AUTOMOTIVE COMMUNICATION

- Increasing Feature Sets
- Increasing Data Rates
- Introduction of new Communication Methods
- New Communication Method as Island Solution
- Network Architectural Changes

- Simple communication by voltage levels or serial (RS-232)
- CAN Bus introduction
- Dedicated functionality per ECU
- Few communication objects, diagnosis
- Increase of E/E functionality
- Many more electric devices replace and expand mechanic ones
- Upgrading of existing network types
- Centralization & integration phases
- Introduction of backbone networks and overall system
- Merging of ECUs: Functionality of several ECUs goes into one
- Distribution of tasks among the system
- Internet, cloud computing, mobile maintenance and upgrade
- Car-2-car communication
- Autonomous driving
- Ad-hoc, individually modifiable options

20 kbit/s
- CAN
- 20 kbit/s

50 … 500 kbit/s
- CAN
- 50 … 500 kbit/s

1 … 10 Mbit/s
- CAN-FD
- Ethernet
- 1 … 10 Mbit/s

2 … 100 Mbit/s
- CAN-FD
- Ethernet
- 2 … 100 Mbit/s

100 Mbit/s … x Gbit/s
- Highspeed Ethernet
- 100 Mbit/s … x Gbit/s

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GATEWAY PROCESSOR EVOLUTION IN AUTOMOTIVE NETWORKS

- Network challenges and architectural changes
- Consequences on gateway processor architecture
- Hardware based routing – a gateway processing peripheral
- Tunneling of CAN(-FD)
- The Renesas Prototype
CHALLENGES AND ARCHITECTURAL NETWORK CHANGES
THE GATEWAY – WITHIN CARS ON THE MARKET TODAY

- Several Bus Systems are attached to a Central Gateway,
- Max. Busload: 50%, Classical CAN Framing
  Overhead: 1/3 of Data.
• More Bus Systems are attached to a Central Gateway at higher rates
  - CAN: SW-Update: Max. Busload: 100%; Regular Traffic: 50%
  - Ethernet: SW-Update: 8 Mbit/s [Program Speed]; Regular Traffic: CAN max. rate of 2.5 Mbit/s
• Probably even harder conditions?

Central Gateway
SW-Update Total Data Bit Rate (all interfaces): 72 Mbit/s
SW-Update Total Data Transfers (excl. overhead): 8.6 MB/s
Diagnosis operation: 30 Mbit/s (Data: 3.6 MB/s)

- Chassis Bus
  - FlexRay or CAN-FD
  - Max. 10 Mbit/s, 5 Mbit/s to GW

- Powertrain Bus
  - CAN-FD
  - Max. 5 Mbit/s

- Comfort Bus
  - CAN-FD
  - Max. 5 Mbit/s

- Body Bus
  - CAN-FD
  - Max. 5 Mbit/s

Diagnosis
Mobile

Diag. Ethernet
Meters all

Update via Mobile, only Programming Speed Limit, Copies to all

Entertainment Ethernet
SW-Update: max. 8 Mbit/s per ECU, Regular Traffic: max. 2.5 Mbit/s

LIN Bus

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NEW NETWORK TOPOLOGY

Diagnosis

Mobile

Backbone Ethernet Ring

Domain Switch
- Chassis Bus FlexRay or CAN-FD
  - ECU

Domain Gateway
- Powertrain Bus CAN-FD
  - ECU
- Comfort Bus CAN-FD
  - ECU

Domain Gateway
- Body Bus CAN-FD
  - ECU

Domain Gateway
- Entertainment Bus Ethernet
  - ECU

External Gateway

Domain Gateway
- LIN Bus
  - ECU
ETHERNENT IN THE CAR?

Physical Layer

• Qualification of PHY devices (temperature range, reliability, lifetime)
• Media to be used (existing cable-tree, shielding)
• Second-Source Policy BroadR-Reach technology (single twisted pair) – more than one manufacturer is required

Data Link Layer

• Communication reliability of Latency and Jitter

Physical Layer Solutions

→ Qualification processes are in good progress
→ Single twisted pair Ethernet (BroadR-Reach technology) is in focus to be used
→ Meanwhile more than one manufacturer of BroadR-Reach Ethernet PHY devices is available

Data Link Layer Solutions

→ Introduction of Time Sensitive Networking (TSN)
ETHERNET PROTOCOL, DELAYS AND JITTER

Apart from pure signal run times through transceivers and cables, Ethernet may have additional delay and jitter sources:

- Ethernet supports large frames, which may block urgent transmissions
- Queue (FIFO) handling in switches, when a transmit port gets data from several reception ports

**Measures in a switch for TSN (Time Sensitive Networking)**

- AVB including Pre-emption Support
- AVB Queues with Priorities
- Time Aware Shaping
- Not Optimized: “Best Effort”
CHALLENGES OF A GATEWAY PROCESSOR

• Scalable architecture for several gateway applications
• Compact design tailored for individual product

• Gateway architecture must be QoS aware
  • High priority messages must go through the system faster than low priority traffic
  • Latency has to be guaranteed under all operation conditions, independently from CPU load

• Precise coordination of activities among connected ECUs
  • Considered on Ethernet by IEEE1588PTP protocol.
  • The gateway could play the role of a master clock device
  • Ensure consistency of data tuples

• Tunnelling of one network domain to another
• Transport protocol support
• Mirroring of information for diagnostics
• Switching of Ethernet traffic (various protocols)
• Security issues (tailored solution required)
ARCHITECTURAL CONSIDERATIONS FOR GATEWAY PROCESSORS
Data traffic situation during a SW-Update process, with typical system speed.
ALTERNATIVES …

Increase the CPU core speed …

Or add additional CPU cores …

The bottleneck stays at the peripheral bus.

So multiplication of all would be the best we have seen so far (with the limitation that the splitting is a binding factor).
COMMUNICATION-ORIENTED DESIGN
EXTENSION OF BUS SYSTEM

- Application CPU core
  - Reasonable calculation power for
    - Higher level tasks (applications)
    - Safety and Supervision
    - Less Interrupt load
    - Focus on main ECU tasks

- Communication (Gateway-) CPU, Routing Engine and Communication Bus
  - Optimized on speed and power for communication requirements
  - Additional feature implementation
  - Low latency
  - Event Driven
GATEWAY IP SYSTEM

- Moving the load of faster & increasing communication
- Frame Routing
- Peripheral direct usage, Configuration
- Application Data / Security, Signal Routing, Supervision
GATEWAY IP PROTOTYPE

- Moving the load of faster & increasing communication
- Frame Routing
- Configuration
- Application Data Supervision, Signal Routing
RENESAS AUTOMOTIVE GATEWAY UNIT

- Up to 8 TSN capable Eth interfaces
- 10/100/1000 Mbit/s full duplex
- MAC Security Module available
- Up to 16 CAN/CANFD interfaces
KEY FEATURES

- Autonomous routing based on
  - MAC
  - VLAN
  - IEEE 1722 (this includes CAN messages)
- 802.1AS support for time synchronisation (gPTP timer)
- Prioritisation of time critical messages by integrated QoS solution
  - Allow end to end QoS accross networks
- Timestamping on all interfaces
  - Based on global 802.1AS (gPTP time, second + nano second part)

- SW optimised data interface based on flexible queues structure
- All data exchanged via integrated Data RAM
- CAN/CANFD tunnelling over IEEE 1722a
  - Time period conversion (convert message repetition rate)
  - Message bunching (multiple CAN messages in one Eth frame)
  - CAN messages are tunnelled in up to 64 streams (shared by 8 interfaces)
- Tunnelling concept expandable to other protocols (e.g. FlexRay)
SCALING DOWN TO DOMAIN LEVEL PRODUCTS *

**Next evolution step**: Gateway hardware support on a more cost-effective base for local domains at lower performance

- Routing through DMA and Global RAM
- CPU Agent integration into peripheral interfaces
- Some routing engine functionality moves into CPU agents
- CPU Signal routing case by case

→ Significant size reduction by removal of wide communication bus system & data RAM
SCALABLE DESIGNS – MULTIPLE APPLICATIONS *

Amount of Ethernet and CAN / other peripheral connections can be flexibly created – for dedicated product lines

Gateway of Domain μC* with GW-IP

End-Station components

* Implementation under discussion.
USING THE GATEWAY IP – SW VIEW POINT (END-STATION)*

- Global RAM: Fast access by CPU
- Descriptors for routing information
- Peripheral access required only to set Tx-Request and for configuration
- Signal routing by CPU software
- Frame routing with hardware support

* Implementation under discussion.
EXECUTION FLOW: TRANSMISSION BY SOFTWARE (FULL GW-IP)

Example flow of a transmission:

- All data handling beyond the CPU RAM area is done by hardware
- Transmit Request is the only peripheral access

1. SW places one or more frames into a queue (data and descriptor)
2. SW sets transmit request for this queue (peripheral access)
3. HW (Agent) reads descriptor(s) from Global RAM
4. HW (Agent) reads data from URAM
5. Data is available in Gateway IP for further processing
FRAME ORGANIZATION IN RAM

All kind of data is handled within IEEE 1722a Ethernet frames (Example: CAN Payload)

- MAC SA/DA
- VLAN Tag
- Type AVTP
- SubType TSCF
- Sequence #
- Stream ID
- Timestamp
- Total Payload Length
- Reserved
- Payload
- Type (CAN), Frame Length, Flags, Bus ID
- Timestamp
- Identifier
- CAN Data (Payload)
- ...
- Type (CAN), Frame Length, Flags, Bus ID
- Timestamp
- Identifier
- CAN Data (Payload)
EXAMPLE ROUTING SCHEME
(TUNNELING OF CAN FRAMES)
These are example CAN IDs used for communication on CAN-A

GW1: Classification in CAN A AFL
- CAN-A 100 to 110 → #1
- CAN-A 200 to 2FF → #2
- CAN-A 153, 1017 → #3
- CAN-A 100 to 1FF → #4

GW1: GW Forwarding Table
- #1 → 1722-StreamId=0x3302_2104, target=Eth-0
- #2 → 1722-StreamId=0xAB60_0177, target=Eth-0
- #3 → 1722-StreamId=0x87A1_bF87, target=Eth-0
- #4 → 1722-StreamId=don’t care, target=CAN-B

Inside the GW hash numbers (#x) are used to distinguish streams

The forwarding engine applies the 1722 header containing the Stream Id. This stream Id is used by Ethernet backbone to identify the end points (target DCs) of this stream. The shown numbers are examples only.

Here only local CAN is target, so Stream Id is not required (but possible if stream is also required in other GW)
DESTINATIONS (GW2, GW3)

System Definition
CAN-A 100 to 110 – AVB#1 → CAN-C, E
CAN-A 200 to 2FF – AVB#2 → CAN-G
CAN-A 153, 1017 – AVB#3 → CAN-D, E, F, G
CAN-A 100 to 1FF → CAN-B

GW1: GW Forwarding Table
#4 → target=CAN-B

GW2: GW Forwarding Table
#1 → CAN-C, CAN-E
#3 → CAN-D, CAN-E

GW3: GW Forwarding Table
#2 → CAN-G
#3 → CAN-F, CAN-G

There is no requirement to use unique hash (#x) numbers in all GWs.
OVERALL RESULT (GW1, GW2, GW3)

System Definition
CAN-A 100 to 110 → AVB#1 → CAN-C, E
CAN-A 200 to 2FF → AVB#2 → CAN-G
CAN-A 153, 1017 → AVB#3 → CAN-D, E, F, G
CAN-A 100 to 1FF → CAN-B
FPGA BASED PROTOTYPE
Prototype Kit:

- Evaluation of Gateway-IP using Ethernet TSN (including security support by MACSEC) and CAN-FD
- Evaluation of new network architectures (feasibility studies)
- Implementation using two high density FPGA types.
- Prototype versions: Under development, continuous improvement is ongoing.