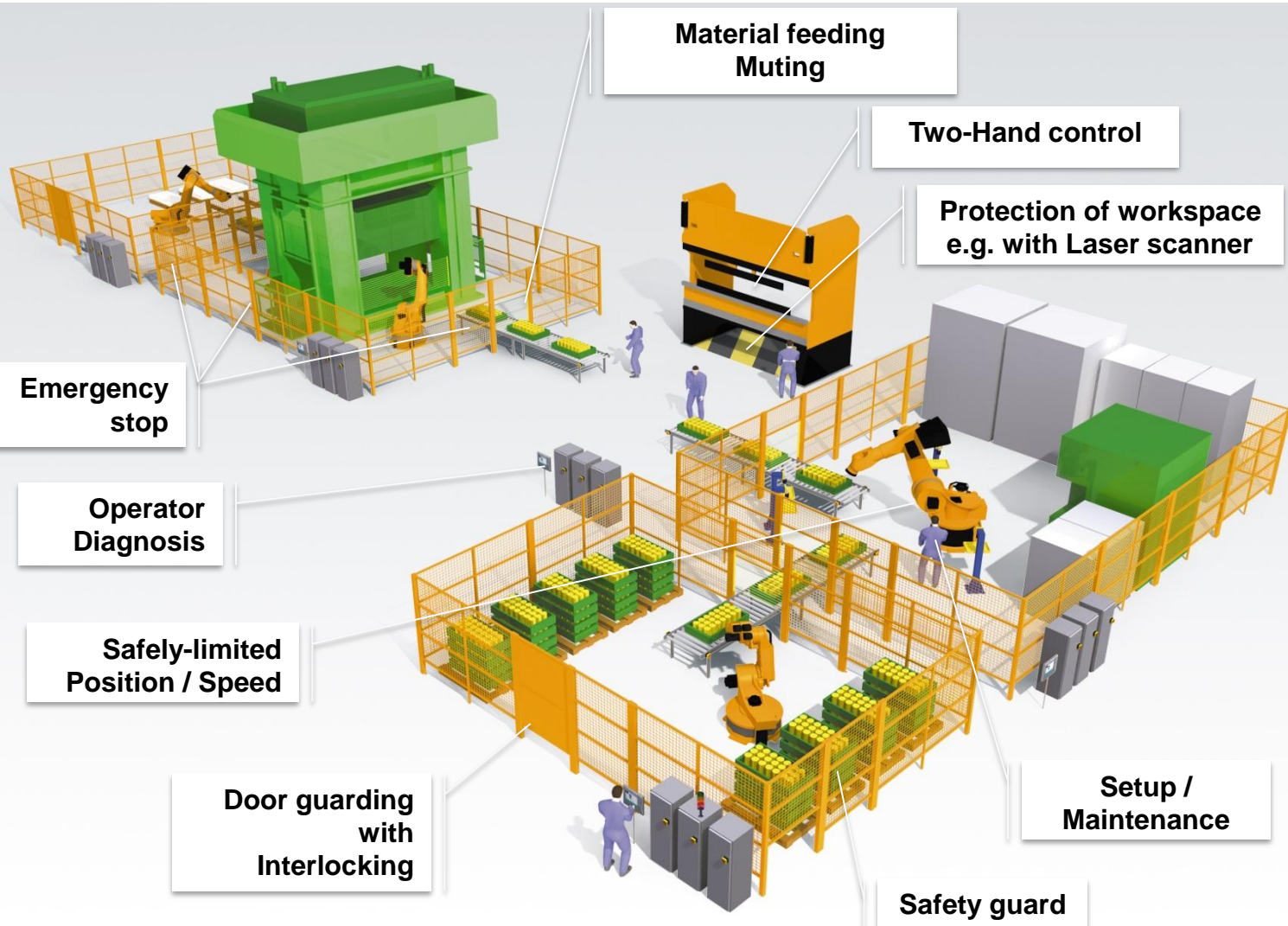
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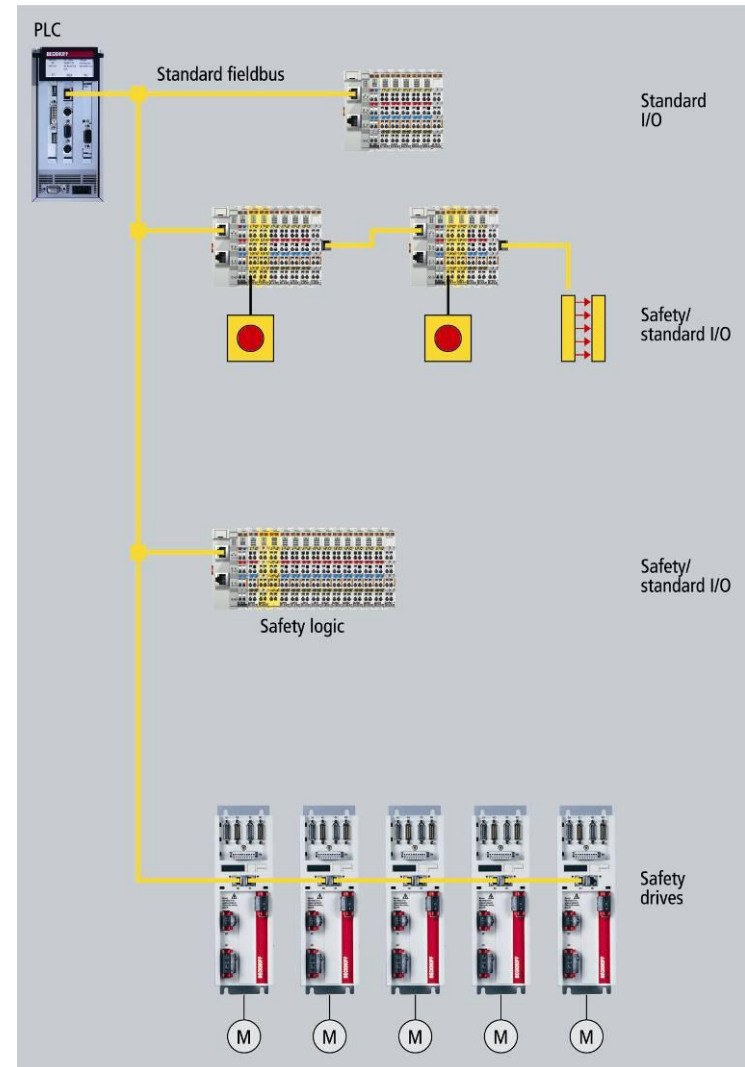
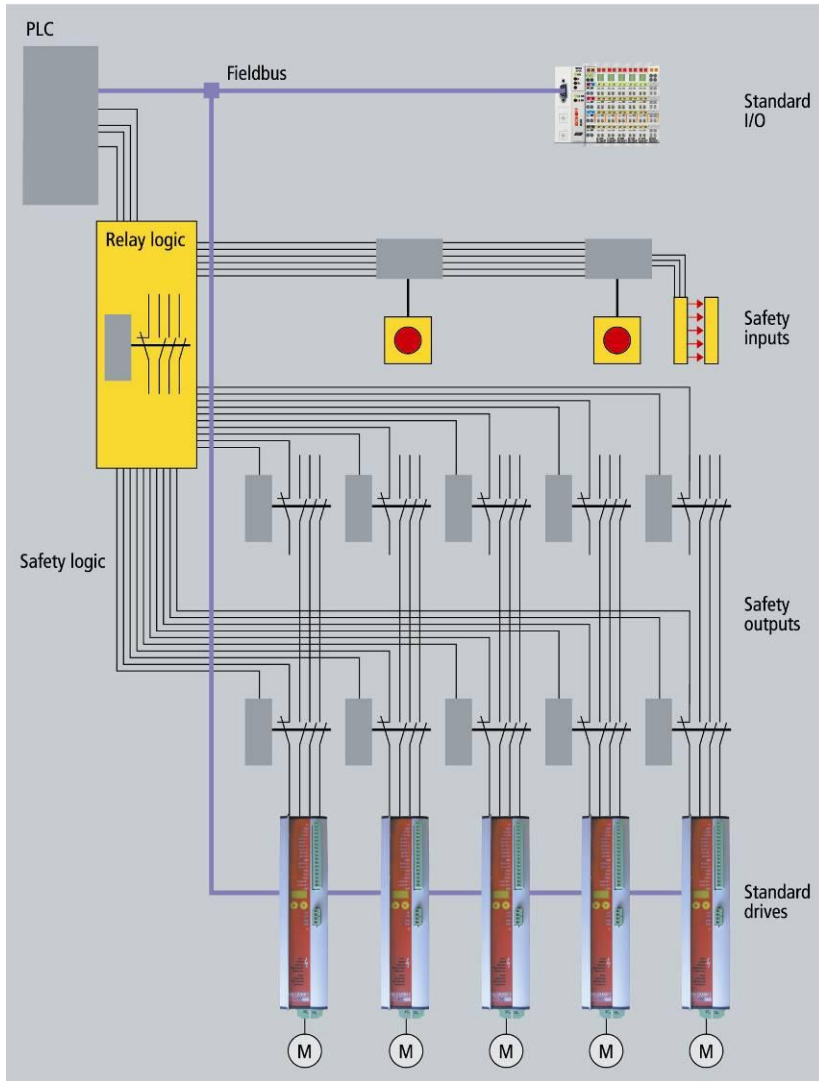
- Conformance and interoperability are very important factors for the success of a communication technology
  - Conformity to the specification is an obligation to all users of the EtherCAT technology
  - Therefore the **EtherCAT Conformance Test Tool (CTT)** is used
  - Test Cases for the CTT are provided by the Working Group „Conformance“ within the ETG community
  - The **EtherCAT Conformance Test** proves conformance with issuing a certificate after passing the test at an official **EtherCAT Test Center (ETC)**

**EtherCAT is:**

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# Modern Machine Safety Concepts



**EtherCAT is:**

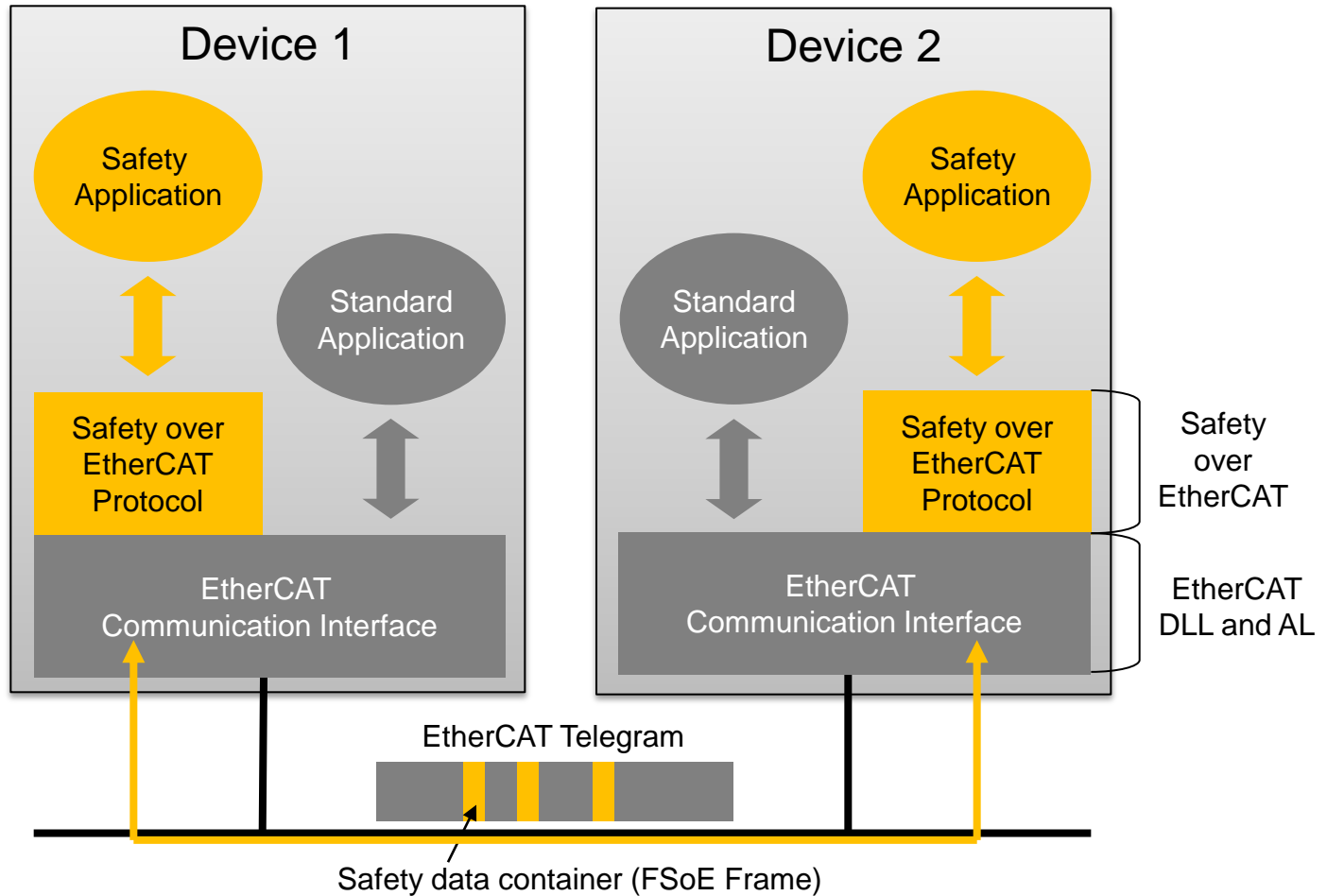
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## Safety over EtherCAT<sup>®</sup>

- Safety over EtherCAT (FSoE) defines a safety communication layer for the transportation of safety process data between Safety over EtherCAT devices.
- FSoE is an open technology within the EtherCAT Technology Group (ETG).
- The protocol is developed according to IEC 61508
  - It meets the Safety Integrity Level (SIL) 3
  - Residual Error Probability  $R(p) < 10^{-9}$
- The protocol is approved by an independent Notified Body (TÜV)

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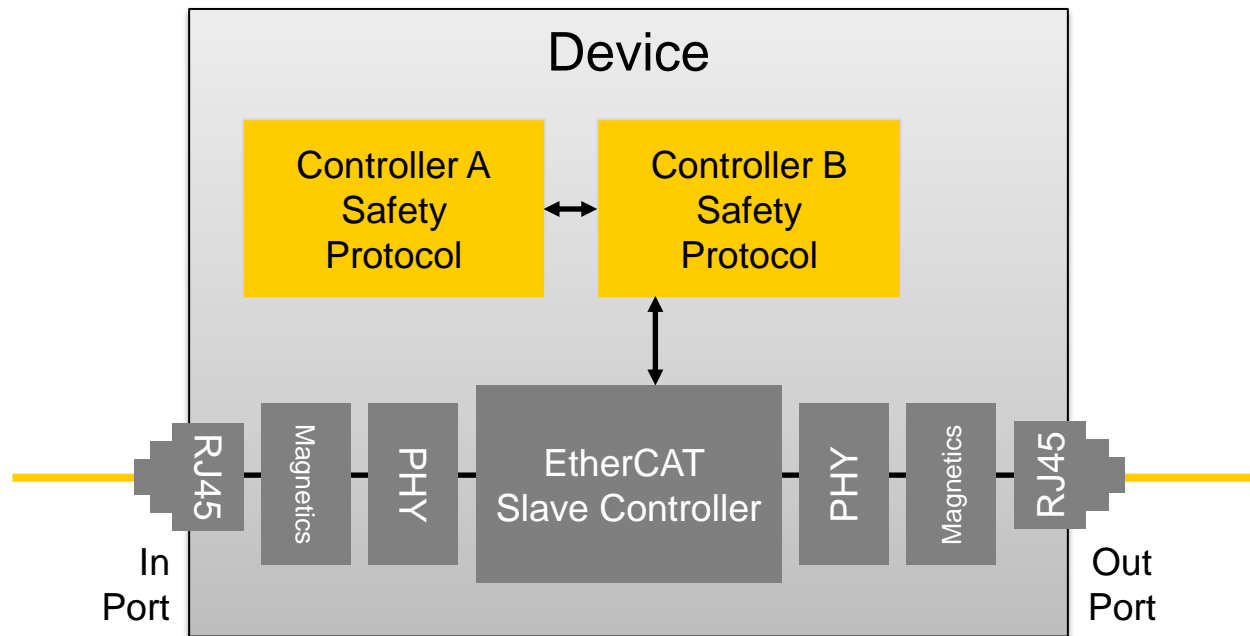


**EtherCAT is used as a "black channel"  
It contains safety and standard information**

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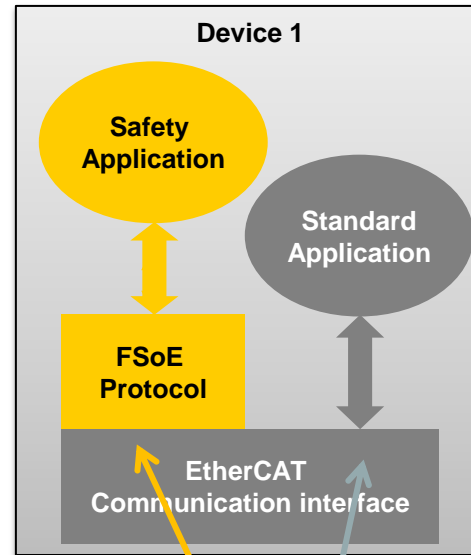
- One channel communication system  
According to model A of IEC 61784-3 Annex A



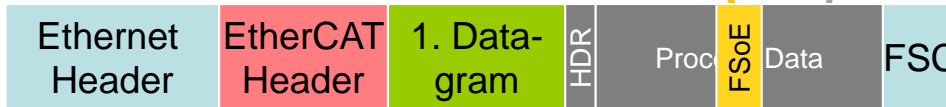
# Safety over EtherCAT: Frame Structure

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**EtherCAT Frame**



**FSoE Frame**



**FSoE Frame**

The FSoE Frame is embedded as a Container in the process data of the device.

Each device detects a new FSoE Frame, if at least one Bit in the FSoE Frame is changed.

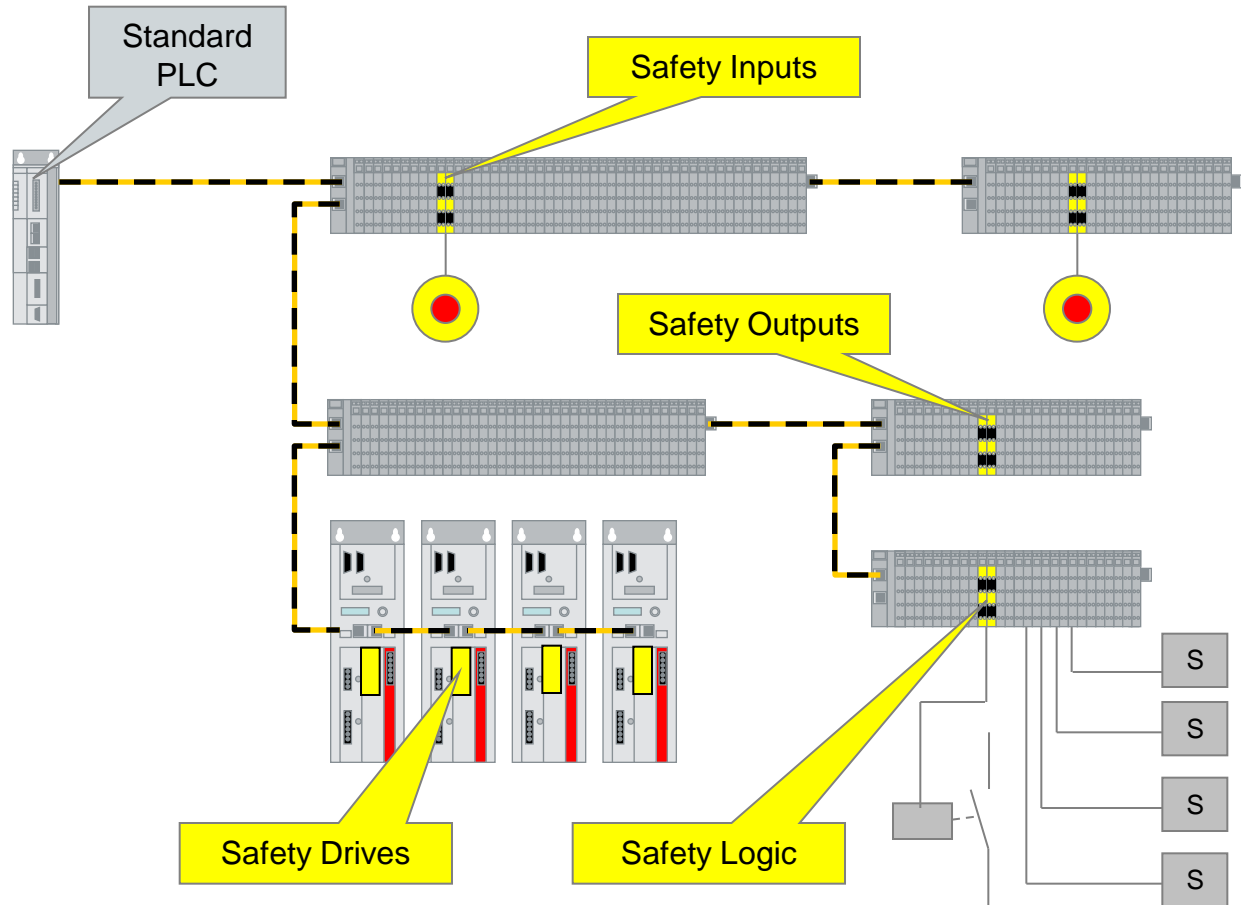
Every 2 Byte SafeData are checked by a 2 Byte CRC

The maximum number of SafeData is therefore not restricted by the protocol.

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- Decentralized Safety-Logic
- Standard PLC routes the safety messages





**EtherCAT is:**

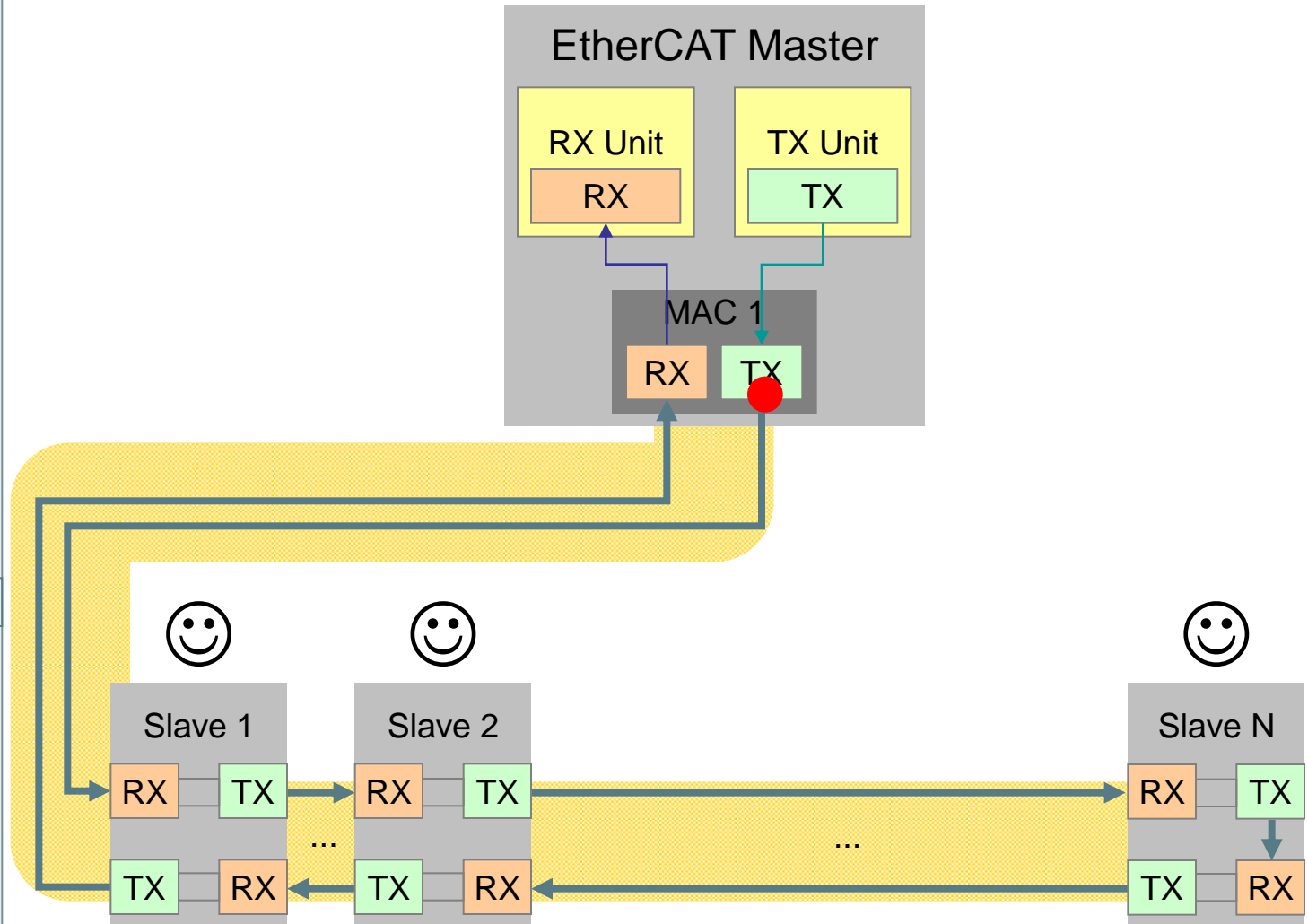
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- Fully integrated solution:
  - safe and standard communication in one channel
- Reduction of fieldbuses and interfaces
- Central configuration, diagnosis and maintenance for safe and ,unsafe‘ I/O in one tool
- Safety application makes full use of EtherCAT advantages:
  - Short reaction times
  - Almost unlimited number of nodes
  - Large network extensions
  - Cable redundancy options
  - High Flexibility with Hot Connect

# Without Redundancy: Normal Operation

**EtherCAT is:**

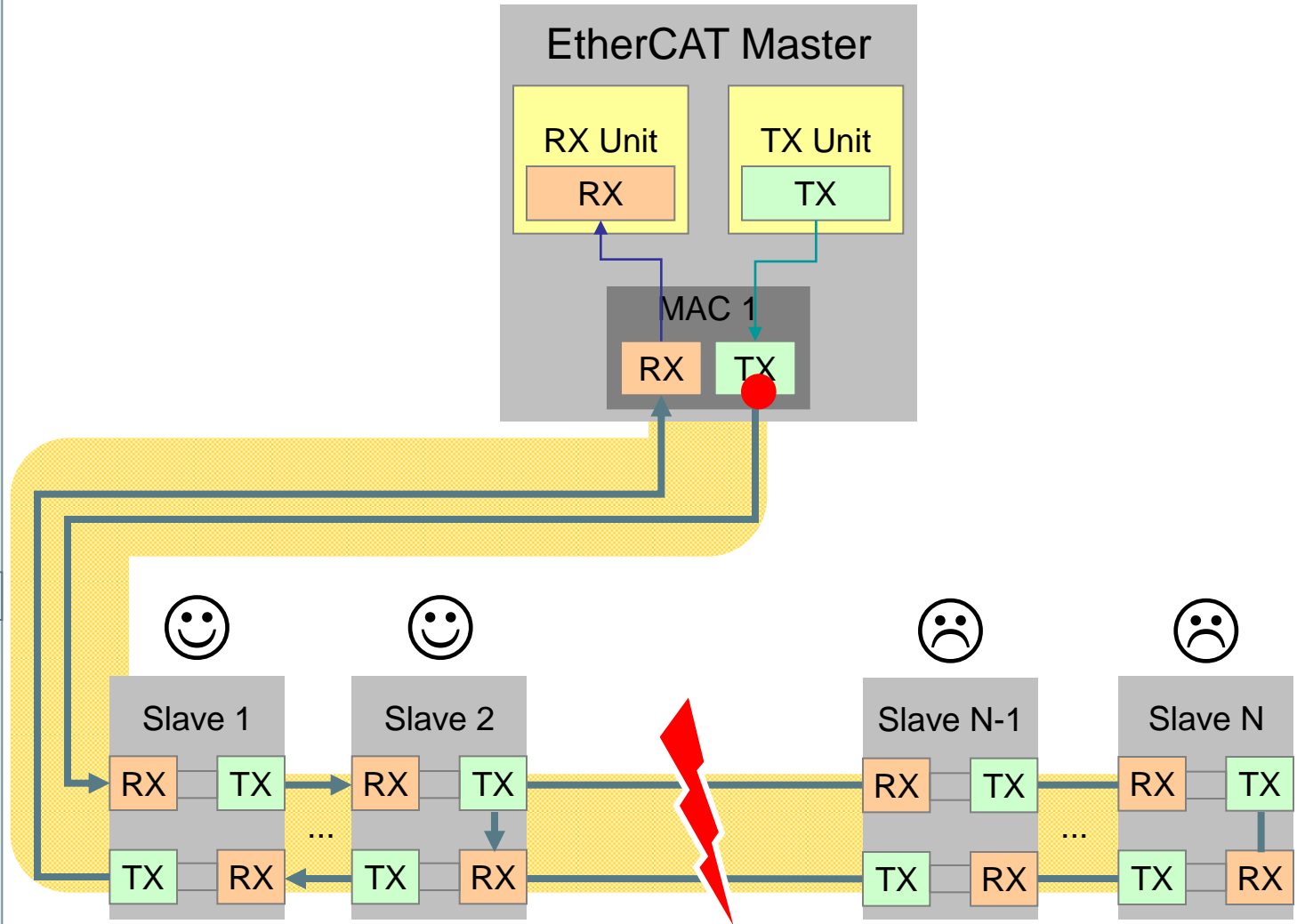
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# Without Redundancy: Cable Failure

**EtherCAT is:**

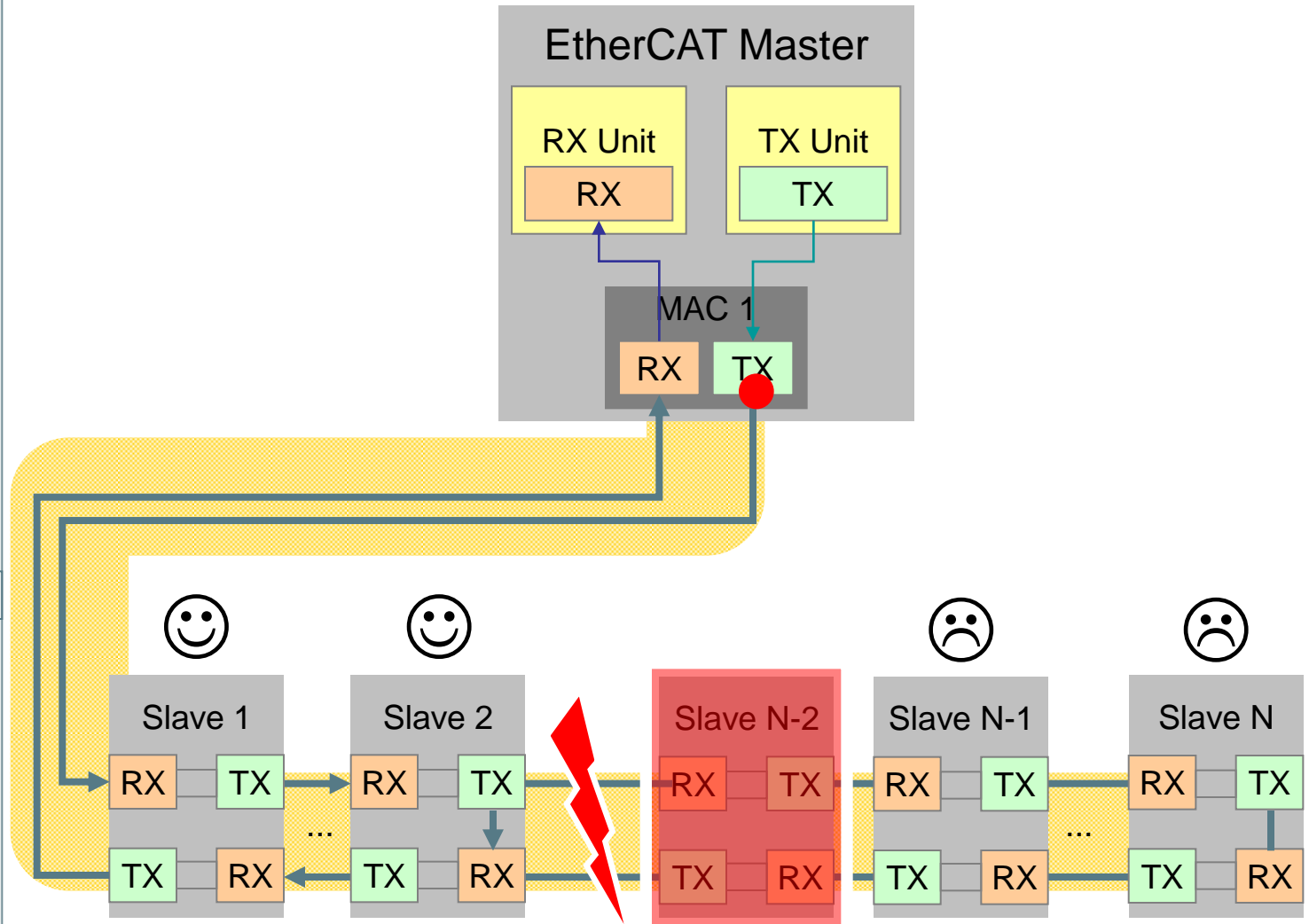
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# Without Redundancy: Node or Cable Failure

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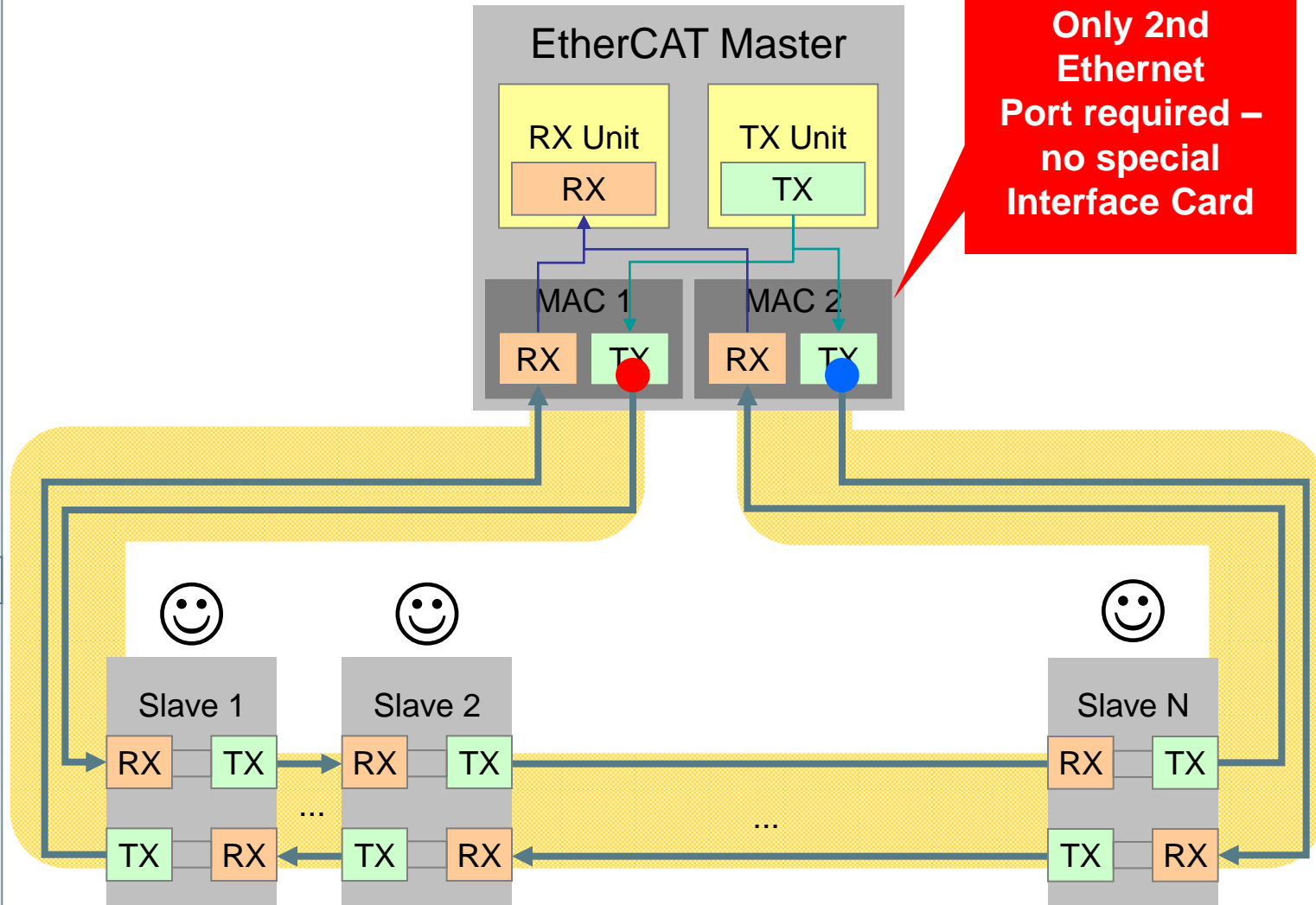
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# With Redundancy: Normal Operation

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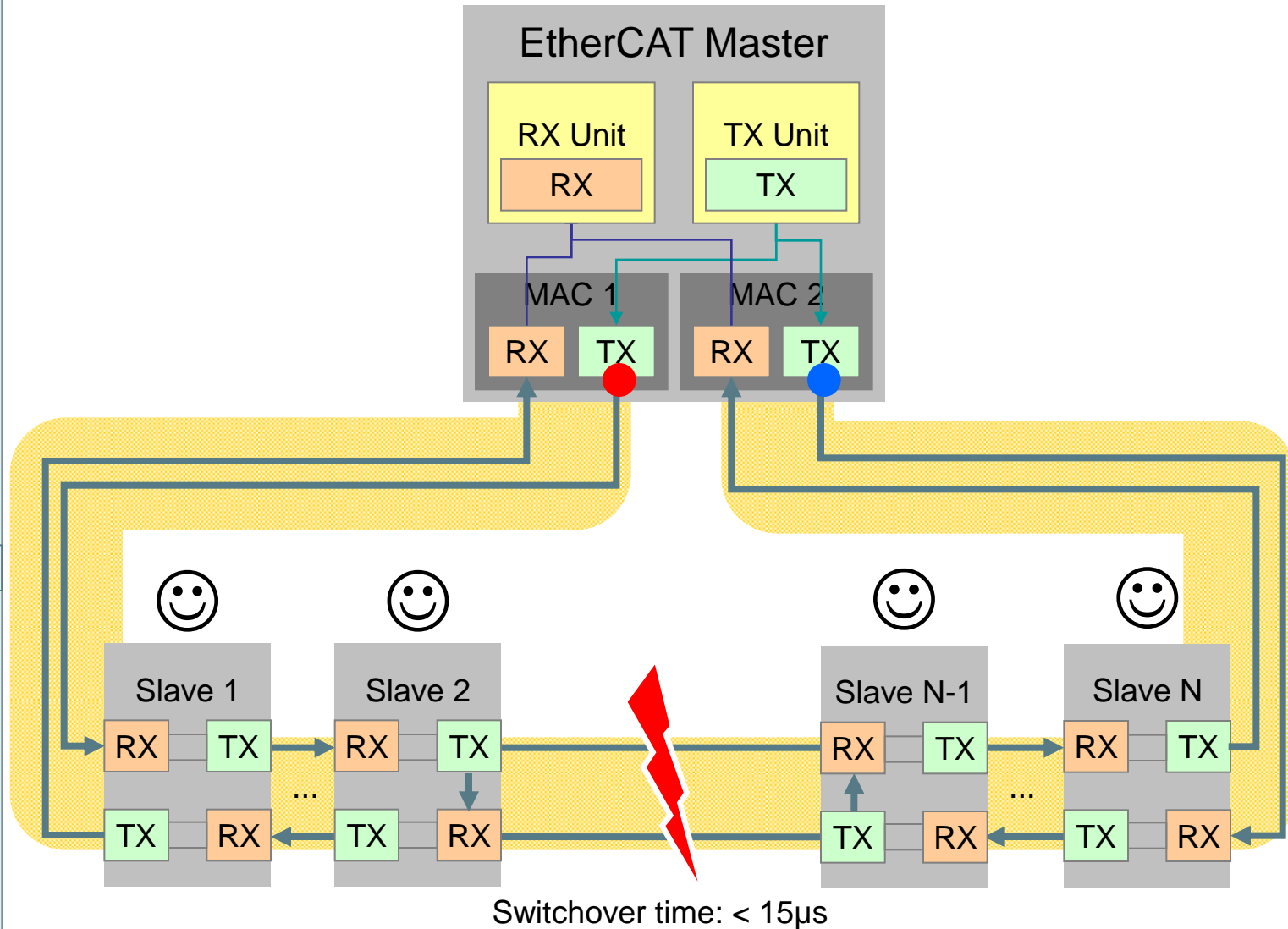
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# With Redundancy: Cable Failure

**EtherCAT is:**

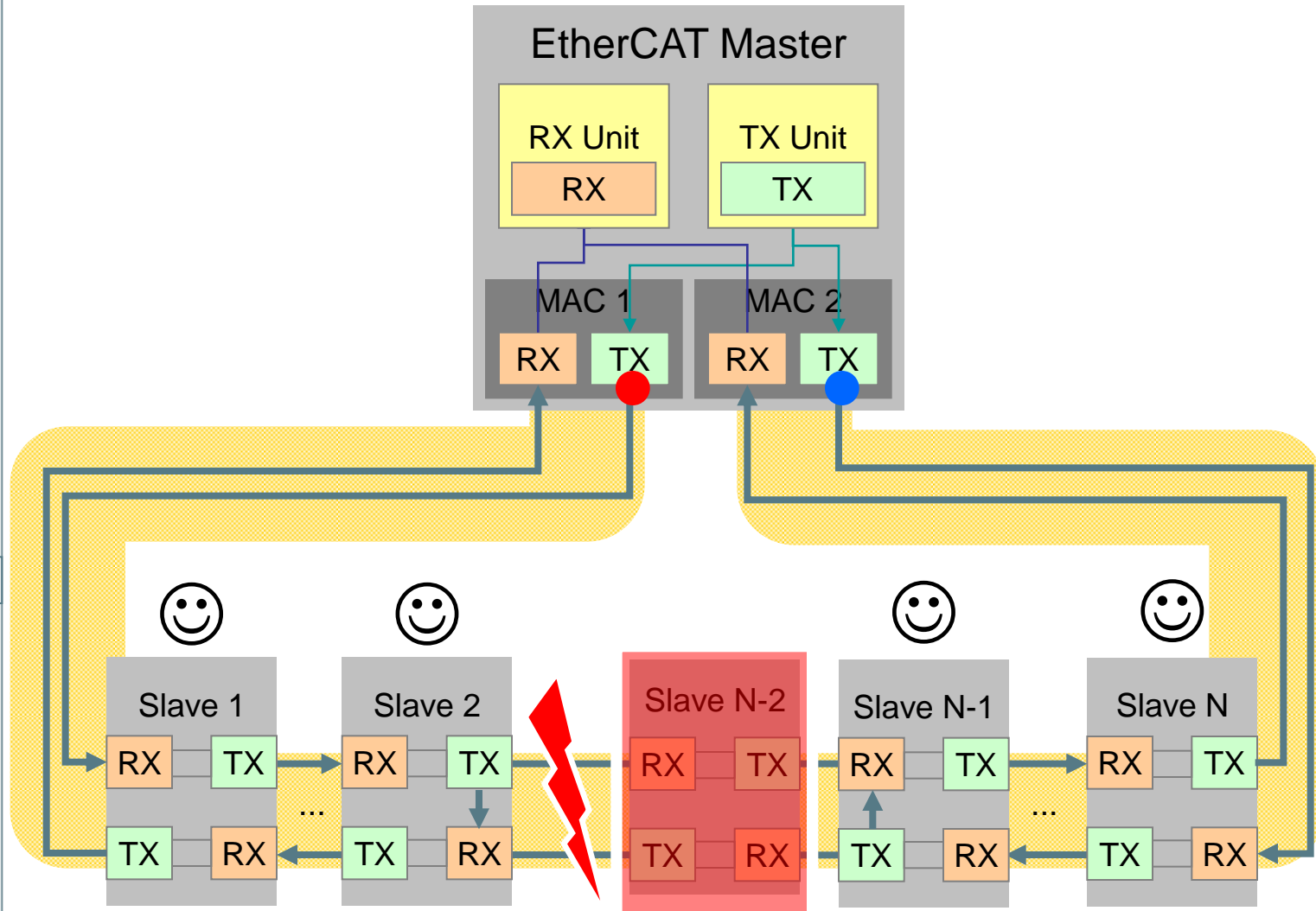
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective ✓
- Easier to implement ✓
- Well proven ✓
- Open ✓
- Conformance ✓
- Safety ✓
- Redundancy
- Versatile



# With Redundancy: Node or Cable Failure

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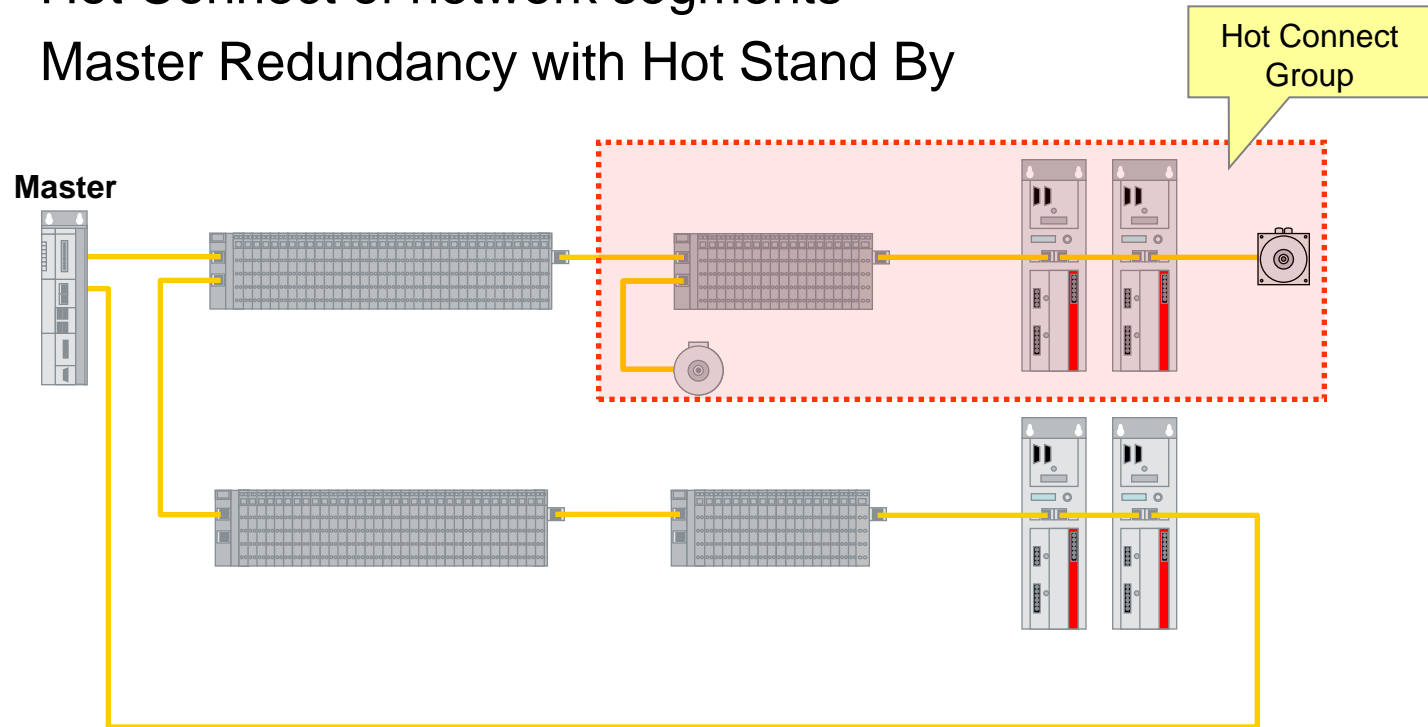


# EtherCAT: High availability

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- Cabling redundancy
  - 2nd Ethernet port needed on master side only
- Hot Swap of devices
- Hot Connect of network segments
- Master Redundancy with Hot Stand By

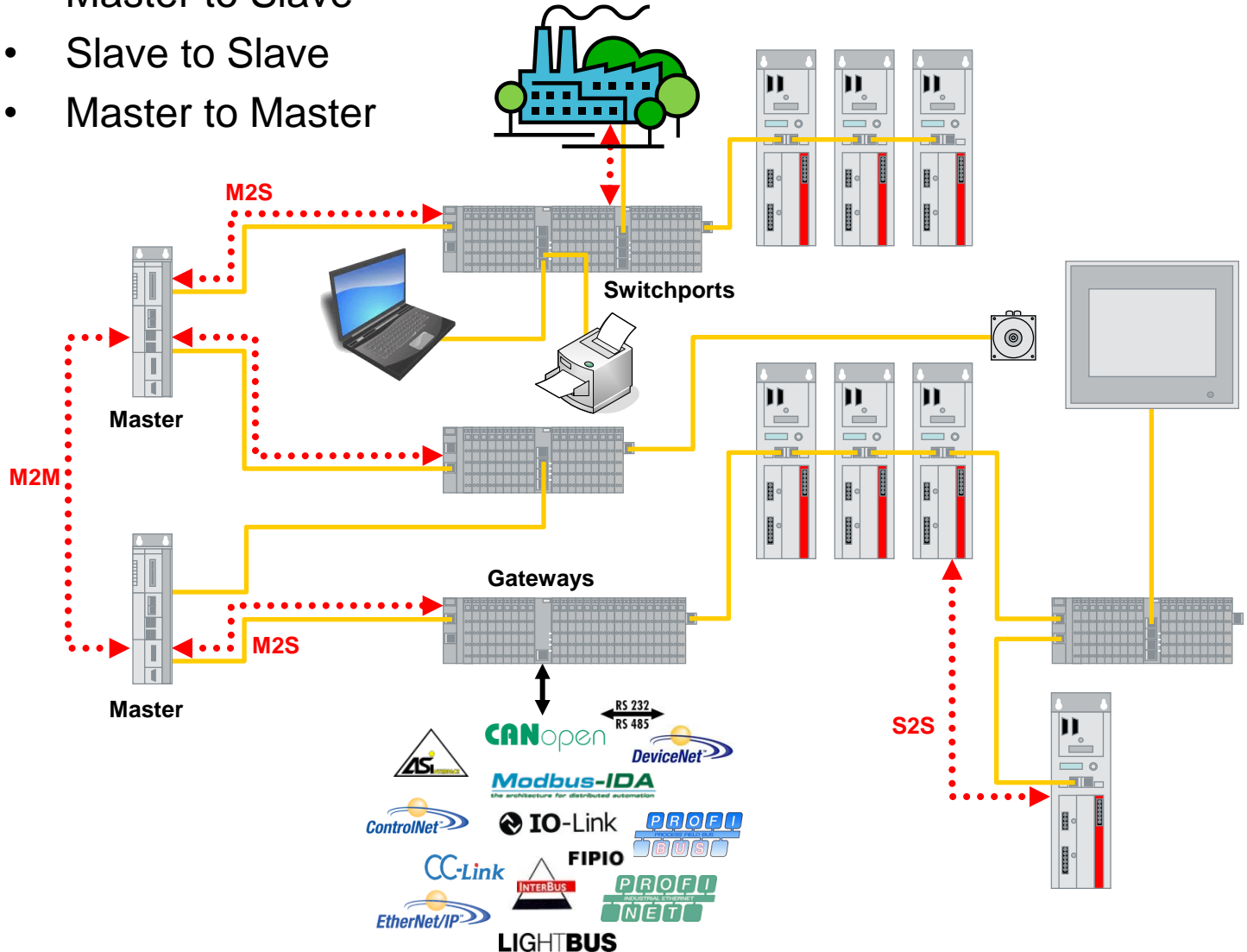




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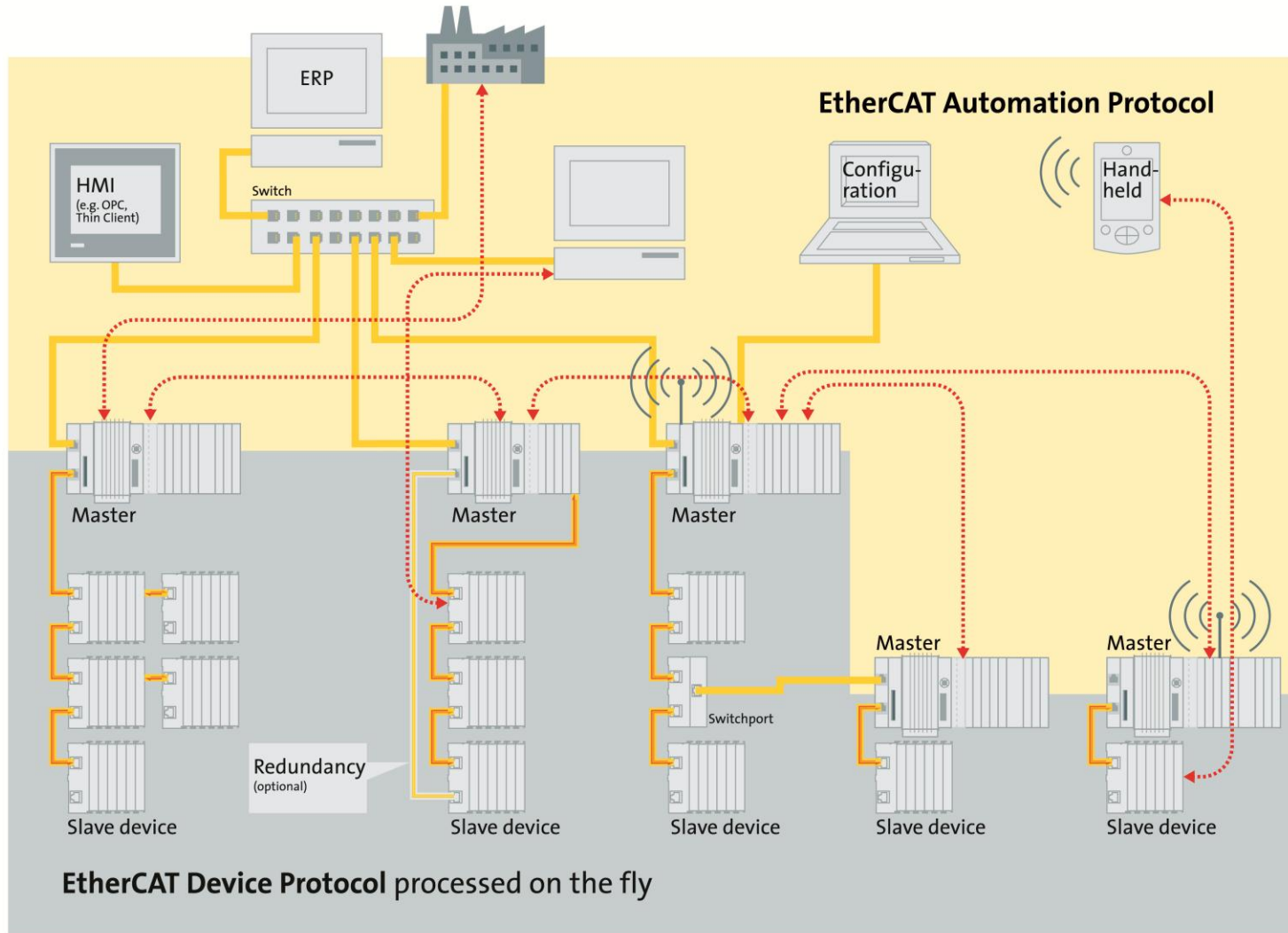
- Master to Slave
- Slave to Slave
- Master to Master

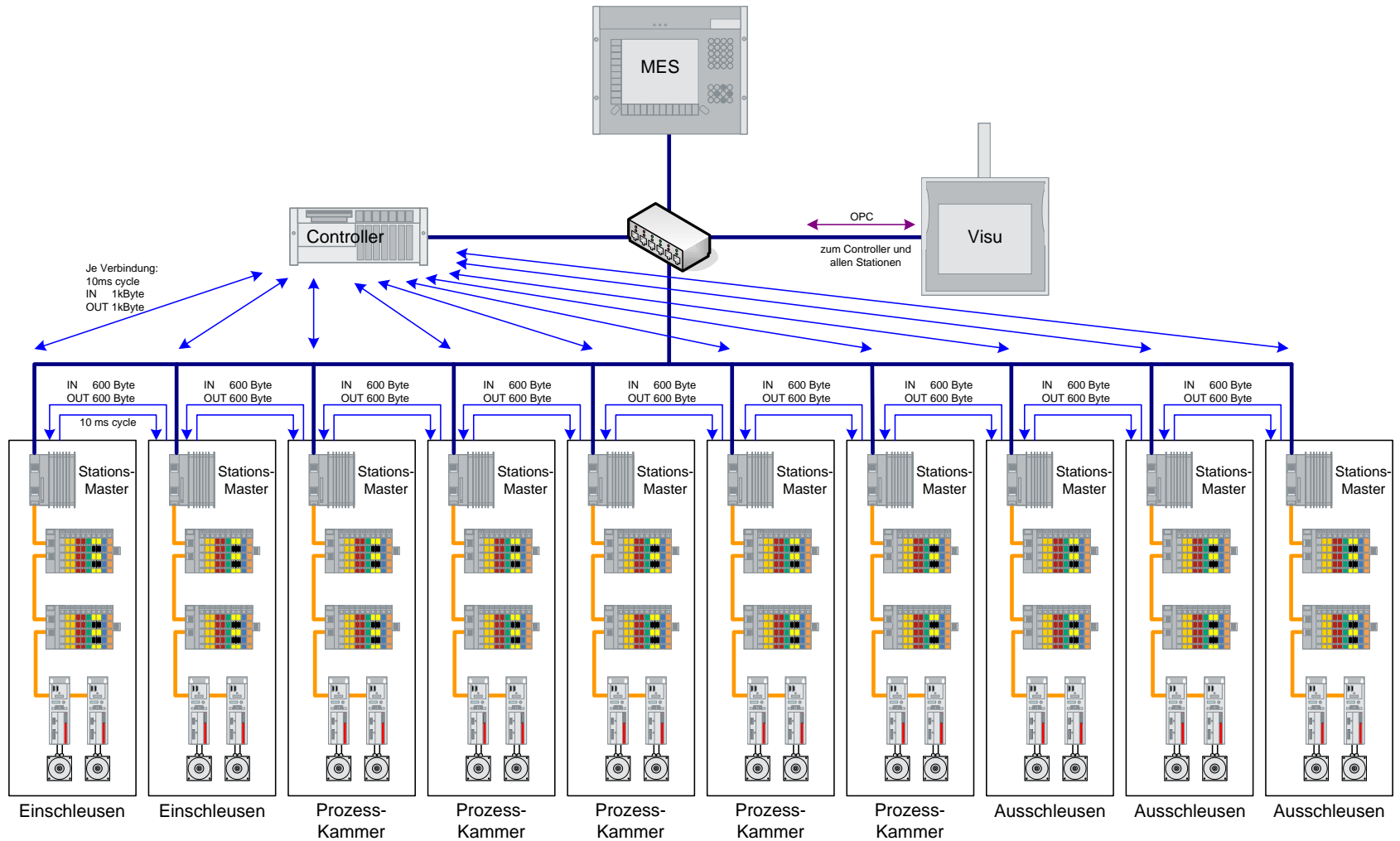


# EtherCAT Automation Protocol

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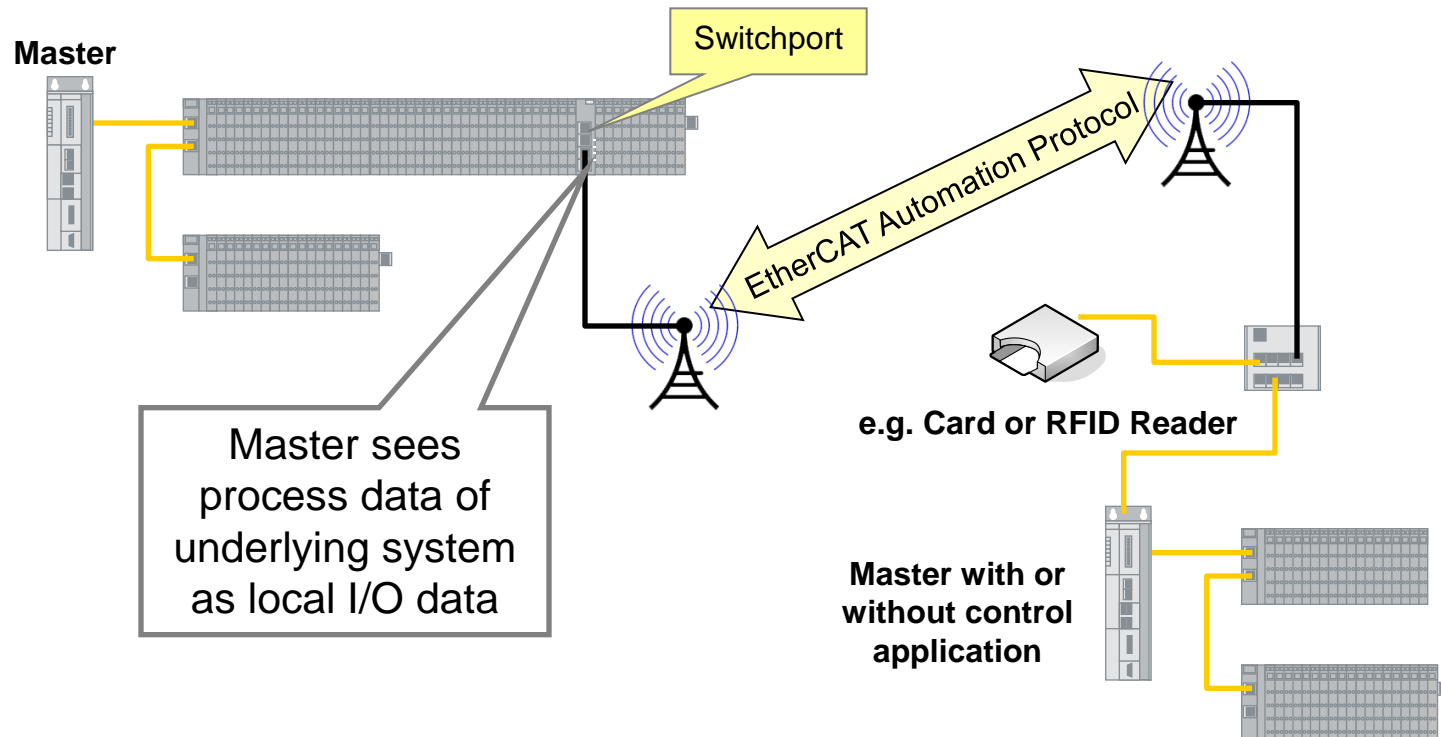


- Ethernet Connection
- EtherCAT Segment
- ↔ EtherCAT Automation Protocol
- ↔ OPC

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- Wireless Devices can be connected via Switchport
- Wireless segment does not slow down EtherCAT communication
- Protocol: EtherCAT Automation Protocol
  - Pushed and/or Polled Process Data Exchange
- Wireless Segment transparent for Master Device



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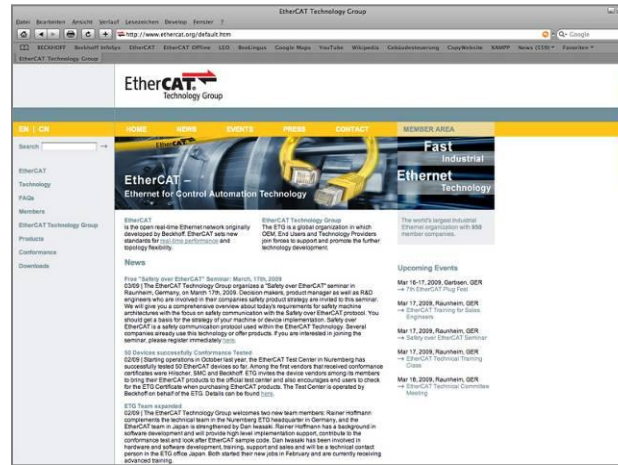
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*Why go for something slower,  
just because it is more  
expensive?*

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Please visit  
[www.ethercat.org](http://www.ethercat.org)  
for more information



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