TRENDS IN IN-VEHICLE NETWORKING

DR. KIRSTEN MATHEUS
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STANDARDS FOR CONNECTED AND AUTONOMOUS TRANSPORTATION
DIGITIZATION CHANGES CARS INTO MOBILITY.

The car manufacturers are facing a time in which they need to continue to strive in ever fiercer competition while having to embrace the changes induced by a digitized world.

With digitization, data and software are the new currency.

This can change everything. From the way we build cars to the products and services we offer.

It results in new requirements on the infrastructure inside the car: the EE-architecture and also the in-vehicle network.
ELECTRONICS, SOFTWARE AND COMMUNICATION ARE THE KEY FOR THE DIGITIZATION, CAUSING A COMPLEXITY EXPLOSION INSIDE VEHICLES.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number ECUs</th>
<th>Legacy ECUs (%)</th>
<th>Cable Length (m)</th>
<th>Communication Technologies*</th>
<th>Signals Onboard NW</th>
<th>Number Fuses</th>
<th>Number Networks**</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>40</td>
<td>5</td>
<td>1.600</td>
<td>3</td>
<td>3000</td>
<td>70</td>
<td>5</td>
</tr>
<tr>
<td>2015</td>
<td>200</td>
<td>40</td>
<td>3.800</td>
<td>12</td>
<td>12.500</td>
<td>180</td>
<td>51</td>
</tr>
<tr>
<td>2021</td>
<td>200</td>
<td>5</td>
<td>3.800</td>
<td>12</td>
<td>12.500</td>
<td>180</td>
<td>51</td>
</tr>
</tbody>
</table>

*) P2P or network

**) Often requiring some form of bridge or gateway in between
CAR MANUFACTURERS CAN CHOOSE FROM A LARGE NUMBER OF DIFFERENT IN-VEHICLE NETWORKING TECHNOLOGIES CONNECTING THE ECUS.

Brutto bitrate [Mbps]

Year of appearance

New developments

Discontinued technologies

P2P

Ethernet

PTP + some

Ethernet

<10GBASE-Tx

>10GBASE-Tx

10GBASE-TX

10GBASE-T1S

2.5, 5, 10G BASE-T1

1G BASE-T1

100BASE-T1

OABR/100BASE-T1

MOST 50

MOST

LVDS

HDMI 1.2

USB 2.0

USB 3.0

USB 3.1

SerDes

Ethernet

Koax

10BASE-T1S

BASE-T1S

BASE-T1

BASE-T

PSI5

PWM

SENT

CXPI

LaS

IseLED

CAN-XL

>1000BASE-T1

1000BASE-T

FlexRay

CAN-FLD

GPOF

HDBaseT

<100

<10

<1

<0,1

<0,01

1

10

100

1k

10k


K. Matheus, BMW AG, Standards for Connected and Autonomous Transportation, December 2-3, 2019
NEED TO REDUCE COMPLEXITY WHILE SUPPORTING MORE COMPLEX SYSTEMS.

- Shift from signal-based to service based communication
- Focus on Ethernet-based communication.
- Use of standards in the EE-infrastructure.
A SERVICE-BASED ARCHITECTURE ALLOWS MORE REUSE AND FLEXIBILITY.

- Provides services and transparency in the complete system (across domains).
- Allows handling the complexity, as it supports encapsulation and hierarchies and testing against interfaces.
- The reuse over vehicle generations is significantly simplified.
- But, large change for control loops with stringent timing requirements.

Example:

- Brake-assist
- Traffic jam-assistent
- Scenario interpretation 1
- Scenario interpretation 2
- Street model and localization
- Fusion of sensor data
- Sensor data processing

![Diagram showing the relationship between services and time]
SERVICE-ORIENTED ARCHITECTURE (SOA) IS A GAME CHANGER.

— New thinking in terms of the creation of distributed vehicle features.
— Provide the base for a vehicle API used by onboard and off-board apps.
— More efficient allocation of processing resources by concepts of static and dynamic binding during runtime.
— Services as a result of deep machine learning (self optimizing distributed systems).
— Perfect match during the transformation to an all IP vehicle approach.

— Standards are essential for structuring concepts, SW stacks, data exchange and tooling.
— Automotive Ethernet as an in-vehicle networking technology inherently supports SOA.
Automotive Ethernet allows to reduce the number of IVN-technologies.

- Fewer technologies
  - No gateways, no gateway tables, no complex coupling.
  - Reduced number of different tools, simpler analysis.

- Ethernet/IP
  - Flexible (for many different applications), scalable (in data rates and features).
  - Inherently supports a service based architecture.
  - State of the art security standards.
  - Eco system goes beyond the borders of automotive.
  - Unified software architecture possible.
  - Inherently supports a zonal architecture (allow one physical network).
  - Unified connectivity to the outside world/cloud.
BECAUSE OF THE STRICT LAYERING NEW SPEED GRADES OR MEDIA INTEGRATE SEAMLESSLY INTO THE NETWORK.

<table>
<thead>
<tr>
<th>Name</th>
<th>Data rate</th>
<th>Status</th>
<th>Cabling</th>
<th>SOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>100BASE-T1*)</td>
<td>100Mbps</td>
<td>Completed Standard</td>
<td>UTP P2P</td>
<td>2013</td>
</tr>
<tr>
<td>1000BASE-T1</td>
<td>1Gbps</td>
<td>Completed Standard</td>
<td>Jacketed UTP P2P or STP</td>
<td>2020</td>
</tr>
<tr>
<td>10BASE-T1S</td>
<td>10Mbps</td>
<td>Taskforce at IEEE, complete within 2019</td>
<td>UTP P2P or multidrop</td>
<td>2022 possible</td>
</tr>
<tr>
<td>2.5,5,10GBASE-T1</td>
<td>2.5, 5, 10Gbps</td>
<td>Taskforce at IEEE, complete 2020</td>
<td>STP (Coax in discussion)</td>
<td>2024 possible</td>
</tr>
<tr>
<td>&gt;10G</td>
<td>25, 50Gbps</td>
<td>Study group at IEEE, NAV Alliance</td>
<td>Open, STP likely</td>
<td>2027 target</td>
</tr>
</tbody>
</table>

Additional features on PHY level are: PoDL, autonegotiation, EEE, wake-up/sleep

Challenges on PHY level: Automotive EMC validation for every speed grade. Patience to wait for the next standard.

The IEEE TSN standards allow the support of applications with different timing requirements.

*) prev. BroadR-Reach or OPEN Alliance BroadR Reach (OABR)
The costs factors generally considered in comparisons are: PHY, CMC, crystal, connectors, cables, sometimes peripherals, sometimes effort in processor, sometimes software (licenses).

In order to have an attractive PHY cost, 10BASE-T1S is developed such that there are (will be) various possibilities to deploy it.

10Mbps Automotive Ethernet addresses the communication with lower data rates which currently represents ~93%.
SUMMARY AND CONCLUSION.

– The car manufacturers are facing a time in which they need to continue to strive in ever fiercer competition while having to embrace the changes induced by a digitized world.

– Service based communication and in-vehicle communication network (IVN) are essential for both efficiency and enabling the future.

– Automotive Ethernet represents the most important trend and offers the chance to simplify the IVN while at the same supporting existing functions, future innovations, service based communication.

– However, to really embrace the future, the automotive industry does not only need standards, it needs a mind change as well.
THANK YOU FOR YOUR ATTENTION
More information on Automotive Ethernet can be found in:

New content includes:

• Detailed explanations of how the 100BASE-T1 PHY and 1000 BASE-T1 PHY technologies actually work.
• A step-by-step description of how the 1000BASE-T1 channel was derived.
• A summary of the content and uses of the new TSN standards.
• A framework for security in Automotive Ethernet.
• Discussion of the interrelation between power supply and Automotive Ethernet communication.