“eMotion in Smart Cities”

25-26th September 2012, University of Bologna, Italy

Automotive Ethernet, Holistic Approach for a Next-generation In-Vehicle Networking Standard

Peter Hank, System Architect
NXP Semiconductors, Germany
Presentation Outline

- Introduction – Connected Mobility
- In-Vehicle Networking – Three Snapshots
- Automotive Networking – A Vision for the Future
- Domain oriented architectures
- Automotive Ethernet
- First Solutions and Products
- Summary
Connected Mobility

… enables communication between cars, people, infrastructure, inside the car
In Vehicle Networking - Three Snapshots

- **Today**
  - Differentiating in standards, driven by demand for comfort, safety, energy saving, infotainment.
  - It's all about managing complexity function-wise, cost-wise, safety-wise.

- **Tomorrow?**
  - Different OEMs, different complexity, needs, solutions.

**Network Protocols**
- 100Mbit/s: Ethernet
- 10Mbit/s: FlexRay
- 1Mbit/s: CAN
- 20kbit/s: LIN

**Nodes per Vehicle**
- Daimler S-Class: >100 nodes
- Tata Nano: 2 nodes

**Company Logos**
- BMW
- GM
- Ford
- Renault
- Hyundai
- Nissan
- BYD
- Honda
- Chery
- Artemis

**Data Analysis**
- Nodes per car over years: 96, 01, 06, 11, 16, 20.
In-Vehicle Networking, a complex Beast

Diagram showing various vehicle components and their connections through different CAN (Controller Area Network) and FlexRay protocols.

- Gateway/BCM
- CAN C (HS-CAN/FT-CAN)
- CAN B (HS-CAN/FT-CAN)
- Powertrain CAN (HS-CAN)
- Powertrain FlexRay (FlexRay)
- Diagnostic CAN or Ethernet

Components:
- Engine control
- Transmission control
- Stability control
- Anti-lock brake
- Power steering
- Airbag control
- (adaptive) cruise control
- Headlight control
- AFS
- Park heating
- Steering sensors angle/torque
- Top column module
- Rear power module
- Door control front left
- Door control rear left
- Door control front right
- Door control rear right
- HVAC main
- Park assistance
- Instrument CAN
- Start/Stop
- Lighting Switch
- Rain Light Sensor
- Immo
- Camera ADAS
- Infotainment Systems
- Ethernet
- Gateway/BCM
- Key
- Headlight control
- Heater left
- Fan left
- Flapper 1
- Fan right
- Flapper 7
- Front power module left
- Front power module right
- Car access module
- HVAC rear
- TPMS
- Roof module
- Antenna
- Garage opener

Legend:
- Clamp 15 ECU connected to ignition line
- Clamp 30 ECU connected to battery, STANDBY (Vreg/uC on)
- Clamp 30 ECU connected to battery, SLEEP (Vreg/uC off)
Vision of IVN network architecture

- High data rate; different data classes coexist on same network
- New standards will come, old will stay; cost remains the driver!
- Increasing robustness demands due to more electronics
Communication and bandwidth requirements increase more and more with more complex car applications, e.g. enhanced safety, driver assistance, entertainment.

Car networks like LIN, CAN, FlexRay are not specified to cover increasing demands for bandwidth and scalability.

Network solutions for higher bandwidth are available but expensive.

End users expect in the car same level of data availability as at home.

Future networking technology shall re-use as much as possible from non-automotive while taking automotive-specific requirements into account.
Why Automotive Ethernet?

- Ethernet is good for **backbone bus** systems connecting domains and **sub-networks** that require higher bandwidth.
- Switched Ethernet networks rely on **point-to-point comm.** and bandwidth is more efficiently used than in broadcast systems (CAN, FlexRay).
- Ethernet is a **paradigm shift in next-generation car networks** to:
  - Connect different application domain networks
  - Transport different kinds of data (control data, streaming, etc.)
  - Fulfil stringent robustness demands (Temp, EMC) across network protocols
AVB (Audio Video Bridging) Ethernet

... provides QoS and synchronous communication needed for Audio/Video streaming and advanced driver assistance applications

- IEEE 802.1AS – Timing and Synchronisation
- IEEE 802.1Qat – Stream Reservation
- IEEE 802.1Qav – Queuing and Forwarding
Ethernet Physical Layer Standards

MII: Medium Independent Interface
GMII: Gigabit Medium Independent Interface
PAM: Pulse Amplitude Modulation
PMD: Physical Medium Dependent
NRZI: Non Return to Zero Inverted

100Base-TX (Fast Ethernet)
- MII
- 4B/5B
- NRZI
- MLT-3
- PMD
- Per twisted pair 100Mbit/s, 125Mbaud, uni-directional
- <<< Transmit <<<
- >>> Receive >>>

1000Base-T (Gigabit Ethernet)
- GMII
- 8B/9B
- 9B/4Q
- PAM-5
- PMD
- Per twisted pair 250Mbit/s, 125Mbaud, bi-directional
- <<< Transmit & Receive >>>

Automotive Ethernet
- BroadR-Reach
- MII
- 4B/3B
- 3B/2T
- PAM-3
- PMD
- Per twisted pair 100Mbit/s, 66.6Mbaud, bi-directional
- <<< Transmit & Receive >>>

Conclusion: BroadR-Reach Technology most promising for 1st generation automotive applications
Due to the standardized MII interface, the PHY technology can be exchanged.
BroadR-Reach vs. 100Base-TX

- Fast Ethernet (100Base-TX) spectrum interferes with radio FM-range.
- Bandwidth of BroadR-Reach can be reduced due to coding scheme.

Emission Spectrum

- Differential Mode Spectrum after magnetic (on the wire)
- Probe: Tektronix P6248
- RDW 120KHz, VBW 500KHz, SWT

FM-Range

Source: Daimler, Product Day 2010
**First Automotive Ethernet Products**

**Enhanced low power management incl.**
- Energy Efficient Ethernet support with Low Power Idle mode
- Lowest power consumption in Low Power Sleep mode
- Robust remote wakeup via Ethernet wires
- INH switch to control ECU supply

**Automotive PHY component**
- Temperature range -40 ...+125°C
- Small HVQFN-36 package
- On-chip 1.8V LDO regulator for single 3.3V supply operation
- MII as well as RMII
- Transmitter optimized for capacitive coupling to UTP cable of up to 25m length

**Automotive Grade EMC/ESD**
- MDI pins protected against:
  - ± 6kV ESD (HBM, IEC61000-4-2)
  - Transient Pulses (ISO7637)
- Enhanced integrated PAM-3 pulse shaping for low RF emission
- EMC optimized output driver strength for MII/RMII

**Diagnosis – Fail Safe Behaviour**
- Diagnosis of cabling errors (shorts and opens)
- Gap-free supply under-voltage detection with fail-silent behaviour
- Internal, external and remote loopback mode for diagnosis
- Dedicated EN pin to disable PHY in case of emergency shutdown

---

**Diagram Details**

1. **Power Unit**
   - 3.3V
   - 1.8V

2. **MAC**
   - MII
   - RMII
   - MDC
   - MDIO

3. **Microcontroller**
   - INTH
   - RSTn
   - VDDA_3V3
   - GNDA_3V3
   - GNDIO1,2
   - EN

4. **Common Mode Termination (CMC)**
   - 25MHz

---

**Components**

- uBAT
- Power Unit
- MAC
- Microcontroller
- EN
- INTH
- RSTn
- VDDA_3V3
- GNDA_3V3
- GNDIO1,2
- EN

**Package Information**

- HVQFN-36
- SOT1092
- 6x6 mm²
Summary

- Increasing bandwidth needed for driver assistance and infotainment
- Network topologies will change from decentralised domain-specific architectures to hierarchical architectures
- Ethernet provides scalability and flexibility for next-generation networks
- New automotive optimised components required
- Promising steps taken with BroadR-Reach technology
- IEEE work has been started for RTPGE (Reduced Twisted Pair Gigabit Ethernet)
- Further studies needed to validate the secure coexistence of different Data Com classes on the same network
Thank you for your attention