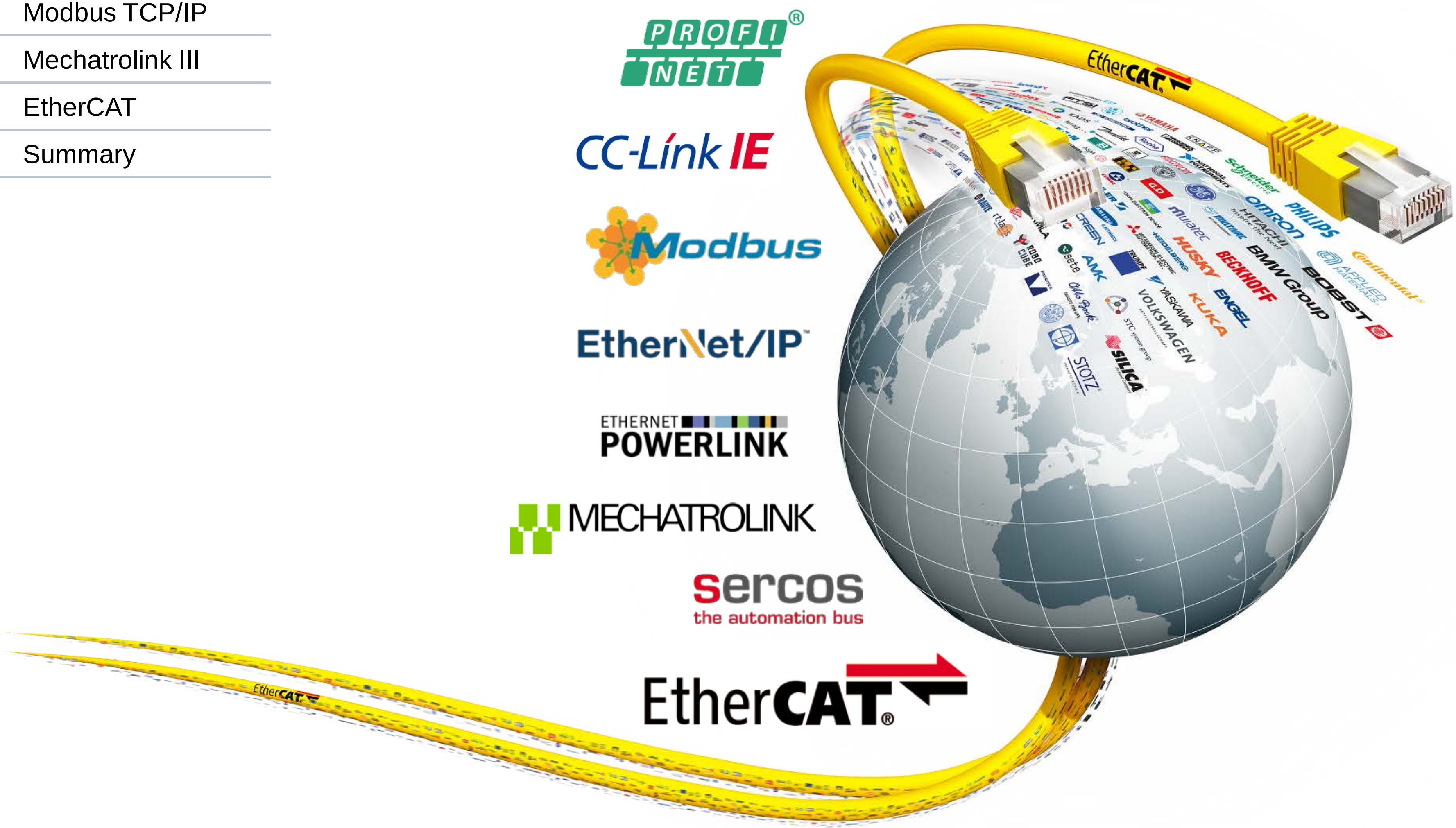
EtherCAT vs. Modbus vs. Mechatrolink

Oliver Fels,
Technology Marketing
EtherCAT Technology Group

EtherCAT Technology Group

Industrial Ethernet Technologies: Overview

- Classification
- Modbus TCP/IP
- Mechatrolink III
- EtherCAT
- Summary



Basic Slave Device Approaches

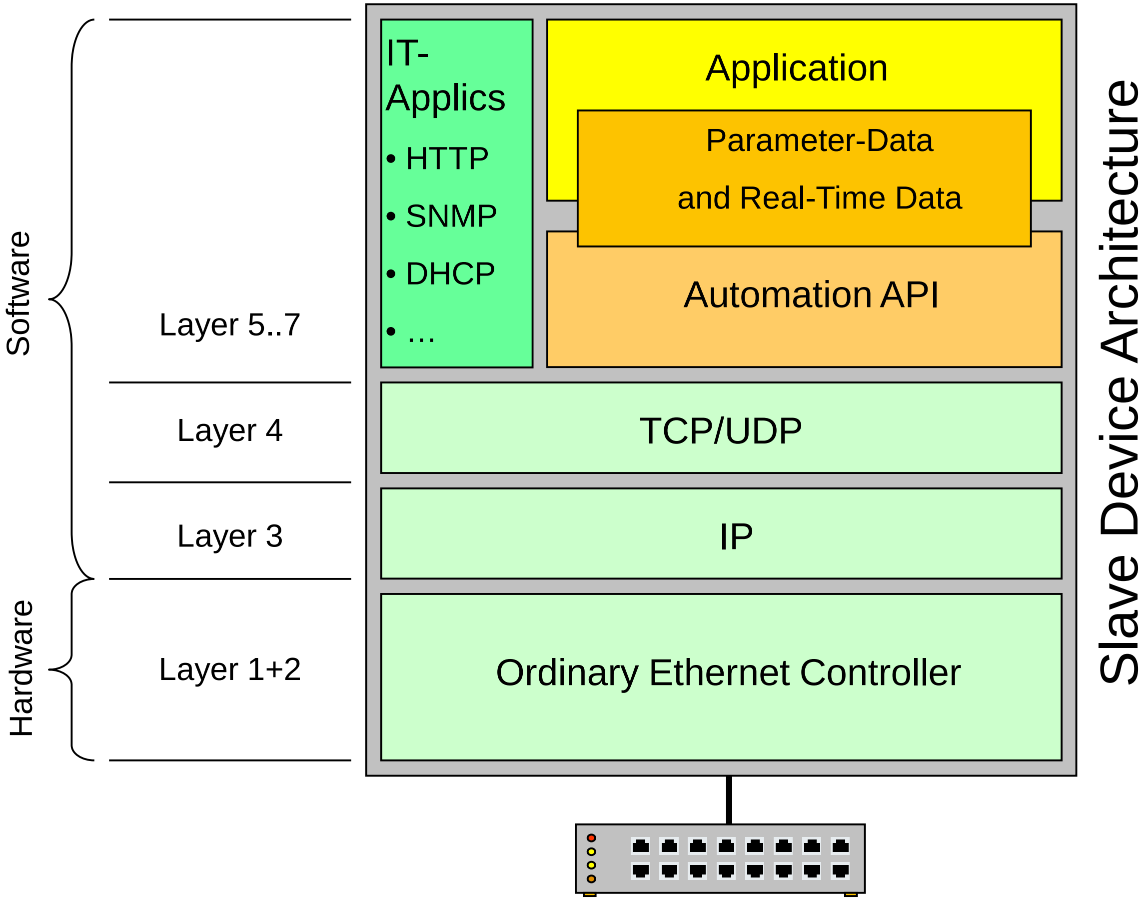
- Completely TCP/UDP/IP based
- Ordinary Ethernet Controllers and Switches

Principle applied by:

PROFINET (CbA)

EtherNet/IP

Modbus



Basic Slave Device Approaches

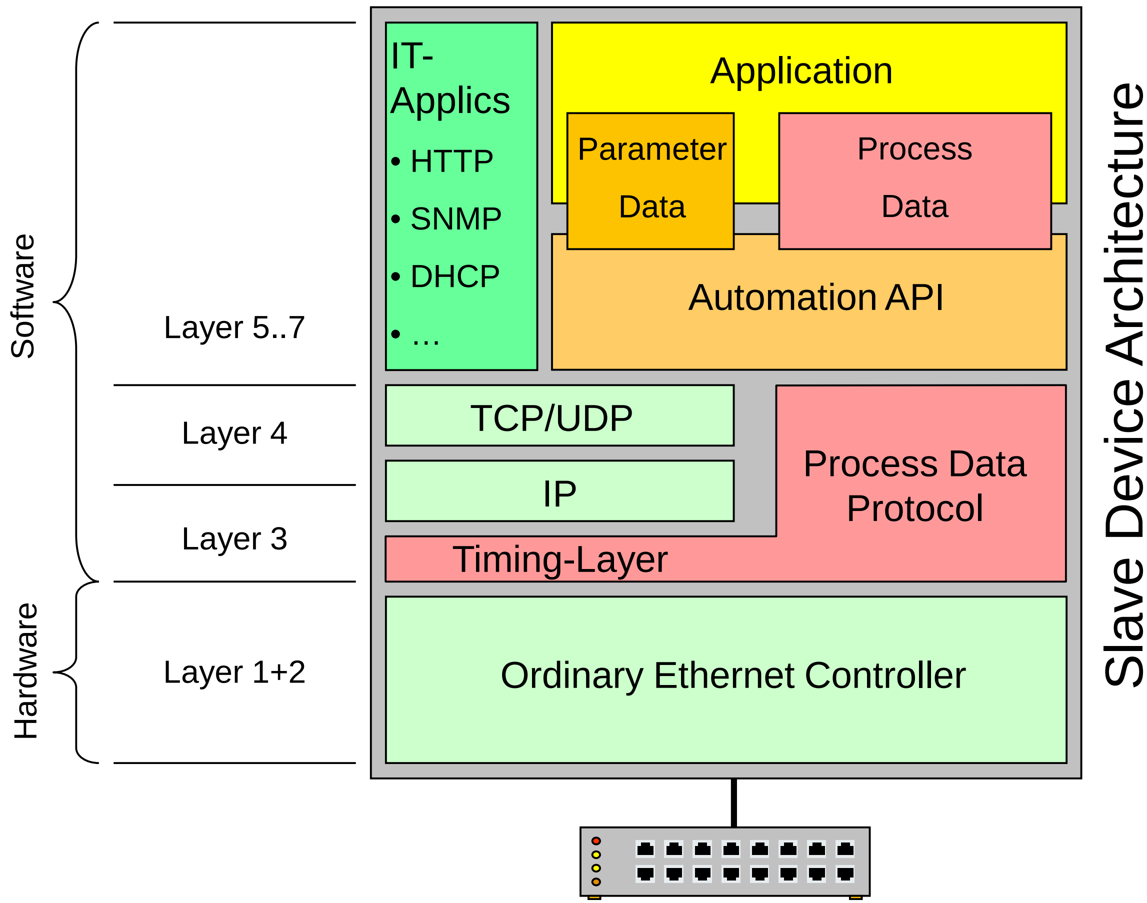
B

- 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



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:

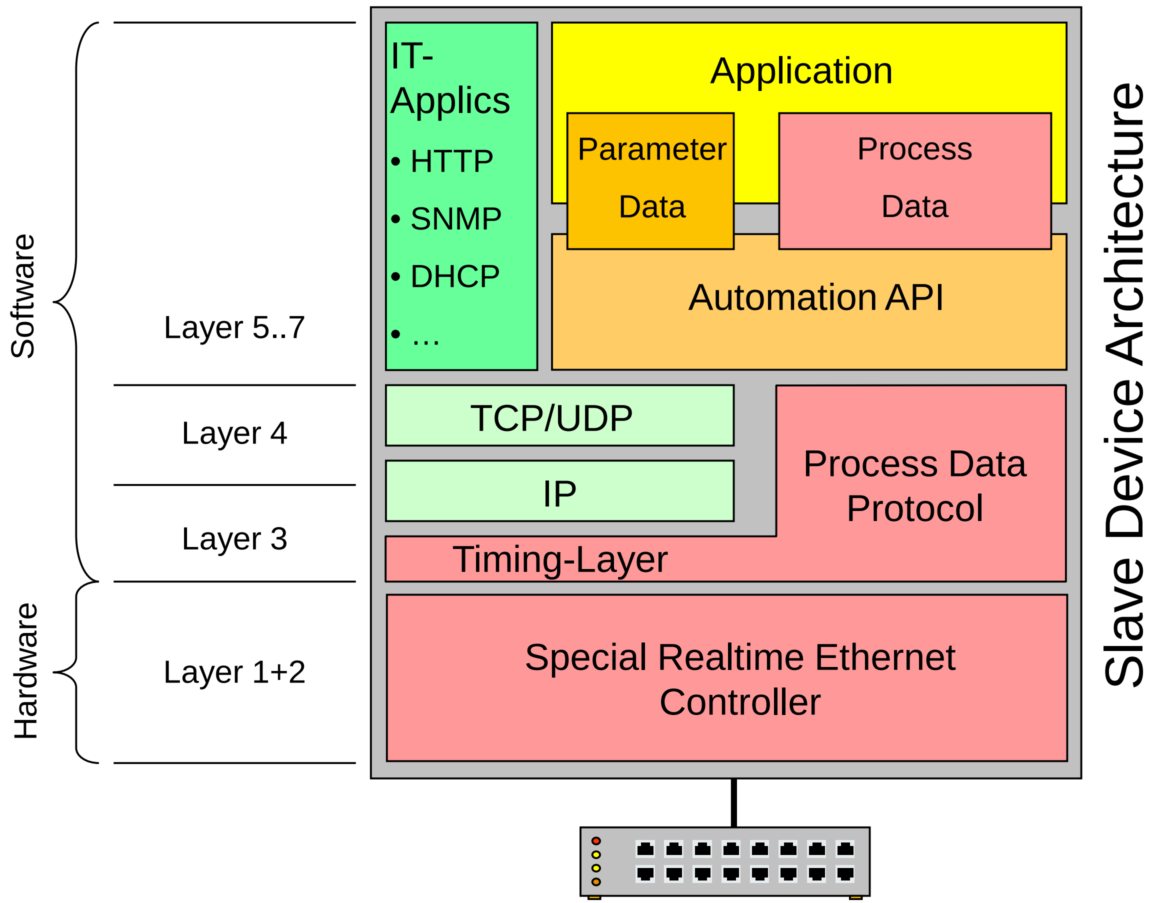
PROFINET (IRT)

CC-Link IE

sercos the automation bus

MECHATROLINK

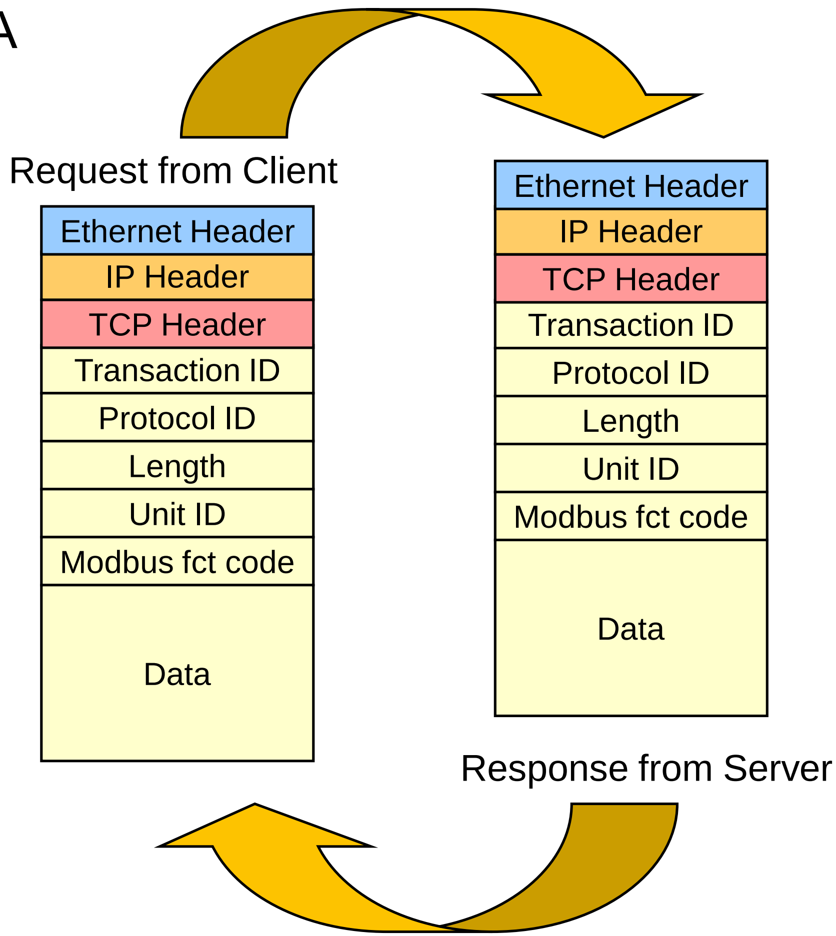
EtherCAT



Modbus/TCP: Overview

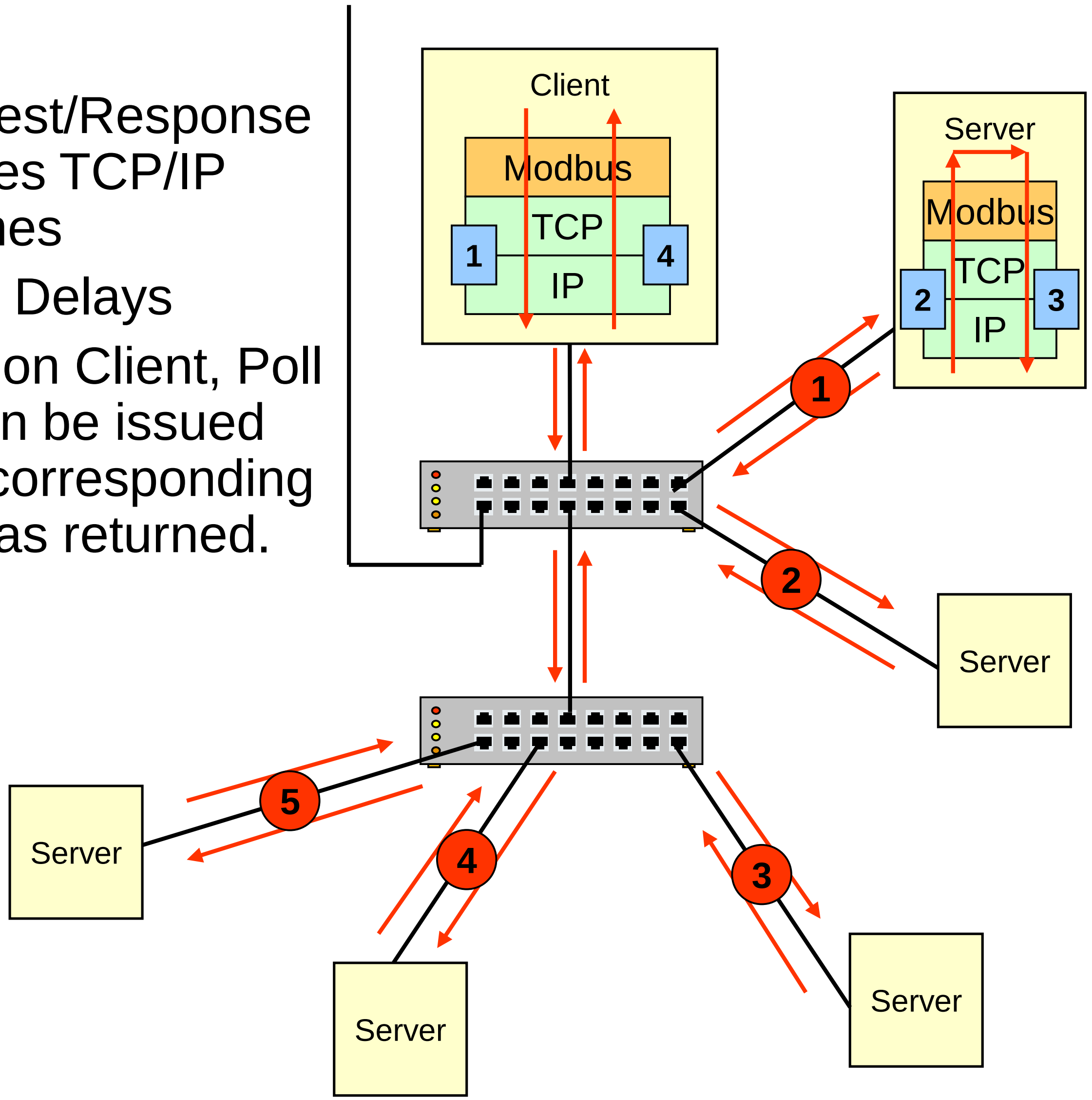
A

- 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.



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Modbus/TCP: Future?

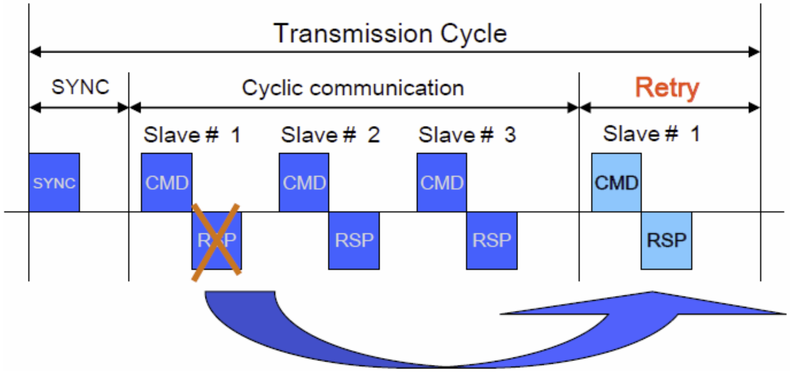
- In April 2007, Schneider Electric joined ODVA as principal member and announced EtherNet/IP products for 2008.
- ODVA announced „to provide compatibility of Modbus®/TCP devices with networks built on CIP"
- A "Modbus Integration SIG" was established to specify the "CIP to Modbus Translator"
- Modbus 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

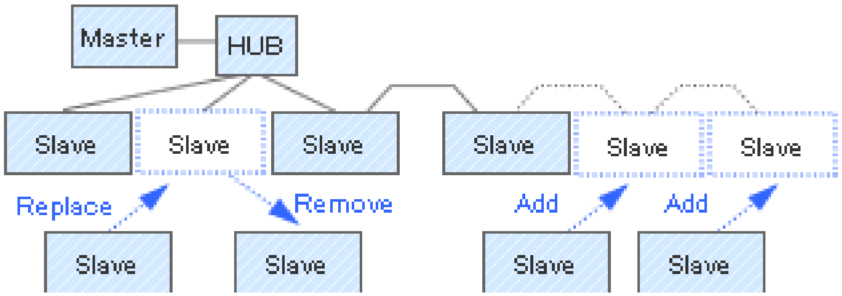
C

- 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



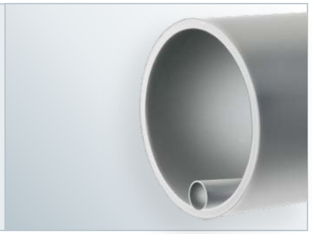
Source: http://www.mechatrolink.org/en/mechatrolink/feature-m3.html

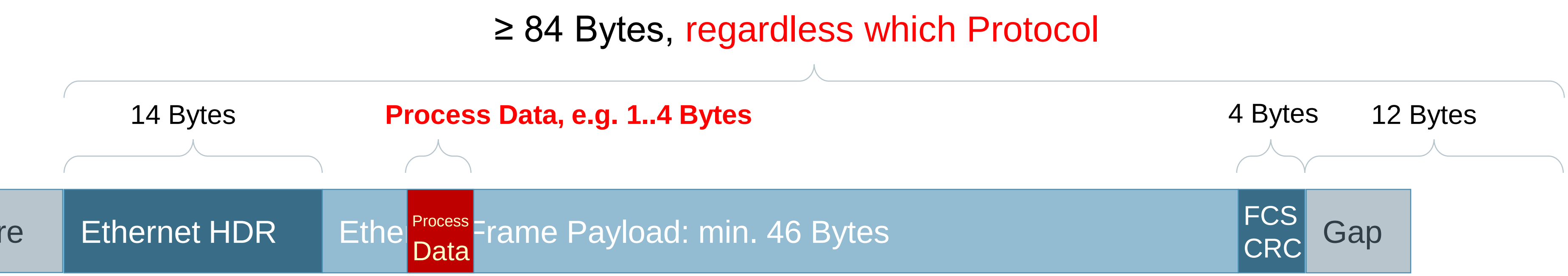
Mechatrolink III: Bandwith Utilization

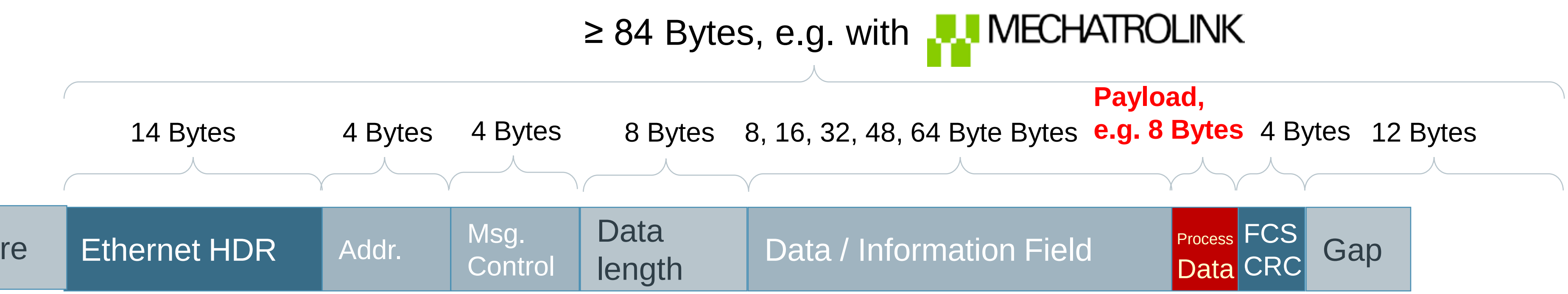
Minimum Ethernet Frame: 84 Bytes

Example: with 8 Bytes Process Data (64 I/O): 8/84 =

9.52 % Application Data Ratio







Mechatrolink III: Performance

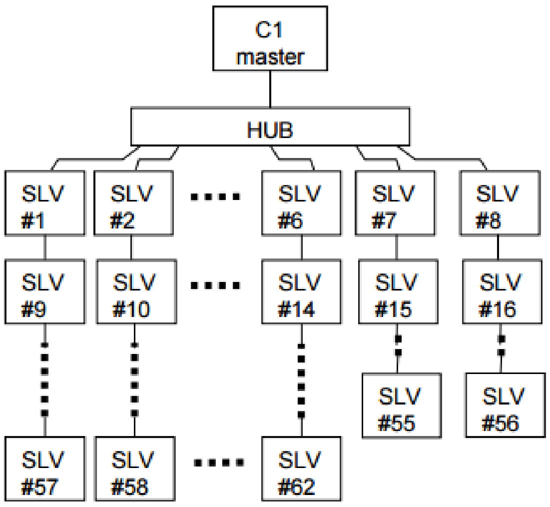
- Performance is limited:
  - by the number of slaves
  - by the number of data
- Typical < 8 Byte (for each device) application allows only a maximum number of 11 slaves (!) at 250us cycle time

Transmission Cycle Time (μsec)	Number of Slaves			
	16byte	32byte	48byte	64byte
31.25	1	1	0	0
62.5	2	2	2	2
125	6	6	5	4
250	11	11	10	9
500	19	19	18	17
1000	31	31	29	28
2000	49	49	47	45
3000	62	62	61	59
4000	62	62	62	62
5000	62	62	62	62
6000	62	62	62	62
7000	62	62	62	62
8000	62	62	62	62

Source: http://www.mechatrolink.org/en/mechatrolink/feature-m3.html
*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

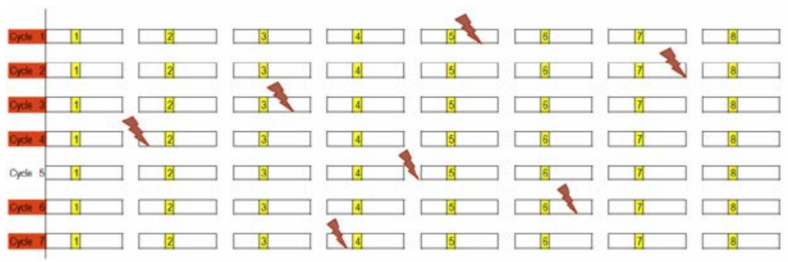


Source: http://www.mechatrolink.org/en/mechatrolink/feature-m3.html

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:



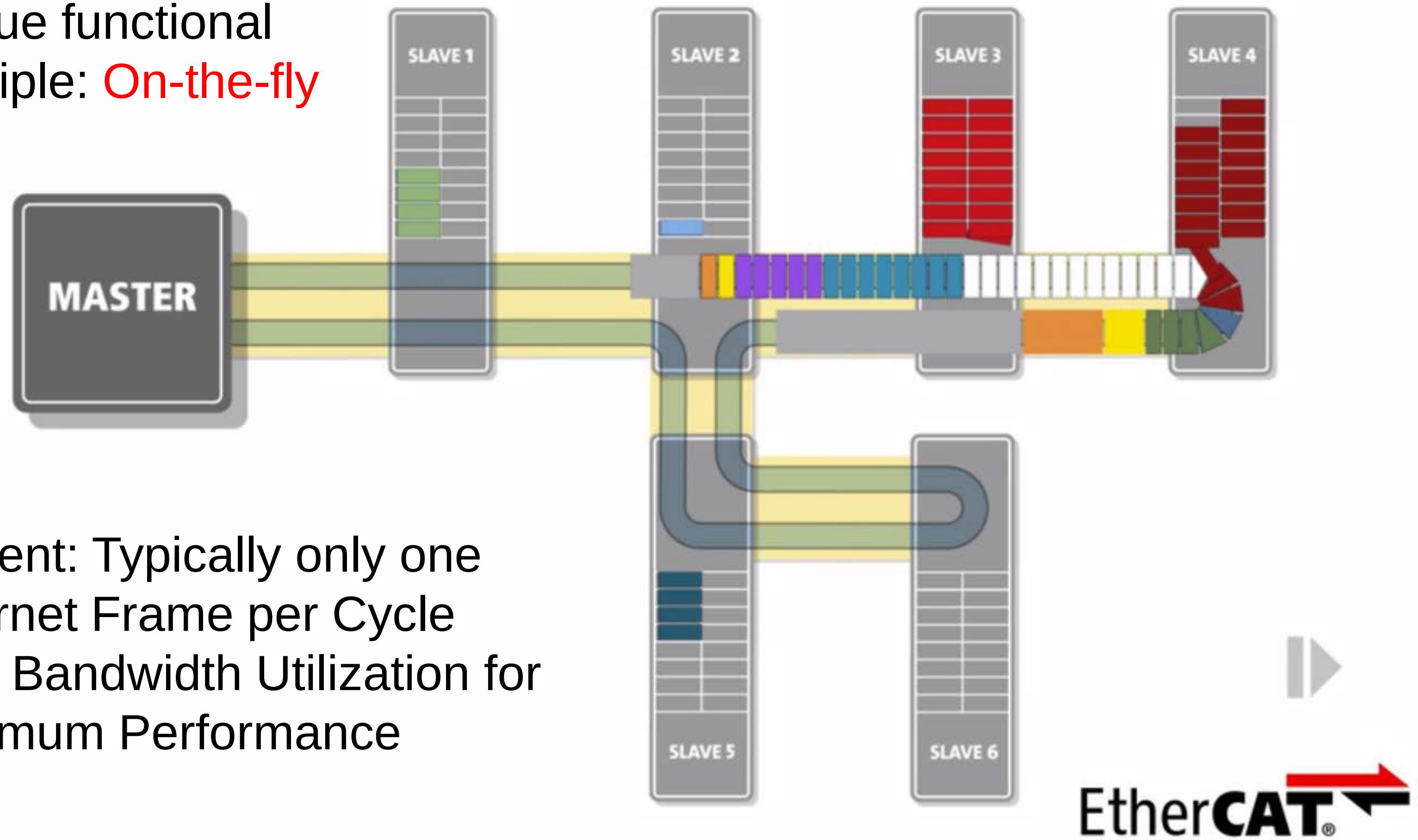
- Example of the effect of statistic cycle time errors @EtherCAT:

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

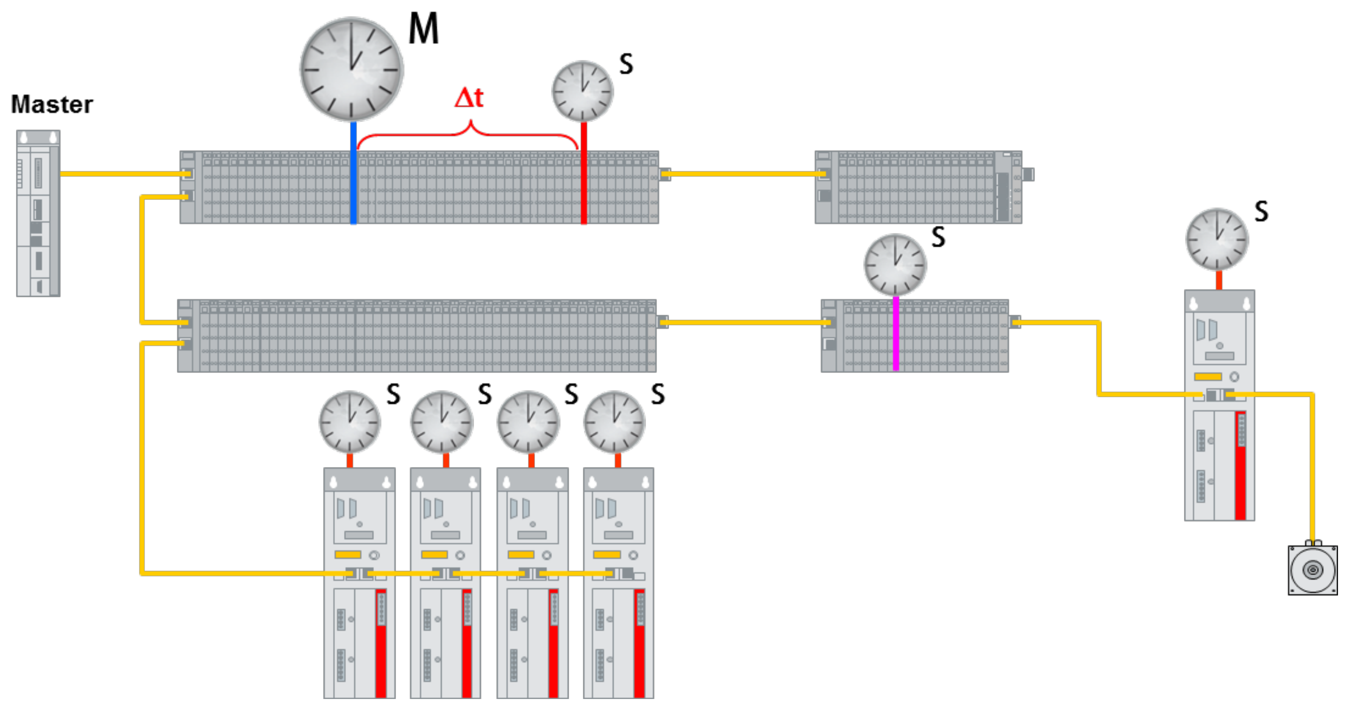
EtherCAT: Highest Performance

- 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

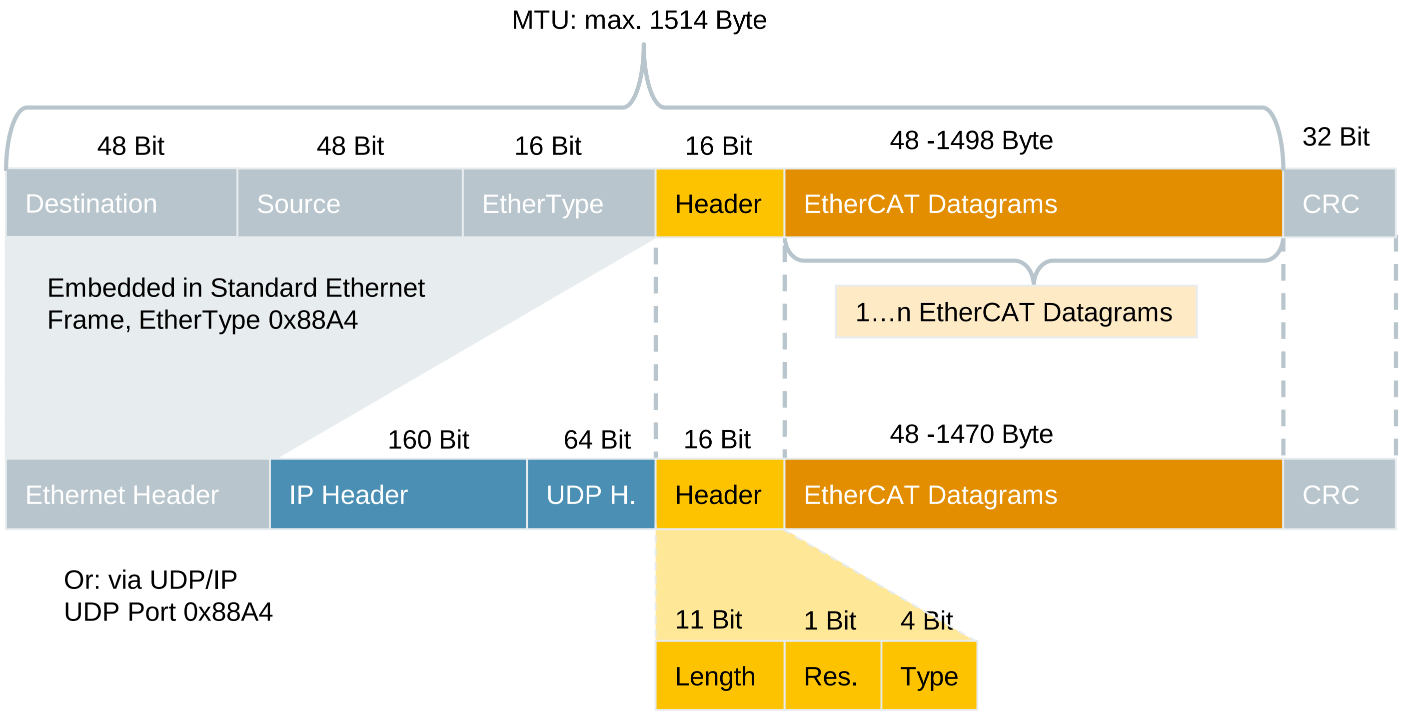
EtherCAT: Synchronization

- 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



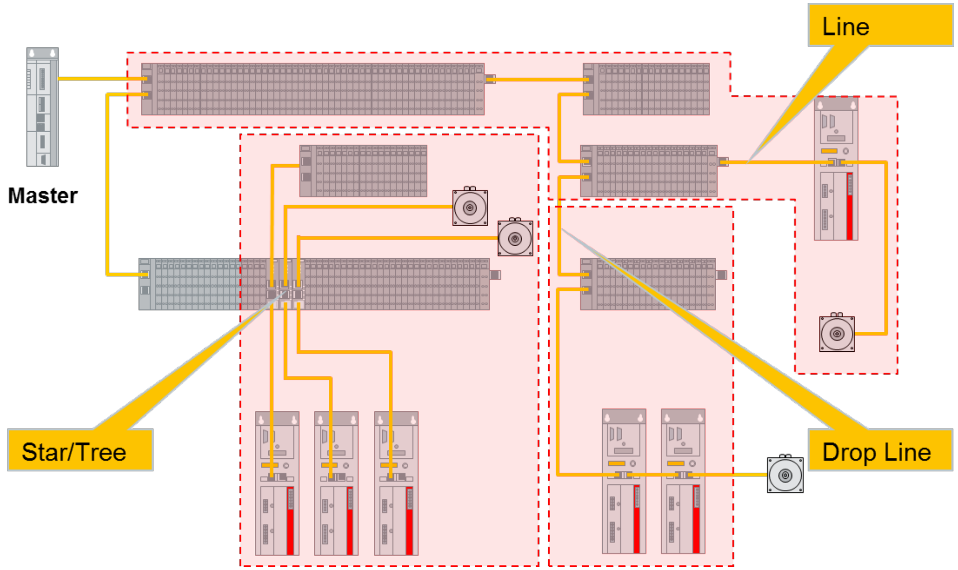
EtherCAT: Standard Ethernet

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



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 Master (Controller) Vendors 193

EtherCAT Drive Vendors

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Panasonic, SEW Eurodrive, LTI Motion (Körber Solutions), Omron, KEB, Beckhoff, JPS, Schneider Electric, Aradex (Automation Drives Controls), Lenze, AMK, Control Techniques, miControl®, LPKF Laser & Electronics, Justek (Linear Motion Technology), Trinamic Motion Control, Bonmet, Sanyo Denki, Toshiba, Kollmorgen (Because Motion Matters™), Delta (Smarter. Greener. Together.), Gather Win, afag, ABB (Power and productivity for a better world™), LS Industrial Systems, Orientalmotor, Faulhaber, Motion Control Inc., Berghof, Danieli Automation, Infranor (Servo Drives & Motion Control), Hiwin (Motion Control & Systems), Hitachi (Inspire the Next), Samsung Electronics, dresden elektronik, Groschopp, Baldor (A member of the ABB Group), JVL (…integration in motion), Parker, Stöber, Festo, Advanced Motion Controls, RS Automation (Reliable & Smart), Co-Trust, Georgii Kobold, Brunner Elektronik, Yaskawa, Kostal, Wago®, ferrocontrol, Hivertec, inc., Step 新时达, Heidrive (Motion & Systems), ACD Gruppe, NCT, Motor Power Company, Technosoft, Jetter, Siko, Lenord + Bauer, Kendrion, Nanotec (Plug & Drive), ESR Pollmeier GmbH (www.esr-pollmeier.de), Baumüller, Cannon Automata, Mechatronic Product Factory, Kuhnke, EPA, LOGic, Sdrive, Moog, Nexcom, iRT (Quality in Motion), Akribis Systems (Where Precision Matters), Robox (motion control), Amoy Dynamics, Macon (Motion Under Control), HWH, Sigmatek, Trio (Motion Technology), esitron, Harmonic Drive AG, metronix servo drives, Higen, Serad (Motion Control), Estun, Phase (Motion Control), IAI (Quality and Innovation), atos, Baumer, Tsino Dynatron 清能德创, Gefran, manz automation, IDAM (INA Drives & Mechatronics), promicon Systems, Prima Electro, Dunkermotoren (advanced motion solutions), LS Mecapion, Jenny Science, Nord, Prodrive Technologies, zub, WEG, Elmo Motion Control, halstrup walcher, Keba (Automation by innovation.), Selema, Nikki Denso, Fastech (Fast, Accurate, Smooth Motion Control), Eckelmann, TDE Macno, Sibonac, Promax (Motion & Control), Wittenstein motion control, Mitsubishi Electric, Ziehl-Abegg, Red One Technologies, copley controls, Eaton (Powering Business Worldwide), Delta Tau Data Systems, Inc., num (CNC HighEnd Applications), Cosmo Techs (Factory Automation Technologies), ACS Motion Control, ingenia (motion control), servan Servoland, ANCA motion, maxon motor (driven by precision), Jenaer Antriebstechnik GmbH, THK (The Mark of Linear Motion), Danfoss, National Instruments, Werner, LinMot®, Harmonic Drive Systems Inc., RTA (Motion Control Systems), Bonfiglioli, Sieb & Meyer, ConverTeam (The Power Conversion Company), DSPautomation, EPA, Föhrenbach Servodrives, CMZ, Servotronix (always in motion™), bachmann., Tetra, Indel AG (Industrielle Elektronik), Fuji Electric FA Components & Systems, 雷赛智能 Leadshine, sipro (sistemi programmabili), Rexroth Bosch Group, elrest

EtherCAT I/O Vendors

105

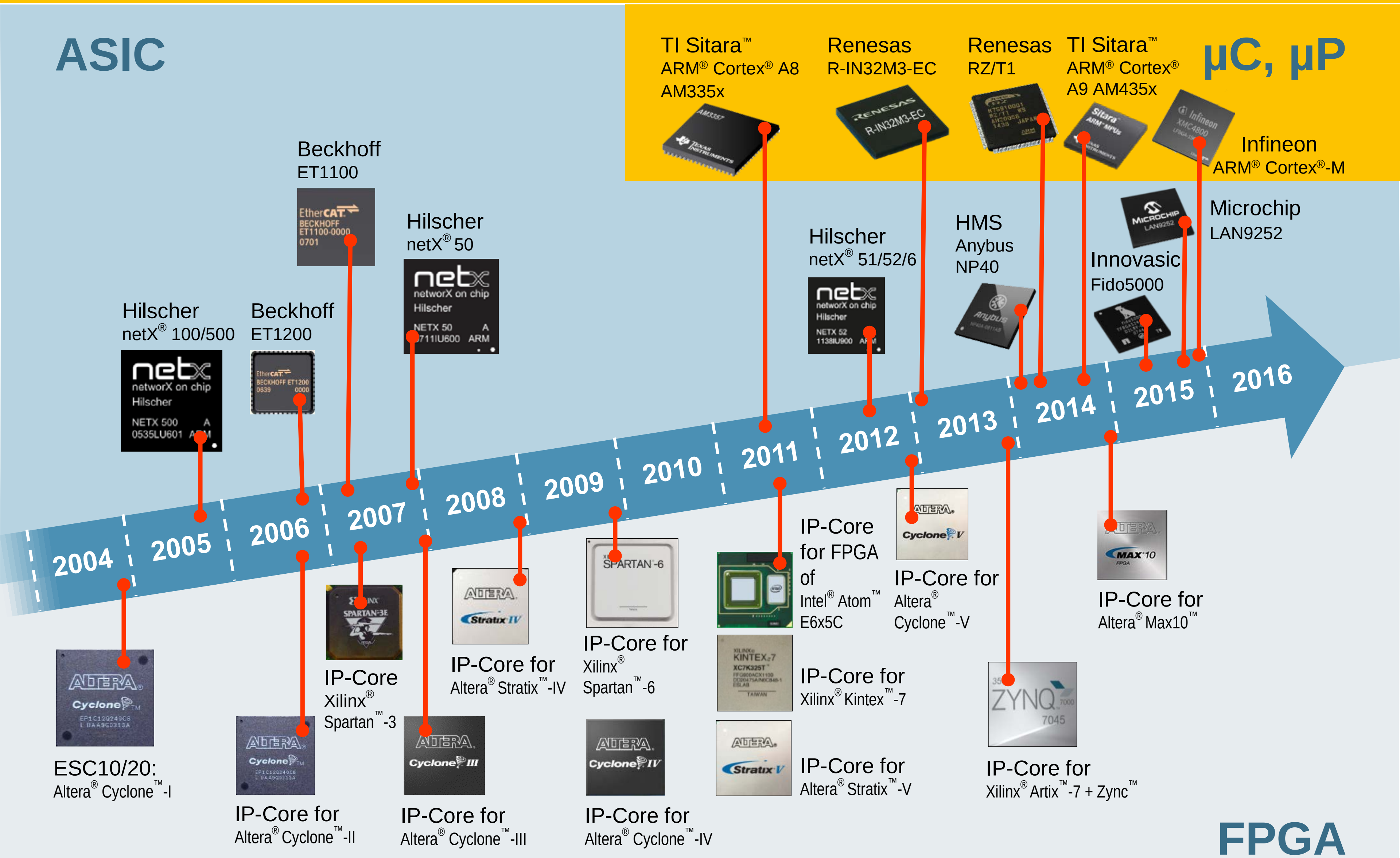
ABB
Ackermann
ACS Motion Control
ADDI-DATA
Adlink
AFT Fahrzeugtechnik
Algo System
Amoy Dynamics
Anca Motion
AutomationX
B&R
Balluff
Baumüller
BBH
Beckhoff
Belden
Berghof
Brunner Elektronik
Bosch Rexroth
CEC
Cosworth
CREVIS
CSM
Deif
DEWESoft
Dina Elektronik
dSPACE
Eckelmann

ectronic
elobau
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
Pilz
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



Summary: Performance, Topology, Wiring

- Classification
- Modbus TCP/IP
- Mechatrolink III
- EtherCAT
- Summary

	Modbus TCP/IP	Mechatrolink III	EtherCAT
Cycle Time	--	o*	++
Synchronicity	--	+	++
Throughput of IP Data	++	+	o
Topology Flexibility	--	+	++
Line Structure	--	o (62)	++ (65535)
COTS Infrastruture Components	++	+	+

Summary: Costs

	Modbus TCP/IP	Mechatrolink III	EtherCAT
Node Interface Costs	o	+	++
Development Effort	++	+	+
Master Costs	+	o	++
Infrastructure Costs	- (Switch)	o	++ (no Switch)

Summary: Strategic Topics

	Modbus TCP/IP	Mechatrolink III	EtherCAT
Size of supporting organization	++	o	++
Worldwide User Group	++	-	++
Worldwide Vendor Group	++	-	++
Technology Stability	++	o	++
Special Hardware used?	++	- (Master/Slave)	o (Slave)
Adoption Rate?	++	.	++
International Standardization	+	?+	+

Contact

ETG Headquarter
Ostendstraße 196
90482 Nuremberg
Germany

Phone:
+49 (911) 540 56 20

E-Mail:
info@ethercat.org

Web:
www.ethercat.org