Automotive Ethernet – Rapid prototyping with open source projects

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1. Self-introduction
Self-introduction

Stefan Aust

- Expert in wireless communication, in particular Wi-Fi.
- Contributed to IEEE 802 standards.
- Working in the automotive field since 2014.
  - IEEE 802.1/3 Automotive Ethernet standardization (PHY/MAC).
  - Audio Video Bridging (AVB) and Time-sensitive Network (TSN) PoC development.
2. Motivation

Why Automotive Ethernet?
New solutions for advanced in-vehicle systems are required.

Functional safety

Automotive networks: CAN, FlexRay, LIN, MOST, Ethernet

Power Train
- Engine control
- HEV/EV motor
- transmission

Chassis
- Steering/EPS
- Brake/ABS
- Chassis control

Safety
- Airbag
- Safety control

ADAS
- Collision warning
- Parking assistant
- Back monitor
- Night vision

Networking
- CAN
- LIN
- FlexRay
- Ethernet
- AVB/TSN
- Bluetooth

IVI
- Car audio
- Connectivity
- Navigation
- Entertainment
- ITS/GPS
The vehicular target system

HU: Head Unit
RSE: Rear Seat Entertainment
IAM: Intelligent Antenna Module
GW: Gateway
DAS: Driver Assist System
TSR: Traffic Sign Recognition
Rview: Rear View
SVS: Surround View System
CAM: Camera
Both in and between application domains, data traffic will increase.
For autonomous driving, increasing number of sensors and sensor resolution will affect to further increase of data traffic.

### Trends in in-vehicle networks

<table>
<thead>
<tr>
<th>Application</th>
<th>2016</th>
<th>After 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powertrain/Body/Chassis</td>
<td>500K-10M CAN</td>
<td>1M-100M CAN FD</td>
</tr>
<tr>
<td></td>
<td>FlexRay</td>
<td>Ethernet AVB/TSN</td>
</tr>
<tr>
<td>ADAS (sensor)</td>
<td>500K-1M CAN</td>
<td>1M-1G or more CAN</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ethernet AVB/TSN</td>
</tr>
<tr>
<td>Diagnosis</td>
<td>500K-1M CAN</td>
<td>1M-1G or more CAN</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ethernet AVB/TSN</td>
</tr>
<tr>
<td>Camera/IVI</td>
<td>30M-3G Analog</td>
<td>100M-1G Ethernet</td>
</tr>
<tr>
<td></td>
<td>LVDS</td>
<td>AVB</td>
</tr>
<tr>
<td>Backbone</td>
<td>500K-10M CAN</td>
<td>1G or more</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ethernet AVB/TSN</td>
</tr>
</tbody>
</table>
Automotive Ethernet

Alliances and Standardization Parties

- Promoting to introduce Ethernet in automotive systems globally.
- OABR 100Mbps, 1-pair twisted pair.
- Reduced Twisted Pair Giga-bit Ethernet (RTPGE) for automotive.
- Promoting AVB/TSN standardization in IEEE.
- Conformance & interoperability.
- Automotive profile.
- Software API.
- Promoting to introduce automotive Ethernet for Japanese automotive industry.
- Scope is from PHY/wire harness deployment to applications.

AUTOSAR and ISO are also preparing to handle with Ethernet.
### IEEE 802.3 standardization (automotive related)

#### Standards overview related to IEEE 802.3 activities

<table>
<thead>
<tr>
<th>Task Force</th>
<th>Work Title Study Group</th>
<th>TF Name</th>
<th>Chair</th>
<th>Employer</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>P802.3bp</td>
<td>Reduced Twisted Pair Gigabit Ethernet (RTPGE)</td>
<td>1000BASE-T1</td>
<td>Steve Carlson</td>
<td>High Speed Design Inc.</td>
<td>Broadcom, Marvel, Bosch</td>
</tr>
<tr>
<td>P802.3br</td>
<td>Distinguished Minimum Latency Traffic in a Converged Traffic Environment (DMLT)</td>
<td>Interspersing Express Traffic (IET)</td>
<td>Ludwig Winkel</td>
<td>Siemens AG</td>
<td>Siemens AG</td>
</tr>
<tr>
<td>P802.3bu</td>
<td>1-Pair Power over Data Lines (PoDL)</td>
<td>1-Pair Power over Data Lines (PoDL)</td>
<td>Dave Dwelley</td>
<td>Linear Technology</td>
<td>Linear Technology</td>
</tr>
<tr>
<td>P802.3bv</td>
<td>Gigabit Ethernet Over Plastic Optical Fiber (GEPoF)</td>
<td>Gigabit Ethernet over Plastic Optical Fiber</td>
<td>Bob Grow</td>
<td>RMG Consulting</td>
<td>KDPOF</td>
</tr>
<tr>
<td>P802.3bw</td>
<td>1 Twisted Pair 100Mbps Ethernet (1TPCE)</td>
<td>100BASE-T1</td>
<td>Steve Carlson</td>
<td>Robert Bosch GmbH</td>
<td>Robert Bosch GmbH</td>
</tr>
</tbody>
</table>
What is AVB and TSN?

**AVB stands for Audio Video Bridging**
- Initial started based on the demand in audio/studio applications.

**TSN stands for Time Sensitive Networking**
- It is the name of the IEEE 802.1 Task Group responsible for the Data Link Layer.
- In TSN steams are delivered with guaranteed bandwidth and latency.

The initial AVB standard set includes:
- IEEE 802.1Qav-2009 – Credit based shaper.
- IEEE 802.1Qat-2010 – SRP (Stream Reservation Protocol).
- IEEE 802.1BA-2011 – AVB systems (umbrella for all AVB standards).

**Others**
- IEEE 1722.1 – AVDECC (Audio Video Discover Enumeration Connection and Control).
- 802.1Qcah cyclic queuing and forwarding.
- 802.1Qbv scheduled traffic.
- 802.1Qbu preemption.
- 802.1Qcc stream reservation and configuration.
- 802.1Qci ingress filtering and policing.
Why AVB and TSN?

Legacy Ethernet uses “best effort delivery”—i.e., data traffic flow is indeterminate, and intervening traffic can delay a data stream. Because of this uncertainty on receiving a stream packet, the receivers in legacy systems typically employ large buffers so as not to underflow, which would result in a loss of critical control information in a control stream.

AVB/TSN ensures the arrival of time-sensitive streams as well as when they will arrive. The FQTSS (Forwarding and Queuing of Time-Sensitive Streams) standard prioritizes AVB traffic ahead of legacy best-effort packets. AVB frames are forwarded with precedence over Best Effort traffic (i.e., reserved AVB stream traffic traversing an AVB bridge has forwarding precedence over non-reserved traffic) and will be subjected to traffic-shaping rules.

AVB and TSN are enabling technologies for the connected car with flexible, scalable and secure in-vehicle networking solutions while addressing an increased need for highly reliable communication in the vehicle.
3. Open Source Projects (Automotive Ethernet)
AVnu/Open-AVB contents (github project status: 6 months ago):

- Open AVB – an AVnu sponsored repository for Audio/Video Bridging technology
- [https://github.com/AVnu/Open-AVB](https://github.com/AVnu/Open-AVB)
- The Open AVB project is sponsored by the AVnu Alliance.
- Providing building blocks for AVB systems.
  - Drivers, libraries, example applications and daemon source code.
- Intel started the creation of the Open AVB repository to motivate a collaborative source code development.

**Licensing**
- Content is licensed under BSD licensing terms.
- Linux kernel mode components are under GPLv2 license.

Third party contributions are welcomed.

- Contains description to
  - gPTP
  - AVTP pipeline
2. AVDECC

AVDECC contents (github project status: 8 months ago):
- A repository of AVDECC example open source code by J. Koftinoff.
- Project website: https://github.com/jdkoftinoff/jdksavdecc-c
- Enables remote configuration among AVB-related devices.
3. AudioScience

AudioScience contents (github project status: 1 month ago):
- A repository for 1722.1 C++ controller libraries.
- Project website: https://github.com/audioscience/avdecc-lib
- AVB device enumeration, discover, and control.
4. XMOS

XMOS contents (github project status: 3 years ago):

- A repository for AVB endpoint reference design in audio and automotive.
- Project website: https://github.com/xcore/sw_avb
- AVB endpoint source code is open source.
5. AGL code

AGL (project status: recent):

- A repository for multiple automotive features.
- Project website: [https://www.automotivelinux.org/software](https://www.automotivelinux.org/software)
- AVBethernet building blocks available.
- Support of
  - multi-core ARM CPU
  - 3D graphics
  - Multi-media codecs
  - LAN/SATA/PCIe
  - BT/Wi-Fi/Radio Tuner
  - MOST, EthernetAVB
4. Rapid Prototyping (Automotive Ethernet)
Rapid prototyping (Automotive Ethernet)

AVB prototype

Requirements:
- Showcase for AVB and Automotive Ethernet functions.
- Simple and cost-efficient (no need for cutting-edge boards).

Why use of AVDECC:
- Simple source and make.
- Support of Arduino.
  - Selection of Arduino due to simple purchase and required HW features (Ethernet).
- Support of standard Ethernet (use of Ethernet hardware).

How to build up:
- Project website: [https://github.com/jdkoftinoff/jdksavdecc-c](https://github.com/jdkoftinoff/jdksavdecc-c)
- Add test script (Ethernet addressing).
- Configuration of target platform (Arduino).
- Test and run the prototype.
How to use AVB open source (AVDECC project)

Hardware environment (recommended)

- Input device
- Ethernet-switch
- AVB-network
- AVB talker
- AVB listener
- Output device (HMI)
AVB prototyping with Arduino and AVDECC project

AVB talker

AVB listener

Ethernet switch

HMI

Arduino board

USB power supply
AVB prototype realization - Discussion

Software
- Smaller software projects (AVDECC) have valuable benefits compared to large open source projects (AVnu/Open-AVB).
- A strong dependency between open source and a target platform have been found disadvantageous (AVnu/Open-AVB, XMOS).

Hardware
- Some hardware platforms are difficult to purchase (price/version/availability).
- The availability of IoT (Internet of Things)-related hardware solutions provide a valuable solution. The Arduino series in combination with open source projects have been found as a good way to realize resource-efficient prototypes.
5. Conclusions
Conclusions

There is an increased need for highly dependable, cross-domain communication in the vehicle.

- Higher bandwidth demand due to new applications (e.g., 360-degree surround view).

Automotive Ethernet aims to modernize and prepare the connected car with flexible, scalable and secure in-vehicle networking technology.

- In AVB/TSN, the maximum latency is deterministic.

Open source projects will help the adoption of Ethernet AVB/TSN in automotive markets.

- The realization of an AVB prototype using open source as presented in this talk has shown the practicability.
Thank you!

Questions & Answers
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