EtherCAT vs. Modbus vs. Mechatrolink

Oliver Fels,
Technology Marketing
EtherCAT Technology Group
Industrial Ethernet Technologies: Overview

Classification
- Modbus TCP/IP
- Mechatrolink III
- EtherCAT

Summary

EtherCAT vs. Modbus vs. Mechatrolink

October 2016
Basic Slave Device Approaches

- Completely TCP/UDP/IP based
- Ordinary Ethernet Controllers and Switches

### Principle applied by:

- **PROFINET (CbA)**
- **EtherCAT**
- **Modbus**

#### Slave Device Architecture

- **Hardware**
  - Layer 1+2: Ordinary Ethernet Controller
  - Layer 3: IP
  - Layer 4: TCP/UDP
- **Software**
  - Layer 5..7: IT-Applcs
    - HTTP
    - SNMP
    - DHCP
  - Layer 4: Automation API
  - Layer 3: Parameter-Data and Real-Time Data
Basic Slave Device Approaches

- Process Data: Parallel Channel to TCP/UDP/IP
- TCP/UDP/IP Timing Controlled by Process Data Driver
- Ordinary Ethernet Controllers and Switches (or Hubs)

Principle applied by:

- PROFINET (RT)
- ETHERNET POWERLINK

**Slave Device Architecture**

- **Hardware**
  - Layer 1+2
  - Layer 3
  - Layer 4
  - Layer 5..7

- **Software**
  - IT-Applics
    - HTTP
    - SNMP
    - DHCP
    - ...

- **Process Data**

- **TCP/UDP**

- **IP**

- **Process Data Protocol**

- **Automation API**

- **Parameter Data**

- **Application**
Basic Slave Device Approaches

- Process Data: Parallel Channel to TCP/UDP/IP
- TCP/UDP/IP Timing Controlled by Process Data Driver
- Special Realtime Ethernet Controllers or Switches

Principle applied by:

- PROFI "NET" (IRT)
- CC-Link IE
- sercos the automation bus
- MECHATROLINK
- EtherCAT

Hardware

- Layer 1+2
- Layer 3
- Layer 4
- Layer 5..7

Software

- IT-Applcs
  - HTTP
  - SNMP
  - DHCP
  - ...

Slave Device Architecture

- Application
- Process Data
- Automation API
- Parameter Data
- Process Data Protocol
- TCP/UDP
- IP
- Timing-Layer
- Special Realtime Ethernet Controller
Modbus/TCP: Overview

- Schneider Electric Approach: serial Modbus on TCP/IP
- Follows Approach A
- Few Services, simple to implement
- Widely used
- Many Products available
- Non-Real-Time Approach
Modbus/TCP: Function Principle

- **Polling**
- Each Request/Response Cycle passes TCP/IP Stack 4 Times
- plus Switch Delays
- Depending on Client, Poll Request can be issued before the corresponding response has returned.
In April 2007, Schneider Electric joined ODVA as principal member and announced EtherNet/IP products for 2008.

ODVA announced „to provide compatibility of Modbus®/TCP devices with networks built on CIP”

A “Modbus Integration SIG” was established to specify the “CIP to Modbus Translator”

Modbus Translation Services for Modbus TCP devices were added to the CIP Specifications in Nov 2007

Only 94 member companies listed as of Oct 4th, 2016

Last press release on website is from 2011 (!)

Future of Modbus/TCP looks uncertain, since driving force seems to walk away
Mechatrolink III: Overview

- Originally developed by Yaskawa, presently maintained by the MMA (Mechatrolink Members Association)
- Two major variants:
  - II (Serial link, 10 Mbit/s)
  - III (Ethernet-based, 100 Mbit/s)
- Follows approach C
- Active Master Plug-in Card, no Standard NICs (or special ASIC/FPGA)
- Medium Access Control by Polling
- Request/Response principle (not in scale)
Mechatrolink III: Limitations

- Maximum number of slaves: 62
- Overall Network Performance depends on Slave Implementation + Topology:
  - Fast response time requires powerful processors on the slave (controller) side – or implementation in Hardware (ASIC or FPGA)
  - Some „idle time“ on the media, caused by stack delays plus cascaded hubs

## Mechatrolink III: Bandwidth Utilization

### Minimum Ethernet Frame: 84 Bytes

Example: with 8 Bytes Process Data (64 I/O): $8/84 = 9.52\%$ Application Data Ratio

≥ 84 Bytes, regardless which Protocol

<table>
<thead>
<tr>
<th>Minimum Ethernet Frame Payload: min. 46 Bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ethernet HDR</strong></td>
</tr>
<tr>
<td>14 Bytes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>≥ 84 Bytes, e.g. with Mechatrolink</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ethernet HDR</strong></td>
</tr>
<tr>
<td>14 Bytes</td>
</tr>
</tbody>
</table>

### Bandwidth Utilization

- **Minimum Ethernet Frame**: 84 Bytes
- **Example**: with 8 Bytes Process Data (64 I/O): $8/84 = 9.52\%$ Application Data Ratio
- ≥ 84 Bytes, regardless which Protocol

![Diagram showing minimum Ethernet frame payload](image-url)
Performance is limited:
- by the number of slaves
- by the number of data

Typical < 8 Byte (for each device) application allows only a maximum number of 11 slaves (!) at 250us cycle time

<table>
<thead>
<tr>
<th>Transmission Cycle Time (μsec)</th>
<th>Number of Slaves</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1Byte</td>
</tr>
<tr>
<td>0.125</td>
<td>1</td>
</tr>
<tr>
<td>0.25</td>
<td>2</td>
</tr>
<tr>
<td>0.75</td>
<td>5</td>
</tr>
<tr>
<td>2.5</td>
<td>11</td>
</tr>
<tr>
<td>5.0</td>
<td>19</td>
</tr>
<tr>
<td>10.0</td>
<td>31</td>
</tr>
<tr>
<td>20.0</td>
<td>40</td>
</tr>
<tr>
<td>30.0</td>
<td>62</td>
</tr>
<tr>
<td>40.0</td>
<td>62</td>
</tr>
<tr>
<td>50.0</td>
<td>62</td>
</tr>
<tr>
<td>60.0</td>
<td>62</td>
</tr>
<tr>
<td>70.0</td>
<td>62</td>
</tr>
<tr>
<td>80.0</td>
<td>62</td>
</tr>
</tbody>
</table>


*min. cycle time = 62.5us (when using a HUB)
Mechatrolink III: Performance

- Performance is limited:
  - by the topology
  - Min. cycle time increases to 62.5us when using a HUB

Mechatrolink III: Error Detection

- Through big overhead by sending one frame per device and command:
  - higher error rate expected
  - higher number of lost frames possible

- Example of the effect of statistic cycle time errors @Mechatrolink III:

- Example of the effect of statistic cycle time errors @EtherCAT:
EtherCAT: Overview

- Originally developed by Beckhoff Automation
- One Version since 2003
- Follows approach C
- Key principle: Frame Processing „on the fly“
- Open technology
- ETG is the biggest Industrial Ethernet organization
- Hard-Real time down to the I/O level
- Master (SW) uses Standard Ethernet Controller
- Slave devices uses cheap ASIC or FPGA
- EtherCAT P offers combined power and communication
- Integrated Safety
- Precise Synchronization
- Unparalleled Product Variety
**EtherCAT: Functional Principle**

- Unique functional principle: **On-the-fly**

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

- Transmission Rate:
  - 2 x 100 Mbit/s (Fast Ethernet, Full-Duplex)

- Update Times:
  - 256 digital I/O in 11 µs
  - 1,000 digital I/O distributed to 100 nodes in 30 µs = 0.03 ms
  - 200 analog I/O (16 bit) in 50 µs, 20 kHz Sampling Rate
  - 100 Servo-Axis (each 8 Byte In + Out) in 100 µs = 0.1 ms
  - 12,000 digital I/O in 350 µs
**EtherCAT: Synchronization**

- Precise Synchronization (<< 1 µs!) by exact adjustment of distributed clocks.
  - Advantage: Accuracy does not depend on master precision, small communication jitter and thus implementation in software only is acceptable and does not deteriorate synchronization
**EtherCAT: Standard Ethernet**

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

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### EtherCAT Datagrams

<table>
<thead>
<tr>
<th>Type</th>
<th>Res.</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Bit</td>
<td>4 Bit</td>
<td>11 Bit</td>
</tr>
</tbody>
</table>

**Or: via UDP/IP**

<table>
<thead>
<tr>
<th>IP Header</th>
<th>UDP H.</th>
<th>EtherCAT Datagrams</th>
</tr>
</thead>
<tbody>
<tr>
<td>160 Bit</td>
<td>64 Bit</td>
<td>48 -1470 Byte</td>
</tr>
</tbody>
</table>

**MTU: max. 1514 Byte**

- **Embedded in Standard Ethernet Frame, EtherType 0x88A4**
- **Ethernet Header**
  - Or: via UDP/IP
  - UDP Port 0x88A4

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**EtherCAT**

Classification
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- Mechatrolink III
- Summary
EtherCAT: Flexible Topology

- Maximum number of slaves: **65,535**
- Topology variants like Line, Star, Tree, Daisy Chain + Drop Lines possible; can be used in any combination!
- Standard Ethernet cabling
  - Copper (100 m), Fibre Optics (> 2km), LVDS
- Branches can be connected/removed at run time ("Hot Connect")
EtherCAT I/O Vendors

ABB
Ackermann
ACS Motion Control
ADDI-DATA
Adlink
AFT Fahrzeugtechnik
Algo System
Amo Dynamics
Anca Motion
AutomationX
B&R
Balluff
Baumüller
BBH
Beckhoff
Belden
Berghof
Brunner Elektronik
Bosch Rexroth
CEC
Cosworth
CREVIS
CSM
Deif
DEWESoft
Dina Elektronik
dSPACE
Eckelmann
ectronic
eclobau
esd
Festo
Foshan Shunde Gather Win Information Tech.
Galil Motion Control
Gantner
GE Intelligent Platforms
Gefran
Grossenbacher
HBM
Helmholz
Hitachi
IDS
Imc/Additive
IPC DAS
ISAC
IXXAT
Jäger Messtechnik
Jetter
Jumo
KEB
KEBA
Keyence
kk-electronic
Knestel
Kolektor Synatec
Kollmorgen
Kuhnke
Lenze
M-System
MaVi
Messung
NEXCOM
MicroControl
Microinnovations/Eaton
Mikrap
MKS Instruments
MKT Systemtechnik
MSC
MTT
Murrelektronik
M-System
National Instruments
NCT
Omron
Panasonic SUNX
Parker Hannifin
Plz
Phoenix Contact
Power Instruments
Prima Electro
Renesas
Schaeffler Engineering
Schweitzer Engineering Laboratories / SEL
SERAD
SEW Eurodrive
SIPRO
Shanghai Xinhua
SHF
SMC
SOFTLINK
Sontheim Industrie Elektronik
TETRA
TexComputer
TR Elektronik
Turck
UFG Elettronica
Unidor
Unitro
VIPA
Wachendorff
WAGO
Watlow
Weidmüller
Wenglor
Wieland Electric
EtherCAT Chips from Multiple Sources

**ASIC**
- ESC10/20: Altera® Cyclone™-I
- IP-Core for Altera® Cyclone™-II
- IP-Core for Altera® Cyclone™-III
- IP-Core for Altera® Cyclone™-IV
- IP-Core for Altera® Stratix™-V
- IP-Core for Altera® Stratix™-IV
- IP-Core for Xilinx® Spartan™-6
- IP-Core for Xilinx® Spartan™-7
- IP-Core for Xilinx® Kintex™-7
- IP-Core for Xilinx® Artix™-7 + Zync™

**FPGA**
- Altera® Cyclone™-I
- Altera® Cyclone™-II
- Altera® Cyclone™-III
- Altera® Cyclone™-IV

**μC, μP**
- TI Sitara™ ARM® Cortex® A8 AM335x
- Renesas R-IN32M3-EC
- Renesas RZ/T1
- TI Sitara™ ARM® Cortex® A9 AM435x
- Infineon ARM® Cortex®-M
- Microchip LAN9252
- Hilscher netX® 100/500
- Beckhoff ET1100
- IP-Core for Altera® Cyclone™-II
- IP-Core for Altera® Cyclone™-IV
- IP-Core for Altera® Stratix™-V
- IP-Core for Altera® Stratix™-IV
- IP-Core for Altera® Max10™
- IP-Core for Xilinx® Artix™-7 + Zync™
### Summary: Performance, Topology, Wiring

<table>
<thead>
<tr>
<th></th>
<th>Modbus TCP/IP</th>
<th>Mechatrolink III</th>
<th>EtherCAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle Time</td>
<td>--</td>
<td>o*</td>
<td>++</td>
</tr>
<tr>
<td>Synchronicity</td>
<td>--</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Throughput of IP Data</td>
<td>++</td>
<td>+</td>
<td>o</td>
</tr>
<tr>
<td>Topology Flexibility</td>
<td>--</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Line Structure</td>
<td>--</td>
<td>o (62)</td>
<td>++ (65535)</td>
</tr>
<tr>
<td>COTS Infrastructure Components</td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>
## Summary: Costs

<table>
<thead>
<tr>
<th></th>
<th>Modbus TCP/IP</th>
<th>Mechatrolink III</th>
<th>EtherCAT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Node Interface Costs</strong></td>
<td>o</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td><strong>Development Effort</strong></td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><strong>Master Costs</strong></td>
<td>+</td>
<td>o</td>
<td>++</td>
</tr>
<tr>
<td><strong>Infrastructure Costs</strong></td>
<td>- (Switch)</td>
<td>o</td>
<td>++ (no Switch)</td>
</tr>
</tbody>
</table>

- o: Better
- ++: Best
# Summary: Strategic Topics

<table>
<thead>
<tr>
<th></th>
<th>Modbus TCP/IP</th>
<th>Mechatrolink III</th>
<th>EtherCAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of supporting organization</td>
<td>++</td>
<td>o</td>
<td>++</td>
</tr>
<tr>
<td>Worldwide User Group</td>
<td>++</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td>Worldwide Vendor Group</td>
<td>++</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td>Technology Stability</td>
<td>++</td>
<td>o</td>
<td>++</td>
</tr>
<tr>
<td>Special Hardware used?</td>
<td>++</td>
<td>- (Master/Slave)</td>
<td>o (Slave)</td>
</tr>
<tr>
<td>Adoption Rate?</td>
<td>++</td>
<td>.</td>
<td>++</td>
</tr>
<tr>
<td>International Standardization</td>
<td>+</td>
<td>?+</td>
<td>+</td>
</tr>
</tbody>
</table>
Contact

ETG Headquarter
Ostendstraße 196
90482 Nuremberg
Germany

Phone:
+49 (911) 540 56 20

E-Mail:
info@ethercat.org

Web:
www.ethercat.org