The Rise and Evolution of Gateways and Vehicle Network Processing

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June 2019  |  Session #AMF-AUT-T3619
Agenda

• What is a Automotive Gateway?
• Gateway Evolution
  – Overview, Market Trends, Architecture
• NXP Gateway Reference Solutions
• Summary
• For More Information
What is an Automotive Gateway?

https://www.nxp.com/video/:AUTOMOTIVE-GATEWAY-VID

Local Video
The Automotive Gateway is Central to the Vehicle
Automotive Gateway is Central for Vehicle Communications
### Key Gateway Functions

<table>
<thead>
<tr>
<th>Gateway Capability</th>
<th>Description</th>
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<tbody>
<tr>
<td>Protocol Translation</td>
<td>Translating data and control information to/from incompatible networks to enable communications between them</td>
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<tr>
<td>Data Routing</td>
<td>Routing of data on a path to reach its intended destination. It may be on different networks requiring protocol translation.</td>
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<tr>
<td>Diagnostic Routing</td>
<td>Routing of diagnostic messages between external diagnostic devices and ECUs which may involve translation between diagnostic protocols such as DoIP and UDS.</td>
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<tr>
<td>Firewall</td>
<td>Filtering inbound and outbound network traffic based on rules, disallowing data transfers from unauthorized sources. Advanced firewalls may include context-aware filtering.</td>
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<tr>
<td>Message Mirroring</td>
<td>Capturing data from received interfaces to transmit over another interface for diagnostics or data logging (storage)</td>
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<tr>
<td>Intrusion Detection</td>
<td>Monitoring network traffic for anomalies that may indicate intrusion</td>
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<tr>
<td>Network Management</td>
<td>Manages the states and configuration of the network and ECUs connected to network, and support diagnostics</td>
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<tr>
<td>Key Management</td>
<td>Secure processing and storage of network keys and certificates</td>
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<tr>
<td>OTA Management</td>
<td>Managing remote OTA firmware updates of ECUs within the vehicle that are accessible from the gateway</td>
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Gateway Evolution – Overview
Automotive Industry Megatrends
Megatrends Force Vehicle Architecture Transformation

**TODAY FLAT / GATEWAY**
- Low bandwidth, flat network
- One MCU per application

**TOMORROW DOMAINS**
- High bandwidth network
- Gateway key to communication between domains

**FUTURE ZONES**
- Domains virtualized by SW – enabling high flexibility
- Easy enable/disable or update functions

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**Unfit for Future Mobility**
**Step to Autonomous Car**
**Step to User-defined Car**
Gateway Rise and Evolution

- No or limited connectivity
- No or limited security
- Basic routing
- Limited bandwidth / scalability (kilobit / Megabit interfaces)

**Connectivity**
- High-speed wireless interfaces (4G→5G, Wi-Fi)
- High security, isolation, public key crypto, contextual firewall, intrusion detection
- Advanced routing, vehicle OTA, analytics, ECU consolidation, new services
- High-bandwidth, scalable architectures (Gigabit interfaces)
Key Gateway Use Cases

• The Gateway is becoming the central, critical component in vehicle architectures
  - System security, OTA management, applications/services, analytics, vehicle compute, and more
• Gateways are shifting to software-centric solutions → introducing new services
  - Enables OEM differentiation, operational efficiency, and new revenue generation
  - Improves customer satisfaction

• Protocol and Data Translation
  - Network protocol-to-protocol translation
  - Raw data-to-contextual information

• Network Security
  - High-performance contextual firewall
  - Intrusion Detection and Prevention System
  - Authentication and Secure Messages
  - Network Key Management

• Over-the-Air (OTA) Updates Management
  - Remote upgrades (new features, safety/security patches…)

• Apps Processing / Services
  - ECU consolidation
  - Analytics (edge processing and edge-to-cloud)
  - Remote monitoring and condition-based maintenance (prognostics / vehicle health monitoring)
  - Centralized functions (vehicle identity, power strategy…)
  - Agile deployment of future functionality
Market Trends: Networking

• Move to a predominately Ethernet backbone
  - Bandwidth needs – autonomous driving platforms, infotainment
  - Domain controller approach – domain isolation; simplifies logistics of deploying vehicle platform
  - IP Routing, VLAN & >L3 firewalling to isolate & protect Ethernet domains
  - Diagnostics over IP (DoIP) usage widespread

• Hybrid Approach during 2020 to 2025
  - Typical: 3-5 Ethernet domains + 10+ CAN

• # of CAN channels increasing
  - Isolation of increasing number of ECUs
  - Up to ~175 ECUs in some high-end vehicles!
Market Trends: Network Security

• **Gateway is considered as a central location for security**
  - Policing vehicle information, monitoring traffic between networks, security key management

• **Growth of Ethernet**
  - Wider range of known attacks
  - Ways to protect:
    ▪ Layered network hierarchy
    ▪ Contextual firewalls, deep packet inspection (DPI), etc…
  - Firewalling & Security brings **significantly greater performance requirements** than CAN
  - Need for a processor with **network security in mind**
Market Trends: Processor Security

• Industry attention after security hacks publicized in 2015

• Need to secure gateway processors from malicious attacks
  – Taking control of the ECU
  – Stealing Intellectual Property

• Connected services driving additional layers of security in the gateway
  – Public Key handling acceleration, connecting through internet
  – Physical protection of keys guaranteed strong root of trust. Extremely high value keys that need protected
Market Trends: Over-The-Air (OTA)

• **Over-the-Air firmware/software updates** is a key trend in the industry

• **Trend to move OTA Management function in Gateway ECU**
  - Centralized management of OTA deployment in-vehicle
  - Interface to OEM servers
  - Security is paramount

• **Utilizing OTA mechanism to deploy new features via SW in field** (Agile SW deployment)
  - Build performance overhead into hardware
  - In-field, test & deploy new customer features as use cases emerge
Market Trends: Connectivity

• Trusted & untrusted connectivity
  - Untrusted infotainment (IVI) system
  - Connected car vs In-Vehicle Network
  - New services being introduced to vehicles (e.g., OTA)

• Move to separation of connectivity
  - Trusted: Gateway
  - Untrusted/Consumer: IVI

• Enabling new features
  - OTA Updates
  - Remote Diagnostics - Tester in gateway (Diagnostics over IP)
  - IoT Connectivity - Translation of raw data into rich information
  - Cloud Offload – e.g., Analytics, Modelling vehicle behaviour
Market Trends: Processing

• 1000’s of DMIPS performance needed to support future service-oriented gateway providing new capabilities and services

• **ECU consolidation**: Feature deployment by SW package rather than new ECU

• **Data Analytics**: Descriptive / Diagnostics / Predictive
  - Edge analytics
  - Cloud connectivity
  - Machine Learning (ML)
Gateway Evolution – Architectures
CAN Central Gateway Architecture

- **Legacy Automotive Networks**
  - Typically 3-8 CAN networks
  - Typically 1-2 FlexRay networks

- **Increased Bandwidth**
  - but, small compared to consumer / networking world
  - Proprietary protocols for higher bandwidth (e.g. MOST)

- **Physical Isolation**
  - Functional domains
  - Safety / Non-safety

- **Gateway Role**
  - Firewall internal traffic
  - Protocol translation
Hybrid Ethernet Architecture

• **Legacy + Ethernet Networks**
  - CAN, FlexRay & Ethernet

• **High-bandwidth Data**
  - 100Mbit → 1Gbit Ethernet
  - ADAS and Infotainment drive higher data rates
  - Improved ECU program time in factory

• **Gateway role**
  - Firewall internal & external
  - Efficient protocol translation
  - ECU consolidation
  - New apps & services
Ethernet Backbone with Domain Controllers

- Ethernet Backbone with Domain Controllers
  - ECU consolidation
  - Distributed gateway

- Central Compute
  - Strategy / Decision making
  - Distributed vs Centralized
Central Compute Architecture

- **Central Compute + I/O Gateways**
  - No functional domains
  - Strategy for vehicle fully owned by Central Compute

- **I/O Gateways Connect Edge Nodes to Central Compute**
  - Distributed processing
  - Optimize network utilization

- **Benefits:**
  - Network architecture optimised to vehicle topology
  - Less wires (less weight, power, cost)

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‘Edge Nodes’
e.g. Radar ECU, Powertrain ECU

[Diagram of Central Compute Architecture]

Central Compute

High Speed Ethernet Network (Mesh/Ring)
Optimised to vehicle topology for Reduced Wiring
Moving Towards Central Compute: “Server in the Car”

- **Network Security**
  - Intrusion Detection and Prevention
  - Firewall
- **Applications Server**
- **Integration of Cloud and Fog Services into the Vehicle Architecture**
- **Proliferation of PHY Technologies**
  - 100Base-T1 -> 1000Base-T1, 10 Mbps, 10 Gbps, 25 Gbps, 10GBASE-KR (802.3ap), …
- **Communication Paradigms Evolve**
  - Service-based versus signal-based
  - Authentication
  - Encryption
NXP Secure Ethernet Gateway Reference Design

Hardware Features
- 5 x 100Mbit/s Ethernet
  - 4x100Base-T1
  - 1x100Base-TX for Diagnosis/SW Update
- 8 x CAN (CAN-FD compatible)
- 2 x LIN
- eMMC (4GB)
- 3 x PWM / Digital IN
- 2 x Analog IN
- 2 x HS Switch OUT
- Wake IN/Wake OUT
- 1 x RS232 (option)
- JTAG Debug

Based on NXP MPC5748G Gateway Microcontroller
MPC5748G-GW

Information:
MPC5748G-GW Secure Ethernet Gateway

NXP Components:
MPC5748G (Gateway MCU), S32K144 (Monitor MCU), FS6522 (Power SBC), SJA1105Q (5-Port Ethernet switch), TJA1044 (CAN PHY), TJA1043 (CAN PHY), TJA1021T (LIN PHY), TJA1102 (Ethernet PHY), TJA1100 (Ethernet PHY)

Cost: $349

How to buy: NXP.com
NXP Secure Ethernet Gateway Block Diagram
Gateway Demo Architecture

Functions description:
- **Central Gateway**: Central communication node, link vehicle with the outside.
- **TCU+SE**: Telematic communication, connect vehicle with the outside.
- **Domain Controller A/B**: Domain communication controller, frames filtering and security guarantee.
MPC-LS Vehicle Network Processing Solution

• Enables Next-gen VNP Solutions
  - Automotive Microcontroller + Network Processing
  - (Gigabit Ethernet Packet Routing) + Applications
  - MPC5748G + LS1043A (MCU + MPU)
  - Available today

• Feature Set
  - CAN Signal Gateway (ASIL B)
  - 4x Arm Cortex-A53 (LS1043A)
  - Packet Forwarding Engine

• OS Support
  - AUTOSAR: Real-time CAN gateway
  - FreeRTOS: limited support
  - Linux: Ethernet routing, applications processing
MPC-LS Vehicle Network Processing (VNP) Reference Design Board (RDB)

- Real-time Gateway Processing
- Applications Processing
- Gigabit Ethernet Acceleration
- Embedded Security

Part Number: MPC-LS-VNP-RDB
- Price: $749   Available: July’19 for approved customers
- Reference Design: 90% of BOM is Automotive Grade
- Includes SW enablement and demonstrations

NXP Components:
- MPC5748G (MCU), LS1043A (Comms Processor), SJA1105SEL (5-port Ethernet switch), PF8200 (Power Management IC)
- TJA1081TS (FlexRay), TJA1024HG (Quad LIN), TJ1102HN (Dual Ethernet PHY), TJA1048T (Dual CAN Transceiver)
- NTS0102 (Dual Supply Transceiver), NX5P3090UK (USB Power Switch)

www.nxp.com/MPC-LS-VNP-RDB
MPC-LS VNP Reference Design Board Key Components

- LS1043A Console connector
- Dual-stacked USB connector
- RGMII EC1 and EC2 connector
- Aquantia 10G connector
- Auto Ethernet Port 1
- Auto Ethernet Port 2
- RGMII Ethernet Phy connected to SJA1105 switch
- MPC5748G Console connector
- Power
- Fault/Power LEDs
- M.2 connector (PCIe) for SSD, peripherals
- CAN connector
- LIN connector
- MPC5748G
- Reset button
MPC-LS-VNP-RDB Block Diagram

- **Processors**
  - MPC5748G Automotive Microcontroller
  - LS1043A Communications Processor

- **Memory**
  - 2 GB DDR3L @ up to 1.6 GT/s
  - 1 GB NAND flash
  - 64 MB Serial NOR flash
  - 8 GB eMMC

- **Storage**
  - M.2 M-Slot for optional PCIe SSD

- **NXP Support Devices**
  - PF8200 Power Management IC
  - SJA1105SEL Ethernet Switch
  - TJA1024 LIN PHY
  - TJA1048 CAN PHY
  - TJA1081 FlexRay PHY
  - TJA1102 100 Mbps Ethernet PHY

- **PCB**
  - Single 6-layer board ~ 6.1 x 6.4 inches
  - 90% of BOM Automotive Grade
Demonstration Software
MPC-LS Demo Applications Software
Ethernet Packet Acceleration

Web-based Application with below functionalities:
- Demonstrating packet acceleration during network load
- Enabling and disabling of HW acceleration (Slow Path/Fast path with load on primary cores)
- Realtime CPU Load monitoring
- Router setup/configuration connecting two PCs

Value Proposition:
- Ethernet Packet Acceleration vs SW-based competition
Automotive Data Logger

- Vehicle Health Parameters recorder - "relevant" data from Vehicle logged into a mass storage.
- Calypso receiving the CAN data from an external CAN traffic generator.
- Data transmitted via IPC to Layerscape for logging.
- Logged Data shared over cloud
- Data fetched from cloud for monitoring.

Value Propositions:
- Cloud connectivity (Apps Processing)
- PCIe memory
- MCU to MPU (CAN-Eth)
- Security (CAN, Eth & Cloud)
Software Defined Network (SDN) in Vehicular Networks

Value Propositions:
- Cloud controlled firewall: Connectivity, Ethernet, Apps Processing.

Full functional SDN Stack showcased on one Arm Cortex-A53 core in Layerscape
Summary
Summary

- **Automotive Gateways** are critical for providing secure communications between vehicle domains, but are evolving to provide more capabilities:
  - Over-the-Air Updates, Intrusion Detection, Analytics, Vehicle Health/Prognostics, Apps/Services...

- **Multiple approaches** to In-Vehicle Network architectures across carmakers and over the next decade:
  - No gateways → Central Gateway
  - Central Gateways + Domain Controllers
  - Central Compute → Server in the Car

- **Gateways** are evolving quickly to meet new demands driven by vehicle electronics: connected car, infotainment, ADAS/autonomous driving,...
  - More performance, security, connectivity, higher bandwidth, safety

- **NXP** is leading the way in / vehicle network processors to help drive the Gateway Evolution and enable carmakers’ innovations
For More Information

• NXP.com resources:
  - NXP Central Gateway Site
  - NXP Secure Gateway & In-Vehicle Networking

• NXP Connects Sessions and Demo:
  - AMF-AUT-T3662 - “Layerscape in Automotive—Multi-Arm Processors for Telematics, Gateway and AD Sensor Fusion”
  - AMF-AUT-T3657 - “Service-Oriented Architecture—Design and Implementation Using Automotive Linux BSP”
  - AMF-AUT-T3697 - “PF81/PF82 PMICs for High-Performance Applications Processors”
  - Demonstration – Technology Lab Kiosk #209 - “Unlocking Vehicle Data with the MPC-LS Chipset”
SECURE CONNECTIONS FOR A SMARTER WORLD