The evolution of In-Vehicle Networking (IVN) and its role in the next generation of automotive systems

Minnesota Tech Day
Automotive SEM
Abstract

The automobile is in a transition at a scope which has never been seen. This transition presents amazing opportunities but also very new challenges to vehicle architectures. This session provides an overview of the role that in-vehicle networking plays in the transition of small task-based networks and compute nodes to higher-level system domains related to the road to autonomy, the connected car, the in-vehicle experience, and the electrified vehicle. It also provides an overview of the technologies TI provides to the market today -- as well as the near future -- to address this transition.
• Intro – 5 minutes
  – What does the vehicle of the future look like for you?

• In-Vehicle Networks (IVN) found in automotive today – 10 minutes
  – Common Network Topologies
  – IVN Technology Comparison – 5 minutes

• Paradigm Shifts in the automobile putting higher demands on IVN – 15 minutes
  – Mechanical Systems becoming Electrified – 3 minutes
  – Smart Sensors becoming Smart Domains – 3 minutes
  – Cable Weight and Complexity – 3 minutes
  – Cloud Connectivity and Security – 3 minutes

• The Future of IVN Technologies to meet these demands – 15 minutes
  – Advancements in CAN/LIN – 3 minutes
  – The demands on SerDes – 3 minutes
  – Adoption of Ethernet – 3 minutes
  – The need for PCIe – 3 minutes
  – Continued Integration of Smart Devices (BLE/WiFi/USB) – 3 minutes

• Questions/Conclusions – 10 minutes
Common Vehicle Architecture on the Road Today

**Infotainment**
- High data rate point to point
- Typically have multiple busses running in parallel
- Gateway for OTA updates

**Powertrain**
- Localized and secure
- CAN info provided from Body and ADAS

**Body**
- Throughout the vehicle
  - LIN localized, CAN throughout
  - Secure gateway of all networks

**ADAS – Driver Assist**
- Localized sensing providing small datasets via CAN
- Point to point video data from backup camera to Infotainment

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**Infotainment**
- High data rate point to point
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**ADAS Domain Controllers**

- **ADAS Domain Controller**
  - Conditionally drive the vehicle
    1. Protect the passengers
    2. Protect the vehicle
    3. Ride comfort (active suspension)
  - Near zero data latency from sensors
    - Around the whole vehicle
    - At multiple distances
  - Deep Learning Algorithms @ minimal power
  - Visually communicate to the passengers
    - Especially the one in the drivers seat
  - Security is critical
    - Very minimal data coming in (verified V2X)
    - Secure drive and reporting data going out
Body Domain Controllers/Gateways

Body Domain Controller
- Largest number of network nodes
  1. And continuing to grow
  2. Focus on the passengers
    1. Convenience – Gesturing/HMI is a growing safety concern
    2. Comfort
    3. Safety – Occupancy detection could become an ADAS sensor
  3. Lighting – Safety, Emissions, personalization of the vehicle
- Latency is not a concern but data rate is especially for the CAN network as it is used by all domains
- Ideal choice for the vehicle gateway
  - Network translation
  - Body network encompasses most of the vehicle
  - Utilizes Ethernet, CAN, and LIN locally
  - Ethernet typically across the domains
IVI Domain Controllers/V2X Gateways

IVI Domain Controller
• Provides audio/video content to the passengers
  1. Video targeting HD/2K/4K displays
  2. HD Audio plus acoustic noise cancellation
  3. Adapting to the evolution of the cockpit
• Augment the driver’s vision in L2+ to L4
• Replace Mirrors eliminating obstructed views
• Secure and Trusted Gateway to outside the vehicle
• V2X data can assist conditional driving decisions, blind left turn for instance
• V2X will also connect / disconnect to a large number of sources quickly
HEV Domain Controllers

HEV Domain Controller
- 48 Volt Technology is expanding the power train beyond under the hood
- Power bus will be located throughout the chassis enabling power train functions locally at the wheel
- Some functions will require low latency coordination with each other and the ADAS domain
  - Adaptive suspension
  - Steering, Acceleration, Braking

48 Volt System
Drive by Wire
Active Suspension

- CAN / 10/100 Ethernet

Domain Controller
Internal Combustion Engine (ICE)
Domain to Domain Communication

Domains
- HEV Domain Controller/BMS
- ADAS Domain Controller
- IVI Domain Controller/Gateway
- BEL Domain Controller/Gateway

Domain based communication
- Enables all the nodes in the vehicle to communicate subsets information
  - Cloud Connectivity/V2X
  - Level 2+/3 Autonomous
- Primary focuses are latency and security
  - Gateways
  - Network translation
- CAN and 10/100 Ethernet are whole car networks (WAN)
- PCIe, LIN, GigE, SerDes are local networks (LAN)
- Domain controllers do not address cabling weight as multiple networks travers the same path
Network duplication by domain

- **ADAS**
  - CAN
  - SerDes
  - Domain Controller
  - Radar
  - Camera
  - Ultrasonic

- **BEL**
  - CAN
  - LIN
  - BLE
  - Domain Controller/Gateway
  - Car Access
  - Lighting
  - HMI
  - Comfort/Convenience

- **IVI**
  - Gig Ethernet
  - AVB Ethernet
  - LVDS
  - Domain Controller/Gateway
  - Premium Audio/Hands Free
  - Telematics/V2X
  - Automotive Displays

- **HEV**
  - CAN
  - Domain Controller
  - Internal Combustion Engine (ICE)
  - 48 Volt System
  - Drive by Wire
  - Active Suspension
# Automotive Interfaces Comparison

<table>
<thead>
<tr>
<th>Technology</th>
<th>Interface</th>
<th>Cable Type</th>
<th>Topology</th>
<th>Data Rate</th>
<th>Latency</th>
<th>Arbitration</th>
<th># of Nodes</th>
<th>Payload</th>
<th>Overhead</th>
</tr>
</thead>
<tbody>
<tr>
<td>SerDes</td>
<td>CSI-II, DSI, DP, HDMI, oLDI, DVI, I2C</td>
<td>Coax/STP</td>
<td>P2P</td>
<td>1.9 to 7.4Gbps</td>
<td>~us</td>
<td>Serializer/Deserializer</td>
<td>1</td>
<td>N/A</td>
<td>0</td>
</tr>
<tr>
<td>PCIe</td>
<td>PCIe</td>
<td>STP</td>
<td>P2P</td>
<td>2 x 8Gb/s</td>
<td>~ns</td>
<td>PCIe</td>
<td>1</td>
<td>Up to 4kB</td>
<td>128/130B</td>
</tr>
<tr>
<td>Ethernet</td>
<td>RGMII/MII</td>
<td>Single Twisted Pair</td>
<td>P2P/Switch</td>
<td>100/1000 Mb/s</td>
<td>Vero Low for large data sets</td>
<td>IP Layer QoS</td>
<td>2^128</td>
<td>64kB</td>
<td>18B MAC / 40B IPv6</td>
</tr>
<tr>
<td>CAN</td>
<td>CAN</td>
<td>Twisted Pair</td>
<td>Multi-master Bus</td>
<td>5Mb/s (FD)</td>
<td>Low</td>
<td>Bit-wise dominant</td>
<td>2048/524,288</td>
<td>0 to 8 Bytes</td>
<td>43/64 bits</td>
</tr>
<tr>
<td>LIN</td>
<td>UART</td>
<td>2 Wire?</td>
<td>Star</td>
<td>20kb/s</td>
<td>Fixed but High</td>
<td>Master/Slave</td>
<td>16</td>
<td>2,4,8 Byte</td>
<td>4 Bytes</td>
</tr>
<tr>
<td>RS485</td>
<td>UART</td>
<td>2 Wire</td>
<td>P2P/Star*</td>
<td>Mb/s</td>
<td>Lower than LIN*</td>
<td>Master/Save</td>
<td>Network defined</td>
<td>1 Byte*</td>
<td>0 Bytes*</td>
</tr>
</tbody>
</table>

* No standard protocol used in Automotive
Automotive CAN/Lin
TI CAN bus value/differentiation

Flexible data rates
- Classic CAN / CAN FD
- From 1Mbps to 5Mbps

Low Emissions
- OEM Approved
- High Immunity
- Choke-less implementations

Voltage
- Wide Operating Voltage
- High Bus Fault Voltage up to ±70V

Protection
- High HBM ESD
- IEC61000-4-2
- AEC-Q100 qualification

Integration
- LDO power options
- SPI Interface
- Galvanic Isolation

Innovation
- SBC solutions
- Ultra-low power
- Advanced packaging options
TI Information – Selective Disclosure

TLIN Complete Automotive Solution

±45 V Bus Protection

TLIN102x-Q1

- Devices Include:
  - TLIN1029
  - TLIN1027
  - TLIN1024
  - TLIN1022
  - TLIN1021

12 V

±58 V Bus Protection

TLIN202x-Q1

- Devices Include:
  - TLIN2029
  - TLIN2027
  - TLIN2024
  - TLIN2022
  - TLIN2021

24 V
Automotive Ethernet
**Standard BASE-TX vs. BASE-T1 Ethernet**

IEEE802.3bw (100BASE-T1, also known as BroadR-Reach) and 802.3bp operate with a single twisted pair which helps save on cabling cost/weight.

<table>
<thead>
<tr>
<th></th>
<th>Standard 100BASE-TX Ethernet</th>
<th>IEEE802.3bw UTP Ethernet</th>
<th>IEEE802.3bp Ethernet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maximum Bandwidth</strong></td>
<td>100Base-TX two twisted pairs</td>
<td>100Base-T1 single twisted pair</td>
<td>1000Base-T1 single twisted pair</td>
</tr>
<tr>
<td><strong>Cabling</strong></td>
<td>100 Mb/s</td>
<td>100 Mb/s</td>
<td>1000 Mb/s</td>
</tr>
<tr>
<td></td>
<td>Two twisted pairs (4 wires)</td>
<td>Single twisted pair (2 wires)</td>
<td>Single twisted pair (2 wires)</td>
</tr>
<tr>
<td><strong>Standard Cable Length</strong></td>
<td>100m per link</td>
<td>15m per link</td>
<td>15m per link</td>
</tr>
<tr>
<td><strong>Data Transfer</strong></td>
<td>Half-duplex</td>
<td>Full-duplex</td>
<td>Full-duplex</td>
</tr>
<tr>
<td><strong>Sample Applications</strong></td>
<td>Diagnostics</td>
<td>Domain to domain connections</td>
<td>Domain to domain connections</td>
</tr>
<tr>
<td></td>
<td>Firmware/Software Upgrades</td>
<td>ADAS/Infotainment</td>
<td>ADAS/Infotainment</td>
</tr>
<tr>
<td></td>
<td>End of line programming</td>
<td>Body Control Module</td>
<td>Body Control Module</td>
</tr>
</tbody>
</table>

IEEE802.3bw PHY (802.bp) interoperable device

IEEE802.3bw (100BASE-T1, also known as BroadR-Reach) and 802.3bp operate with a single twisted pair which helps save on cabling cost/weight.
DP83848Q-Q1
Extended Temperature Single Port 10/100 Mb/s Ethernet PHY

Highlights
• Industry’s gold standard
• Robust and reliable
• AEC-Q100 Grade 2 Qualified
• QFN40 package
• Operating Temperature -40C to 105C

Key Specs
• MII/RMII/SNI MAC interfaces
• Deterministic, low transmit and receive latency
• <270mW typical power consumption

Automotive Applications
• Telematics/OBD
• Trains: Surveillance and in-cabin network control
• Aftermarket connections needing standard Ethernet
Automotive SerDes
What can you do with FPD-Link?

- Rear-seat Entertainment
- Passenger Display
- Infotainment
- Cluster
- HUD
- DLP Headlights
- eMirror
- Rear View Camera
- Forward Camera
- Driver Monitoring
- CMS
- Surround View
- Radar/LiDAR
Display & Camera Resolutions – next generation
Automotive BLE
BLE in Automotive Market trends

Today
• Phone as a Key / Digital Key
• Relay Attack prevention with BLE
• Personalization
• Car sharing / Remote Parking
• Secure remote firmware update

Trends
• Wireless Battery Management Systems
• Cable replacement
BLE for Automotive - Why TI?

**Portfolio**
- 4th generation connectivity
- Best-in-class RF performance
- Lowest power consumption
- Next platform designed for automotive connectivity

**Innovation**
- Software defined radio – versatile, future-proof architecture
- Customizable RF core
- Real-time Localization System (RTLS) platform
  1. RSSI w/ connection monitor
  2. Angle of Arrival (AoA)
  3. Time of Flight (ToF)
- Software innovation, scalability

**Commitment**
- Superior customer support
- 8+ years of BLE in the market
- Robust BLE5 SW products
- Quality and reliability
  - ASPICE
  - AEC-Q100
CC2640R2F-Q1 Automotive Wireless MCU

Features and Benefits

• AEC-Q100 automotive qualified
• Most integrated wireless MCU – Design versatility and single-chip SoC
• Lowest power consumption - ~6mA radio RX/TX and low sleep current for increased battery life
• Longest range – 101 dB link budget for increased range and reliability
• Grade 2 Temperature Rating (-40°C to +105°C) – Use in areas where elevated temperatures are common
• Wettable flanks package – Enables faster and lower cost production line inspection

Software and Tools

• Software Development Kit, including royalty free Stack
• BT v4.2 support with qualified Adopted Profiles (BLE 3.x)
• SmartRF Studio & TI iOS/Android Multitool
• Sensor Controller Studio

Hardware Development Kits

CC2650 SensorTag  CC2640R2F LaunchPad

Example Applications

• Car Access (RKE, PKE, PEPS)
• Car sharing
• Piloted parking
• Cable replacement and remote control

http://www.ti.com/product/cc2640r2f-q1

TI Confidential– NDA Restrictions
Automotive PCIe
Use Case Summary
- Insertion loss from media interconnects necessitate redrivers or retimers for PCIe Gen-3/4 signal integrity.
- Redrivers and retimers give opportunity for all system components to contribute to channel equalization.
When to Use Redrivers:
- Total link channel with 17 dB - 32 dB insertion loss (24” to 47” FR4 with 2 connectors)
- Environments where additional margin in signal integrity is needed to ensure error-free transmission
- Applications prioritizing low power and ultra low latency
Summary

- The Evolution of In-Vehicle Networking is being driven by a range of advancements in automotive
  - The next level of autonomous driving, requiring multiple sensors reporting data at near zero latency
  - The 48V (mild EV) adoption, moving powertrain systems from the hood to throughout the vehicle
  - The large increase of vehicle-defining electronic body/comfort features even in lower end vehicles
  - Real-time, high-speed connectivity outside of the vehicle

- Domain to Domain connectivity is a requirement; Security, very low latency, high data-rates are the new challenges being faced by OEMs.

- Cabling weight is still a major concern, the solution of which may be very large data backplanes.

- USB connectivity still prevalent in vehicles, as is Wifi AC, TPMS, RKE

- Texas Instruments also produces processors targeted for domain controllers