Layering with TSN and EtherCAT
- A contribution regarding document exchange

Karl Weber
EtherCAT is the open technology of

ETG = EtherCAT Technology Group (www.ethercat.org)

Foundation: November 2003

Tasks: Support, Advancement and Promotion of EtherCAT

The world’s largest fieldbus organization

More than 4500* member companies from 65 countries in 6 continents:

- Device Manufacturers
- End Users
- Technology Providers

Membership is open to everybody

* as of Sept 2017
EtherCAT is:

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

ETG Members worldwide

As of Oct 27, 2017:

4543

ETG members from 65 countries and 6 continents
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EtherCAT Technology Group: a truly Global Organization!
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© EtherCAT Technology Group
EtherCAT is Standard and Open

- Protocol specifications open:
  - EtherCAT is IEC Standard (IEC 61158, IEC 61784 und IEC 61800-7)
  - EtherCAT is ISO Standard (ISO 15745-4)
  - EtherCAT is SEMI Standard

- Slave Controller Chips (ESC) from several vendors
- ESC provides high level of interoperability

- ETG provides Technical Support by Phone oder via Forums by Training classes

- ETG organizes Plug Fests
- ETG provides Conformance Testing procedures
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**Functional Principle | Ethernet „on the fly“**

- Ethernet-compatibility maintained
  - Master Implementation on standard Ethernet interface
  - Standard PC or Embedded PC sufficient - no dedicated plug in card on-board Ethernet Port is fine
- Minimal overhead (= shared frame)
  - Optimized frame structure for I/O modules connected
  - L2 Communication in hardware: maximum predictable(!) performance
  - No bridging, just forward to next station in the loop …….
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Functional Principle: Ethernet “on the fly”

- Efficient: Typically only one Ethernet Frame per Cycle
- Ideal Bandwidth Utilization for maximum Performance
Precise, Robust, Ease of use

- High precision Synchronization
  DC=Distributed Clocks

- Safe Operation
  → Errors will switch I/O in safe operational mode

- Minimum Configuration
  - Automatic topology
  - Diagnosis with localization
  - No address setting required (assigned automatically)
  - Performance independent of:
    - Slave implementation
    - Network components (no Switches/Hubs)

- No dedicated extra components for communication

- Simple Slave Controller, No Processor@Application<=>Communication
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EtherCAT Application examples

- packaging
- cars
- tyres
- high speed presses
- test beds
- measurement

... also

- Semiconductor
- Medical
- Wind turbine
- Stage control
- Mobile machines
- Data acquisition
- Solar panels
- Race sailing

ETG congratulates Emirates Team New Zealand for winning the America’s Cup 2017

06/2017 | The world’s largest fieldbus user organization, the EtherCAT Technology Group (ETG), congratulates its member Emirates Team New Zealand for winning the America’s Cup ...With a 7-1 scoreline the New Zealanders dominated the final ...in Bermuda. The high-tech America’s Cup Class catamarans used … employ sophisticated hydraulics to control ... Super-fast and reliable bus communication is a key element of the hydraulic control system, and the EtherCAT Technology Group is thrilled that its technology has been of help for taking the Cup back to NZ.
Ethernet started over 40 years ago
- Establish flexible computer interconnections
  - Workstations to servers
- = Best-effort + client-server connection
- Introduction of bridging in IEEE 802.1
- Enable different speeds
- Large Network dimensions, scalable(!)
- = Still Best effort
- Change of this paradigm in AVB
  (introduction of streaming)

30 Years ago: Fieldbusses ➔ service quality
- Efficient bandwidth use
- Low frame drop rate
- Limited communication delay
- Later: Ethernet qualified for fieldbus as well
But IEEE 802 is a challenge at I/O level

- Efficiency: low byte count (8 bytes) vs. 84 octets minimum for IEEE 802.3
- Forwarding: line speed for fieldbusses vs. store and forward/bridging

- This leads to the **EtherCAT** approach

- Efficiency **Shared frame** instead of individual frame
  \[ \rightarrow \] performance improvement: overhead 50 Bytes instead of 750/1500
  … in a network of 10/20 I/O stations

- Processing on the fly with topological forwarding (automatic)
  Instead of address based forwarding
  \[ \rightarrow \] performance improvement: 0.7\(\mu\)s instead of >3\(\mu\)s (7\(\mu\)s/store&forward)
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The bridging mechanism utilized by EtherCAT is “processing on the fly”

- 90%+ efficiency
- Minimized bridge delay
- Jitter removed
- No congestion

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EtherCAT architecture model

<table>
<thead>
<tr>
<th>7</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Presentation</td>
</tr>
<tr>
<td>5</td>
<td>Session</td>
</tr>
<tr>
<td>4</td>
<td>Transport</td>
</tr>
<tr>
<td>3</td>
<td>Network</td>
</tr>
<tr>
<td>2</td>
<td>DL higher layer</td>
</tr>
<tr>
<td>1</td>
<td>Physical</td>
</tr>
</tbody>
</table>

**This is Ethernet**

- DL lower layer
- IEEE 802.3

**MAC**

- IEEE 802.1
- Bridging (“switching”)
- Forwarding, buffering
- Frame format: e.g. min/max frame size, framing
- MAC: Media Access Control

**PHY** (bit coding, signaling)

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IEEE 802.3

### Bridge

Nov 2017
Possible Application Scenarios: TSN network between master and EtherCAT segment

EtherCAT

Bridged Network
(802.1 based incl. TSN)

Bridged Network
(TSN bridges only)

EtherCAT slave

EtherCAT slave

Any PLC

MES

Bridged Network
(802.1 based incl. TSN)
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Application Scenarios: Adaption of TSN stream to EtherCAT segment in first EtherCAT slave
Application Scenarios: Adaption of TSN stream to EtherCAT segment in Switch

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Application Scenarios:
- Adaption of TSN stream to EtherCAT segment in Switch
- Bridged Network (802.1 based incl. TSN)
- TSN Switch
- EtherCAT slave
- EtherCAT slave
- OPC/UA
- Any PLC
- Printer
- TSN-EtherCAT adaption
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Possible Application Scenarios: EAP transferred on TSN-enhanced 802.1 network

Bridged Network (802.1 based incl. TSN)

Any PLC

EtherCAT slave

EtherCAT slave

TSN Switch

printer

MES

OPC/UA Bridge

TSN-EtherCAT adaption
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Stream Adaption: Details

- Always a pair of streams is set up
- Minimum one pair, but more might be set up, e.g.
  - One for cyclic
  - One for acyclic (strict priority)
  - for additional transfers
- Traffic class for pair of stream always the same
- Maintain Traffic Class (VLAN Prio)
- Maintain length
  (EtherCAT Rx/TX frame length identical)
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Protocols use different fields:

- EtherCAT Master – EtherCAT segment corresponds to a Identifier (VID)
- Corresponds to Identification ExplDeviceID of EtherCAT
- MAC addresses (StreamDA) constructed of
  - A unique EtherCAT address part registered by IEEE
  - The VLAN / ExplDeviceID
  - Stream selector
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If you have the choice, take both!

Stream adaption uses TSN but does not modify it!
Stream adaption uses EtherCAT but does not modify it!

Profile is outside the circle.