Automotive SDN: Prototype and Use-cases

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Agenda

- Introduction
- Use cases
- Architecture
- Evaluation
- Conclusion
Why Automotive SDN?

✓ Vehicle network architecture trend and future roadmap

- High Bandwidth
- Ethernet backbone among ECUs
- Heterogeneous network around zone ECUs

✓ Further consideration of future vehicle network

- Fail-over
- Dynamic bandwidth control
- Flexibility of future network capability
Key characteristics of SDN

1. SDN can provide fail-over operation in case of failure
2. SDN can control bandwidth dynamically based on the vehicle situation
3. SDN can reconfigure the network after the new service is deployed


**SDN in general**

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Plane</td>
<td>• Centralized software</td>
</tr>
<tr>
<td></td>
<td>• Global view of the network</td>
</tr>
<tr>
<td>Data Plane</td>
<td>• Control by SW-based control application</td>
</tr>
<tr>
<td></td>
<td>• Programmable</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Flow</td>
<td>• Control packet forwarding table</td>
</tr>
<tr>
<td></td>
<td>• Use case : Routing control</td>
</tr>
<tr>
<td>NETCONF</td>
<td>• Control network configuration</td>
</tr>
<tr>
<td></td>
<td>• Use case : Bandwidth control</td>
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</table>

✓ **Software Defined Network**

- An alternative to the traditional switch-based network
- Centralized Control
- Programmability

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2022 IEEE-SA Ethernet & IP @ Automotive Technology Week, Hyun taek Hong (LG Electronics) & Kilho Lee (Soongsil University)

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Considerations for Automotive SDN

✓ Relatively small compared with traditional data center
  • Number of network nodes for end-to-end communications are small

✓ Hardware upgrade is limited
  • Once the vehicle is delivered to customer, it should be maintained more than 10 years

✓ The possibility of physical damage is higher than the legacy IT system
  • Crash can be happening a lot compared with traditional systems

✓ Co-existance with legacy network like CAN
  • Legacy network traffic is combined with Ethernet traffic

✓ Energy efficient network management
  • Minimal network operation according to the given situation
Previous study of Automotive SDN

✓ MC-SDN (Mixed-Criticality SDN)
  - Network flows with different levels of criticality
  - Dynamic scheduling policy depending on the system mode

✓ FR-SDN (Fault-Resilient SDN)
  - Recover from link failure by finding alternative routes
  - Perform path restoration from SDN controller-driven to switch-driven

Adaptive Cruise Control
Adjusting the car speed to maintain the safe distance.

Goal
Preserving the cruise control performance against link faults

At here, a link fault happens in the following car.

Safe distance 1.5 m

0 m

15 m
SDN use-case 1: Dynamic bandwidth/priority control

✓ Scenario
  • Reserve bandwidth to the front camera / sensors when emergency event is detected

✓ It dynamically manages bandwidth/priority guarantees according to the runtime network usages

✓ Bandwidth/Priority controls
  • Queue management
SDN use-case 2: CAN signal transfer with priority

- Scenario
  - Radar signal transfer when lane-change is triggered

- There will still be CAN signals as it will take a long time to eliminate legacy parts

- Priority controls
  - Select relevant priority when transferring
  - Transfer frequency control
  - Packet size control
SDN use-case 3: Maintain reliable communication

✓ Scenario
  • It maintains reliable communication even if a fault happens on some network link/node

✓ Upon detecting a fault, it then establishes an alternative path to detour the fault.

✓ Path reconfiguration
  • Flow table update
  • Measure QoS
  • Control path re-establish
Reference architecture: Overall design

✓ Draft architecture considering 3 scenarios

System Architecture

SDN 3 Layers

- Network planner
  - Fault handling
  - BW-aware routing
  - Network status

- Northbound interface (App – controller)
- Control Layer
- SDN controller abstraction
- Southbound interface (controller – switch)
- Infra Layer
- SDN switches
Reference architecture: Network planner

✓ Role of Network planner

• Monitors & maintains the global information of all the network nodes
• Reserves the bandwidth for a specific flow by controlling multiple nodes
• Reconfigures the path by monitoring each network node status

✓ Considerations for Network planner for automotive networking systems

• Dynamic bandwidth reservation & packet prioritization
• Reliable communication based on runtime fault recovery
Reference architecture: Routing

✔ Role of the routing component
  • Determines a proper route subject to the flow requirement

✔ Considerations for the routing component
  • Responsiveness
  • QoS/timing requirements
  • Runtime dynamic routing
Reference architecture: Fault handling

✓ Role of the fault handling component
  • Restores flow routes upon link/node faults

✓ Considerations for the fault handling component
  • Fault detection
  • Responsive route update
  • Control channel recovery
Reference architecture: Signal to Service Translator

✔ Role of Signal to Service Translator
  • Focusing on deterministic transmission of CAN signals with priority control logic

✔ Considerations for Signal to Service Translator
  • Priority control
  • Filtering while translation (eliminate duplication, scenario based filtering)
  • Relationship with SOA

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<tr>
<td>Signal Handler</td>
<td>Translate CAN signal to Service message</td>
</tr>
<tr>
<td>Service Handler</td>
<td>Translate Service message to CAN signal</td>
</tr>
<tr>
<td>Filter</td>
<td>Filter CAN signal to translate</td>
</tr>
<tr>
<td>Priority Manager</td>
<td>Assign priority to Service message</td>
</tr>
<tr>
<td>CAN Manager</td>
<td>Send / Receive CAN signal</td>
</tr>
<tr>
<td>SOME/IP</td>
<td>Send / Receive Service message</td>
</tr>
</tbody>
</table>
Reference architecture: Experiment

✓ Prototype implementation
  • Networked embedded nodes
  • Physical Ethernet & CAN communications
Evaluation: bandwidth reservation

- Efficacy of routing & bandwidth reservation
  - The target (safety- or mission-critical flow) effectively reserves the bandwidth.
  - Despite the contending best effort flows.

- Setup
  - Target flow: RR $\rightarrow$ V-COM, UDP, 70Mbps
  - Background: FR $\rightarrow$ VCOM, TCP, BE (up to 100Mbps)
Evaluation: CAN signal prioritization

- Efficacy of CAN signal prioritization
  - The safety-critical CAN signal shows stable latency
  - Despite the contending best effort flows.

- Setup
  - Target CAN signal: CAN device → CAN-BUS → RR(S2S) → VCOM (8 Bytes@1000 Hz, UDP encap.)
  - Background: FR → VCOM, TCP, BE (up to 100Mbps)
Evaluation: Fault handling

- Efficacy of Fault handling
  - Effectively restores flow route upon link failure.

- Setup
  - Target CAN signal: CAN device → CAN-BUS → RR(S2S) → VCOM
Conclusion

✓ Recap: automotive SDN
  • Key issues and use-cases
  • Reference architecture
  • Prototyping & evaluation

✓ Implications
  • Better flexibility, efficiency, and reliability → essential features for SDV.

✓ Discussion & further considerations
  • Security
  • Functional Safety
  • Better SDN interfaces for automotive
  • Integration with the automotive software architecture
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