

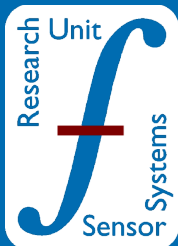


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Austrian Academy  
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# State-of-the-Art on Ethernet Based Real-Time Protocols

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# Real Time Networks

- Agenda

- Ethernet based wired real-time networks
  - PROFINET
  - TTEthernet
  - EtherCAT
  - Ethernet POWERLINK
  - SERCOS III
  - Ethernet/IP
  - INTERBUS, MODBUS TCP, IEC 62439
- How they work, peculiarities, prerequisites



# PROFINET Industrial Ethernet standard for automation

Features	Description
	<ul style="list-style-type: none"><li>• Requires Siemens chip</li></ul>
Network structure	<ul style="list-style-type: none"><li>• Topology – line, bus, star or tree</li><li>• Switched Ethernet transmission with shielded twisted pair cable, alternatively Fiber Optic Media</li><li>• All field devices determine their neighbors - in case of a fault allows replacing field devices without additional tools and prior knowledge</li><li>• Possible to integrate existing networks through proxies</li><li>• Slotted communication</li></ul>
In numbers	<ul style="list-style-type: none"><li>• Data rate 100 Mb/s, in future possible up to 1 Gb/s</li><li>• Each node up to 1.500 bytes per telegram frame</li><li>• Max bus extension 100m</li></ul>



# TTEthernet



Features	
Availability	<ul style="list-style-type: none"><li>• Not open source</li><li>• Patented by TTEch Computertechnik AG and Honeywell</li></ul>
Network structure	<ul style="list-style-type: none"><li>• Hierarchical master/slave network</li><li>• Multiple redundant end systems, switches and segments</li><li>• Can be implemented in HW or SW</li></ul>
Message types	<ul style="list-style-type: none"><li>• Time-triggered messages – highest priority, delay predefined guaranteed</li><li>• Rate-constraint messages – bandwidth predefined, delays have defined limits</li><li>• Best-effort messages – lowest priority</li></ul>
In addition	<ul style="list-style-type: none"><li>• Data rate up to 1Gb/s, upgradeable to 10 Gb/s, available tools for verification of bandwidth requirements for the future design</li><li>• Configurable bus cycle</li></ul>



# EtherCAT high performance Ethernet-based fieldbus system

Features	
Availability	<ul style="list-style-type: none"><li>• Open Source implementation was hindered by licensing problems (30.09.2008)</li><li>• Slave IP Cores for FPGA/ASIC are available, but not free</li></ul>
Principle	<ul style="list-style-type: none"><li>• Environment supports all internet technologies</li><li>• Tolerates other Ethernet-based services and protocols on the same physical network</li></ul>
Network structure	<ul style="list-style-type: none"><li>• Topology – line, tree, star</li><li>• Only one master, does not require a special hardware and can be implemented in software on any standard Ethernet MAC</li><li>• Slave devices read the data addressed to them or insert input data while the telegram passes through the device, many nodes can be addressed with just one frame</li><li>• Data rate up to 100 Mb/s, size - 65535 devices</li></ul>
Synchronization	<ul style="list-style-type: none"><li>• Distributed clock mechanism</li><li>• Slaves are synchronized with the master, knowing the latency of other slaves</li></ul>



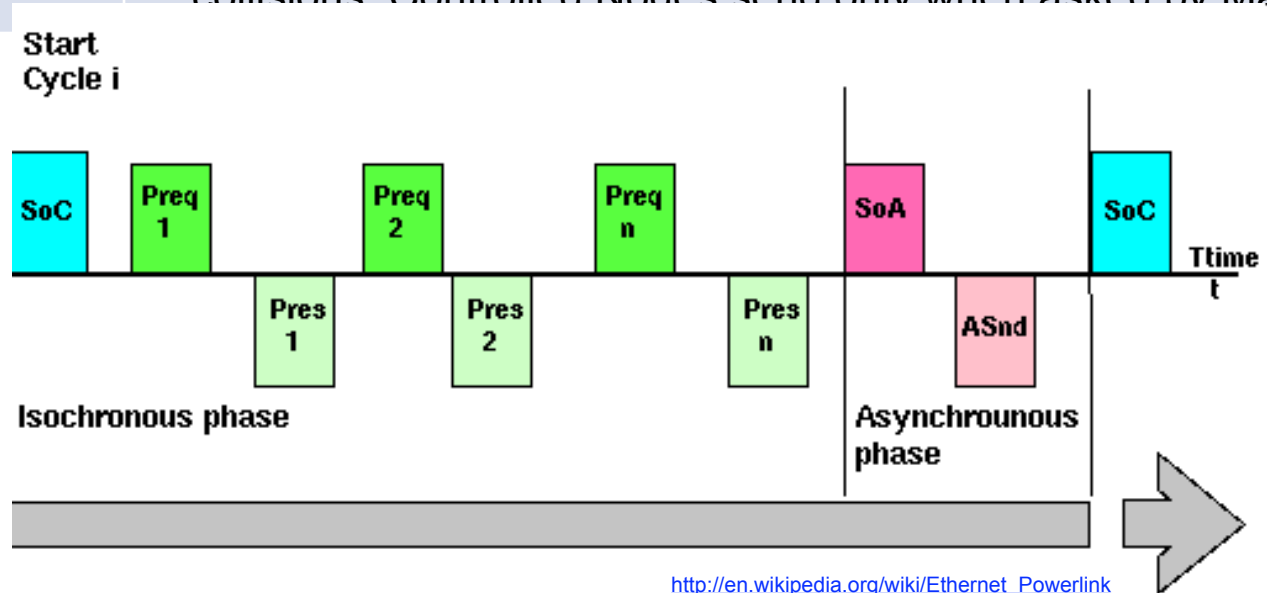
# Ethernet POWERLINK deterministic RT protocol

Features	
Availability	<ul style="list-style-type: none"><li>• Open Source stack implementation (openPOWERLINK)</li><li>• No IP cores available for free</li></ul>
Principle	<ul style="list-style-type: none"><li>• Expands Ethernet with a mixed polling and time slicing mechanism, bringing together Ethernet, CANopen and a newly developed stack for RT data communication</li></ul>
Network structure	<ul style="list-style-type: none"><li>• Topologies - star, tree, ring or daisy chain</li><li>• Hot plugging for any node on the bus</li><li>• Cross-traffic</li><li>• Using repeating HUBs instead of switches minimizes jitter and latency</li><li>• Irrelevant whether data is transmitted via copper patch cables, fiber-optic lines</li><li>• RT segment must be separated from “normal” traffic by a bridge/router</li></ul>



# Ethernet POWERLINK

Features	
Data transfer	<ul style="list-style-type: none"> <li>• Time slicing mechanism guarantees transfer of time-critical data in short isochronal cycles with configurable response times</li> <li>• Non-time-critical data is transferred in asynchronous phase, access is granted for a single message only</li> <li>• Transmissions checked by a Managing Node to avoid collisions. Controlled Nodes send only when asked by Manager</li> </ul>



[http://en.wikipedia.org/wiki/Ethernet\\_Powerlink](http://en.wikipedia.org/wiki/Ethernet_Powerlink)



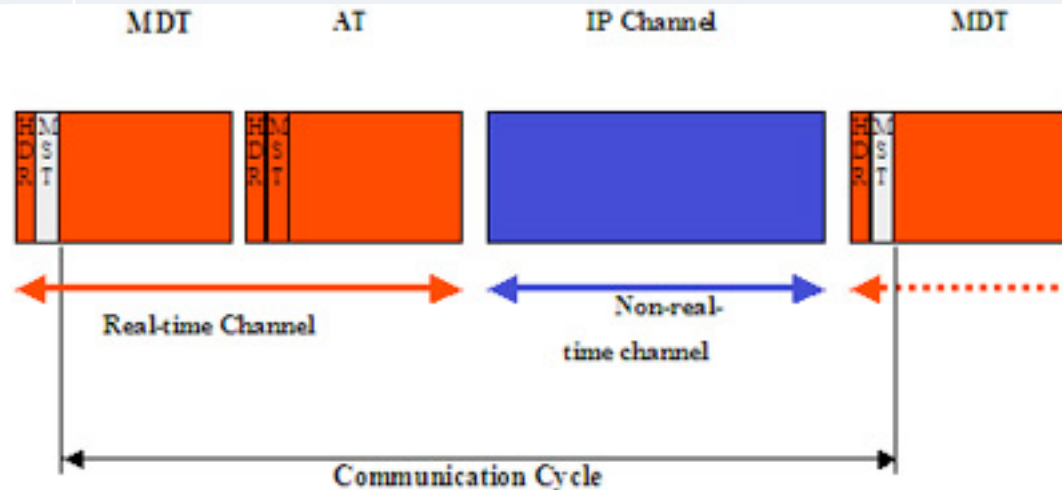
# Ethernet POWERLINK

Features	
Synchronization	<ul style="list-style-type: none"><li>• Clock-synchronization of all nodes in the sub-microsecond range to the Managing Node</li><li>• At the beginning of each isochronous phase, the MN transmits the multicast SoC message very precisely to synchronize all nodes</li></ul>
Redundancy	Enables following types: <ul style="list-style-type: none"><li>• ring redundancy,</li><li>• partial ring redundancy,</li><li>• cable redundancy,</li><li>• Managing Node redundancy (up to 10)</li></ul>
In numbers	<ul style="list-style-type: none"><li>• 1 Gb/s support</li><li>• Max nodes 240</li><li>• 100 meters per connection</li><li>• Cycle times under 200 <math>\mu</math>s</li></ul>



# SERCOS III Serial Real-time COmmunication System

Features	
Availability	<ul style="list-style-type: none"> <li>• License free slave IP core available for download</li> <li>• Standardized under IEC 61491</li> </ul>
Principle	<ul style="list-style-type: none"> <li>• Sending data in cyclic telegrams – Master Data Telegram (MDT) and Acknowledge Telegram (AT)</li> <li>• Processing is done in hardware (“on the fly”) while telegrams are passing through the mode</li> <li>• All Ethernet protocols (TCP/IP, UDP/IP) can be transmitted parallel to SERCOS III RT communication</li> </ul>





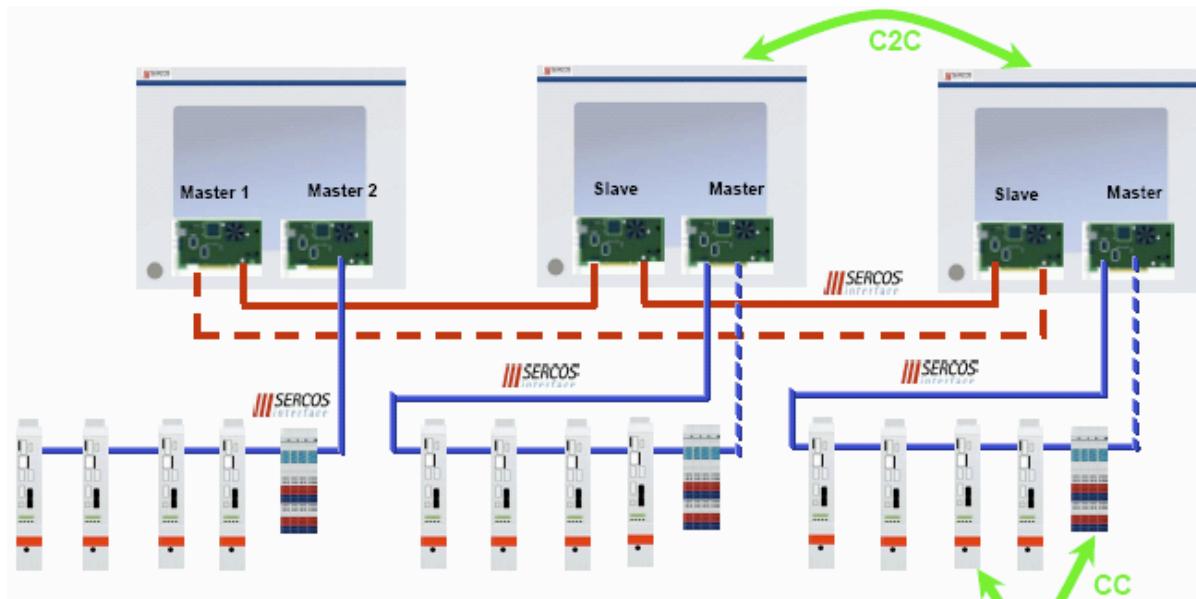
# SERCOS III

Features	
Data transfer	<ul style="list-style-type: none"><li>• Messaging protocol (SMP) allows a fragmented- cyclic and acyclic transmission of data within a data container. Header controls the fragmentation or priority of the messages</li><li>• M/S data channel - master/slave exchange of functional data</li><li>• CC device channel - peer-to-peer communication between devices</li><li>• Service channel - Service data exchange</li></ul>
In numbers	<ul style="list-style-type: none"><li>• Data rate up to 100 Mb/s</li><li>• Up to 254 nodes</li><li>• Cycle time configurable, 1ms typical, down to 31<math>\mu</math>s</li><li>• Reconfiguration time is &lt;25<math>\mu</math>s</li></ul>
Network structure	<ul style="list-style-type: none"><li>• Line and ring topologies</li><li>• Hot-plugging</li><li>• Cross communication</li><li>• Time-slot mechanism</li><li>• Synchronization maintained in the case of redundancy</li></ul>



# SERCOS III

Features	
Network structure (cont.)	<ul style="list-style-type: none"> <li>Slave connectivity based on FPGA devices or controllers, IP core software for low-cost FPGA (RT and service channels, asynchronous service channel realized inside the core)</li> </ul>



C2C (Controller-to-Controller) = Querverkehr zwischen Master-Geräten

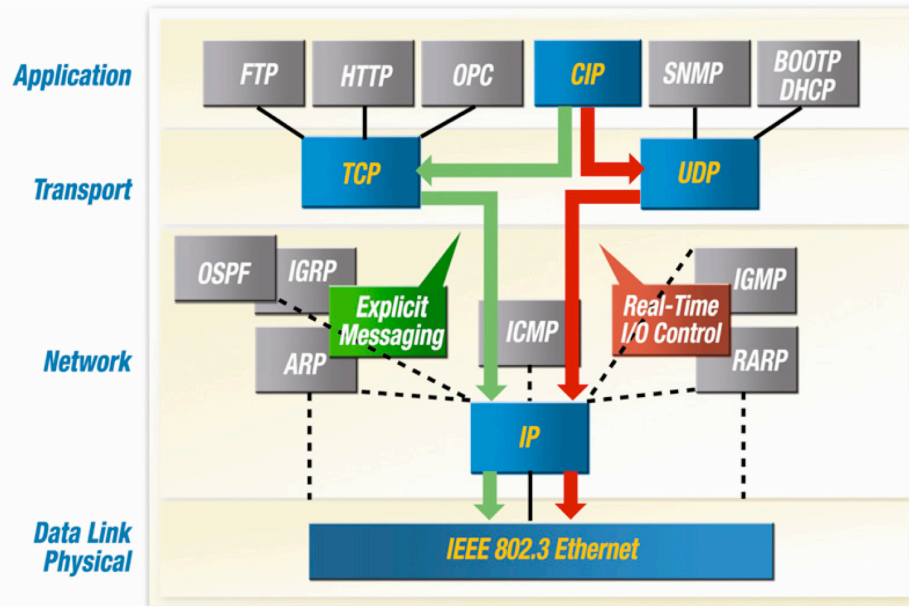
CC (Cross Communication) = Querverkehr zwischen Slave-Geräten

<http://www.sercos.com>



# EtherNet/IP open standard for industrial networks

Features	Description
Principle	<ul style="list-style-type: none"> <li>Based on the Ethernet TCP/IP standards and the Common Industrial Protocol (CIP, ISO layer 7 )</li> <li>Compatible with standard Internet protocols and standard data access and exchange</li> </ul>
Availability	<ul style="list-style-type: none"> <li>Freeware source code (for PC)</li> <li>Spec not available for free?</li> </ul>





# EtherNet/IP

Features	Description
Network structure	<ul style="list-style-type: none"><li>• Mostly in star topology, line or tree structure with a 3-port switch</li><li>• Backbone of switches connected with 100Mb/s-fiber optic cables, other ports of the switch can use twisted pair or fiber cables</li><li>• Operate either in a master/slave or distributed control architecture using peer-to-peer communication</li></ul>
Messaging	<ul style="list-style-type: none"><li>• I/O data uses UDP/IP and the information data uses TCP/IP protocols</li><li>• For real-time messaging, EtherNet/IP employs UDP over IP, which allows messages to be multicast. This is how CIP I/O data transfers (implicit messaging) are sent.</li><li>• Explicit messaging connections are point-to-point relationships to facilitate request-response transactions between two nodes. Explicit messaging connections utilize TCP/IP.</li><li>• Transmission rate – 10/100 Mb/s up to 1 Gb/s</li></ul>



# INTERBUS, MODBUS TCP, IEC 62439

Features	
INTERBUS	<ul style="list-style-type: none"><li>• Active ring topology - the data forward and return lines are led to all devices via a single cable</li><li>• Master/slave system connection of up to 512 devices</li><li>• Transmission rate 500 kb/s</li></ul>
ModbusTCP	<ul style="list-style-type: none"><li>• OSI layer 7, TCP/IP based</li><li>• Restricted to 247 devices on one data link</li><li>• Master/slave protocol, master node must routinely poll each field device, and look for changes in the data</li><li>• Half-duplex transmission</li><li>• Openness, no license fees</li></ul>
IEC 62439	<ul style="list-style-type: none"><li>• Ring topology</li><li>• Redundancy either within the network or in the end nodes</li><li>• Recovery time 4.8ms-1s, depending on redundancy protocol and number of end nodes</li></ul>



## Conclusion



- Ethernet POWERLINK and SERCOS III are the most "open" protocols
  - POWERLINK has inadequate asynchronous support
  - Low number of nodes for SERCOS III
  - Definitely at least study specification to get concepts and issues to be tackled in RT protocols
- EtherCAT missed possibility for open source
  - hindered by licensing problems
  - Slave IP Cores are available, but not free
- Keep MODBUS TCP in mind
  - Concepts could be useful



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# Thank you for your attention!

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