The Vector Embedded Ethernet Stack and Its Use Cases in Motor Vehicles
Overview

Ethernet@Automotive webinar series

- **Part 1: Introduction to Automotive Ethernet**
  - Host: Jan Bossert
  - May 8th (de), 3rd (en), 2018

- **Part 2: Moving Forward: Tool Supported Development for Automotive Ethernet in Time Sensitive Networks**
  - Host: Patrick Pfeifer
  - May 17th (de + en), 2018

- **Part 3: The Vector Embedded Ethernet Stack and Its Use Cases in Motor Vehicles**
  - Host: Markus Helmling, Bernd Jesse
  - June 6th (de), 7th (en), 2018

- **Part 4: Service-Oriented Architectures and Ethernet Design with PREEvision**
  - Host: Daniel Gebauer
  - June 25th (de + en), 2018
Overview

Ethernet in Automotive – How?

- Signal-/PDU-based communication
- Service-oriented communication (SOME/IP and SOME/IP-SD)
- UDP network management
- Diagnostic communication over Internet Protocol (DoIP)
- DoIP flash bootloader
- XCP on Ethernet
- XCP routing (Embedded Solution GW)
- Mirroring (Embedded Solution GW)

Vehicle-to-Grid – MICROSAR.V2G

- Smart Charge Communication according to ISO and DIN
- Customer-specific functions

Not part of this webinar

Audio/Video Bridging – MICROSAR.AVB

- Time synchronization
- Traffic shaping
- Stream management
- Audio/Video data transmission and reception
Overview

Network Characteristics

**CAN (FD)**
- Bus
- Broadcast

**FlexRay**
- Active Star
- Broadcast

**Ethernet**
- Fully switched network (point-to-point)
- Unicast
- Multicast and broadcast
Overview

AUTOSAR and MICROSAR Software Architecture

MICROSAR.ETH – In-Vehicle Ethernet Communication
MICROSAR.ETH – Diagnostics
MICROSAR.AVB
Summary
### Ethernet Communication Stack (1)

**ETH** – Ethernet Driver
- Uniform API to access all Ethernet controllers of the same type

**ETHTRCV** – Ethernet Transceiver Driver
- Uniform API to access all Ethernet transceivers of the same type

**ETHSWT** – Ethernet Switch Driver
- Configuration of Ethernet switches – e.g. Virtual Local Area Networks (VLANs) and routing tables
- Uniform API to access all Ethernet switches of the same type (ETHSWTEXT for external switches which are configured e.g. via SPI)
**Ethernet Communication Stack (2)**

**ETHIF – Ethernet Interface**
- Hardware independent interface
- Virtual Local Area Network (VLAN) Handling

**vETHFW – Vector Ethernet Firewall**
- Static packet filter firewall

**ETHSM – Ethernet State Manager**
- Communication control

**TCPIP – TCP/IP stack**
- User Datagram Protocol (UDP)
- Transmission Control Protocol (TCP)
- Internet Protocol version 4/6 (IPv4/v6) \(^1\)
- ARP, NDP, ICMPv4/v6, DHCPv4/v6 \(^2, 3\)

---

1) IPv4 and IPv6 can be used in parallel
2) Address Resolution Protocol (ARP)
   Neighbor Discovery Protocol (NDP)
   Internet Control Message Protocol version 4/6 (ICMPv4/v6)
   Dynamic Host Configuration Protocol version 4/6 (DHCPv4/v6)
3) DHCPv4 server and client, DHCPv6 client
vTLS – Transport Layer Security Client

- Authentication and encryption for TCP

SOAD – Socket Adaptor

- Transformation of socket-based into AUTOSAR PDU-oriented communication

vETM – Ethernet Testability Module

- TCP/IP protocol conformance testing
- Requires 3rd party test tool
Agenda

Overview 2
AUTOSAR and MICROSAR Software Architecture 6

► MICROSAR.ETH – In-Vehicle Ethernet Communication 11
MICROSAR.ETH – Diagnostics 16
MICROSAR.AVB 22
Summary 28
Signal-/PDU-based communication

- **Classical Automotive communication principle**
  
  ![Signals to PDU to Frame]

- **New concept: Dynamic Multi-PDU-to-Frame mapping**
  
  ![PDU to Frame (UDP packet)]

- **Assemble frames with receiver-specific content if unicast communication is used**
  - Location of a PDU within a frame is dynamic
  - Different frame triggering mechanisms available
  - Realization in AUTOSAR by the Socket Adaptor (SoAd)
    - IpduM can be used as well but SoAd offers more options
MICROSAR.ETH – In-Vehicle Ethernet Communication

Service-oriented Communication (1)
Scalable Service-oriented Middleware over IP (SOME/IP)

Service (Consumer/Provider)
(Client/Server)

- Methods
- Events
- Fields

Service Discovery

- Find communication partners during runtime

Data serialization

- Data (de-)serialization during runtime
  - Signals and PDUs of dynamic length

Classical

Signals

PDU

SOME/IP

Structured data

struct

uint32 val1
float32 val2
int8 arr[1..9]
uint8 val3

RPCs

Request

Return

Events

Subscribe to event group

Subscribe to event group ack.

Notifications

Fields

Request

Return

Offer service

Find service

Find communication partners during runtime

Data serialization

- Data (de-)serialization during runtime
  - Signals and PDUs of dynamic length

<table>
<thead>
<tr>
<th>DB</th>
<th>val1_1</th>
<th>val1_2</th>
<th>val1_3</th>
<th>val1_4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>val2_1</td>
<td>val2_2</td>
<td>val2_3</td>
<td>val2_4</td>
</tr>
<tr>
<td></td>
<td>arr.len</td>
<td>arr_1</td>
<td>arr_2</td>
<td>val3_1</td>
</tr>
</tbody>
</table>
Realization of SOME/IP and SOME/IP-SD in AUTOSAR 4.3.x

- Example: Server sends event notification

1. Service Discovery communication to handle service offer and event group subscription (interaction with SW-C over BSWM)
2. Service Discovery configures communication paths in the Socket Adaptor (PDU-to-Frame/Socket mapping)
3. Software Component (SW-C) sends signals (structured data)
4. Structured data is serialized in the RTE transformer (SOMEIPXF) and SOME/IP header information is added
5. Socket Adaptor adds second part of SOME/IP header information (PDU header for dynamic Multi-PDU-to-Frame mapping)
6. Socket Adaptor decides when to send a frame, based on the different frame triggering options
MICROSAR Software Architecture

SD – Service Discovery (SOME/IP-SD)
- Management of service states
- Configuring communication paths over the Socket Adaptor e.g. disable routing if service is not available

SOMEIPXF – SOME/IP Transformer (SOME/IP)
- Data serialization and deserialization
- Large Data COM (LDCOM) should be used to save resources

UDPNM – UDP Network Management
- Coordinated shut down of Ethernet ECUs
- Connection to NMIF is not shown in the figure
Overview

AUTOSAR and MICROSAR Software Architecture

MICROSAR.ETH – In-Vehicle Ethernet Communication

MICROSAR.ETH – Diagnostics

MICROSAR.AVB

Summary
ISO 13400

- Vehicle discovery and access protocol
- Diagnostics and ECU re-programming

Classical setup: Tester is connected via Ethernet to the gateway and uses DoIP for diagnostics and ECU re-programming

- Addressing of ECUs is based on logical DoIP addresses
  - Gateway maintains address mapping table and forwards UDS messages
- High bandwidth of Ethernet, enables parallel ECU re-programming
MICROSAR.ETH – Diagnostics

DoIP Gateway to CAN

Activation line active

[UDP] DHCP-based IP address assignment

[UDP] DoIP Vehicle Identification

[TCP] Connection setup

[TCP] DoIP Routing Activation

[TCP] DoIP Diagnostic Messages
1. Diag. Message (diagnostic request)
2. Diag. Message Acknowledgement
3. Diag. Message (diagnostic response)

[TCP] Connection shutdown
Diagnostics of In-Vehicle Ethernet ECUs

Not explicitly specified by ISO 13400, but there are two paradigms

- Transparent switch, i.e. tester has direct access to in-vehicle Ethernet ECUs
- Locked switch, i.e. tester has no direct access to in-vehicle Ethernet ECUs
  - E.g. via VLAN encapsulation
  - When using a locked switch, the gateway can implement security mechanisms but also needs to route all messages (performance)

- Combinations possible
AUTOSAR Socket Adaptor PDU Header Option can be used as a slim transport protocol

- Only route the data which is required – no DoIP protocol overhead

MICROSAR.ETH – Diagnostics

DoIP Gateway to Ethernet – Simplified Routing

Activation line active

Static IP address assignment for in-vehicle Ethernet ECUs

No identification for in-vehicle Ethernet ECUs necessary

[TCP] Connection setup

No in-vehicle routing activation necessary

[TCP] Diagnostic communication
1. Diagnostic request
2. Diagnostic response

[TCP] Connection shutdown

Ethernet ECU

Central Gateway
DHCP Client
DoIP Server

Tester
DHCP Server
DoIP Client

19/33 © 2018. Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector. V4.00.02 | 2018-05-08
DOIP – Diagnostic over Internet Protocol

- Implementation of ISO 13400-2
- The handling of the DoIP protocol was specified as Socket Adaptor plug-in in AUTOSAR 4.0.x and became a separate module in AUTOSAR 4.1.x

Flashbootloader

- Communication (COMM and PDUR) wrapper
- Flash/EEPROM driver
- FBL security module
- FBL diagnostics
- FBL application
Agenda

Overview 2
AUTOSAR and MICROSAR Software Architecture 6
MICROSAR.ETH – In-Vehicle Ethernet Communication 11
MICROSAR.ETH – Diagnostics 16
MICROSAR.AVB 22
Summary 28
Audio/Video Bridging Use Cases

Audio/Video Bridging (AVB) was developed to transport audio and video streams

- Through standard Ethernet network technology
- With simple cabling
- Fast and in real-time
- Well synchronized and prioritized

Today, parts of AVB/TSN are more and more interesting also for transport of safety critical data e.g. in the advanced driver assistance domain.
Introduction and overview:
IEEE 802.1BA – Audio Video Bridging Systems

Time synchronization:
IEEE 802.1AS – Timing and Synchronization for Time-Sensitive Applications

Traffic shaping:
IEEE 802.1Qav – Forwarding and Queuing Enhancements for Time-Sensitive Streams (FQTSS)

Stream management:
IEEE 802.1Qat – Stream Reservation Protocol (SRP)

Audio/Video data transmission and reception

Audio/Video Transport Protocol (AVTP):
IEEE 1722 – Layer 2 Transport Protocol for Time Sensitive Applications

The Time-Sensitive Networking (TSN) Task Group will add more standards to this list.
MICROSAR.AVB

AVB System – Timing & Time Stamping

- Jack-to-Jack latency (includes Application Time)
- Application-to-Application latency (includes AVTP format conversion time)
- Max Transit Time for streaming packets

 IEEE 802.1 Ethernet AVB/TSN

Talker

<table>
<thead>
<tr>
<th>Time Sensitive Application</th>
<th>AVTP</th>
<th>Eth If</th>
<th>Eth Drv</th>
<th>Eth Trcv</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eth TSyn/ StbM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ingress Time Reference Plane

Egress Timestamp point

Presentation Time Reference Plane

Listener

<table>
<thead>
<tr>
<th>Time Sensitive Application</th>
<th>AVTP</th>
<th>Eth If</th>
<th>Eth Drv</th>
<th>Eth Trcv</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eth TSyn/ StbM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

IEEE 802.1 Ethernet AVB/TSN

Application-to-Application latency (includes AVTP format conversion time)

Max Transit Time for streaming packets

Jack-to-Jack latency (includes Application Time)
Software Architecture for Layer 2 based protocols

<table>
<thead>
<tr>
<th>RTE</th>
<th>Appl.</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMM</td>
<td>STBM</td>
</tr>
<tr>
<td>ETHSM</td>
<td>ETHTSYN</td>
</tr>
<tr>
<td>vETHFW</td>
<td>vSRP</td>
</tr>
<tr>
<td>vETHFW</td>
<td>vAVTP</td>
</tr>
<tr>
<td>ETHIF</td>
<td>ETHSWT (FQTSS)</td>
</tr>
<tr>
<td>ETH (FQTSS)</td>
<td>ETHTRCV</td>
</tr>
</tbody>
</table>

**ETHTSYN – Time Synchronization over Ethernet**
- Time synchronization between Ethernet ECUs acc. to AUTOSAR acc. to IEEE 802.1AS (with limitations) to enable time synchronization over Ethernet

**FQTSS – Forwarding and Queuing Enhancements for Time-Sensitive Streams**
- Extension of the Ethernet and Switch driver (if supported by hardware) acc. to IEEE 802.1Qav to allow traffic shaping (Credit Based Shaper)

**vSRP – Stream Reservation Protocol for End Nodes**
- Reservation of bandwidth on communication paths acc. to IEEE 802.1Qat by supporting a dynamic stream announcement with admission control

**vAVTP – Audio/Video Transport Protocol**
- Transmission and reception of audio and video streams acc. to IEEE 1722
vRTP – Real-Time Transport Protocol

- Transmission and reception of audio and video streams over UDP acc. to:
  - IETF RFC 3550 Transport Protocol for Real-Time Applications
  - IETF RFC 6184 RTP Payload Format for H.264 Video
  - IEEE 1733 Layer 3 Transport Protocol for Time-Sensitive Applications in Local Area Networks
    - Specifies a new RTCP Control Packet type "208" to utilize IEEE 802.1 within RTP

- vRTP substitutes typically vAVTP but requires at least ETHTSYN as Layer 2 protocol for time synchronization purpose.
Agenda

Overview 2
AUTOSAR and MICROSAR Software Architecture 6
MICROSAR.ETH – In-Vehicle Ethernet Communication 11
MICROSAR.ETH – Diagnostics 16
MICROSAR.AVB 22

Summary 28
MICROSAR.ETH is the basis of MICROSAR.V2G and MICROSAR.AVB

- All clusters and use cases can run in parallel
- Figure does not show the flashbootloader
High-level operating systems (OS) like Linux, QNX and Integrity get more and more important, especially in the ADAS and infotainment domain

- ADAS and infotainment are also the drivers for Ethernet communication
- The MICROSAR communication stack for Ethernet can also be used together with such a high-level OS
  - The Socket Adaptor was extended to support the BSD socket API in parallel to the AUTOSAR API
  - Adapted Ethernet driver to enable AVB support
- Other interfaces, e.g. towards the OS and for error reporting, have to be considered
Summary

ECU Configuration Flow for MICROSAR.ETH

- **System Description / ECU Extract of System Description**: AUTOSAR 4.1.x / 4.2.x / 4.3.x
  - Contains system information which are needed for the ECU

- **DaVinci Configurator Pro 5**
  - Configuration of RTE + BSW
  - Editing and Generation

- **Base ECUC Generation**
  - .xml
  - .cdd / .odx
  - CANdela Diagnostic Data

- **ECU Configuration Description**
  - .xml

- **Other AUTOSAR tools**
  - Embedded Coder
  - TargetLink

- **DaVinci Developer**
  - Software Component Description files
  - .xml

- **BSW module configuration header and code files**
  - .c .h
  - RTE header and code files
  - SWC header files
Vector Ethernet Solution

Automotive Ethernet and TCP/IP

- Ethernet and TCP/IP technologies have made their way into the vehicle and they are expected to expand into new application areas.
- Automotive OEMs and suppliers are facing diverse challenges here.
- Vector supports you in meeting these challenges with professional tools, embedded software and services.

Summary

Vector Ethernet Solution

Automotive Ethernet and TCP/IP

- Ethernet and TCP/IP technologies have made their way into the vehicle and they are expected to expand into new application areas.
- Automotive OEMs and suppliers are facing diverse challenges here.
- Vector supports you in meeting these challenges with professional tools, embedded software and services.

Summary

Vector Ethernet Solution

Automotive Ethernet and TCP/IP

- Ethernet and TCP/IP technologies have made their way into the vehicle and they are expected to expand into new application areas.
- Automotive OEMs and suppliers are facing diverse challenges here.
- Vector supports you in meeting these challenges with professional tools, embedded software and services.
Summary

Ethernet@Automotive webinar series

- Part 1: Introduction to Automotive Ethernet
  > Host: Jan Bossert
  > May 8th (de), 3rd (en), 2018

- Part 2: Moving Forward: Tool Supported Development for Automotive Ethernet in Time Sensitive Networks
  > Host: Patrick Pfeifer
  > May 17th (de + en), 2018

- Part 3: The Vector Embedded Ethernet Stack and Its Use Cases in Motor Vehicles
  > Host: Markus Helmling, Bernd Jesse
  > June 6th (de), 7th (en), 2018

- Part 4: Service-Oriented Architectures and Ethernet Design with PREEvision
  > Host: Daniel Gebauer
  > June 25th (de + en), 2018
For more information about Vector and our products please visit

www.vector.com

Authors:
Markus Helmling, Bernd Jesse
Vector Germany