“Service-Oriented Gateway: Connecting Automotive Ethernet and Cloud for Efficient Development of Connected Car Services”

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Service-oriented Gateway

• End-to-End Service-oriented Architecture
• External Connectivity : Challenges & Approach
• Structural Concept
• Software Architecture
End-to-End Service-oriented Architecture

- Extended Service-level Transparency and Integrated Service Design

End-to-End Service-level Transparency
External Connectivity: Challenges and Approach

- **External Devices on External Network**
  - Vehicle needs to interwork with external devices like *cloud servers* and smart devices.
  - Interworking need gets much larger for ADAS and other connected car services.
  - External networks have very different characteristics compared to IVN: availability, bandwidth, latency, cost, etc.
  - Application Protocols for external connectivity are usually different from those for IVN in general.
  - High-risk security issues when interworking through external networks.

- **Service-oriented Gateway**
  - Handles issues related with external device/network interworking.
  - **Converts Application Protocols** and Translates Services.
  - **Caches external information** to deal with availability & cost issues of external networks.
  - Applies **Policy** and Performs Service-level **Access Control**.
  - Should be implemented on ECU with external connectivity.
Structural Concept

- Structural Concept of Service-oriented Gateway Interworking with Cloud Functions & Services
  - In-vehicle Service Applications use Data/Functions from Cloud
  - Cloud uses Data/Functions provided by In-vehicle Service Applications

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**Service Domain**

- Consu. App
  - SOME/IP
  - TCP/IP

- Service
  - Aut. Ethernet

**External Domain**

- Service-oriented G/W
  - Ext. NW. Interface

- Cloud Functions & Services
  - Cloud Servers
    - Get_Loc
    - Get_Speed
    - RoadCond
    - WeathFcst

- Ethernet Switch

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Other In-vehicle ECU’s

- Location
- Veh. speed

*In-Vehicle Service*

- Get_RoadCond
- Get_WeatherFcst

*Cloud Service*
Software Architecture

- Service-oriented G/W relays information between External Devices and In-Vehicle ECU’s
  - With external devices: HTTP/MQTT/SMS depending on communication pattern
  - With in-vehicle ECU’s: Service-oriented communication based on SOME/IP
Features of Service-oriented Gateway

- Protocol Conversion – Service Communication
- Protocol Handling – Service Discovery
- Edge Processing
- Policy & Access Control
- Network Utilization
Protocol Conversion: Service Communication

- **Two-way Communication**: Vehicle Origination
  - Service Consumer makes method requests to G/W and the requests are relayed to External Networks using HTTP.

![Diagram showing two-way communication between service application and cloud via service-oriented gateway](image-url)
Protocol Conversion: Service Communication

**Two-way Communication:** Vehicle Termination

- After receiving requests from Cloud, G/W makes corresponding method calls to an appropriate Service Provider and relays the responses to Cloud.
Protocol Conversion: Service Communication

- **One-way Communication: Vehicle Origination**
  - Service Provider fire an event to G/W and then G/W relays the event data to Cloud using HTTP
  - To facilitate communication with In-vehicle ECU, G/W utilizes SOME/IP SD to subscribe to events
Protocol Conversion: Service Communication

- **One-way Communication**: Vehicle Termination
  - G/W relays data from Cloud to In-vehicle ECU’s as event notification
Protocol Conversion: Service Communication

- External Connection Status is mapped to corresponding Service Domain Behavior
  - Example
    - In case of unstable network or busy server: Retry Server Connection (NOT_OK if Time out)
    - In case of no available network: Respond with NOT_OK
Protocol Handling: Service Discovery

- G/W performs Service Discovery for service-oriented communication with In-vehicle ECU’s
  - Uses SOME/IP SD Protocol
  - Adaptive Operation Timing and Behavior Modes in accordance to External Network status

(Example)
Edge Processing

- **Caching** Responses from External Networks
  - Prevents unnecessary excessive connections to external networks
  - Improves Responsiveness & Reduces Network Cost

![Diagram]

1. **GetWeatherInfo**
2. **Service-oriented Gateway** with a cache
3. **Cloud**
4. **Service Consumers** #1 and #2

Request:
- Cloud to Service-oriented Gateway
- Service-oriented Gateway to Service Consumers

Response:
- Service Consumers to Service-oriented Gateway
- Service-oriented Gateway to Cloud
Edge Processing

📅 Filtering & Aggregation

- Relays **less data and less frequently** to Cloud than received from in-vehicle ECU’s.
- Performs Period-based or Contents-based Filtering.
- Aggregates Multiple Events from One or Several Service Applications.
- Reduces Communication loads and Network costs.

![Diagram of filtering and aggregation process](image.png)
Policy & Access Control

- **Service-level Access Control**
  - Access Control at Service Level or Service Element Level (e.g., for each method or event)
  - Access Control Policy can be applied Statically or Dynamically from Cloud

- **Operation Policy**
  - Policy can be applied for other G/W operations like Filtering, Caching, and Network Mapping.
Connected Car Service Example

- Door Control Service
- Emergency Alarm Service
Connected Car Service Example

Remote Door Control Function

- Utilizes existing “Door Control Service” provided by SoA Adaptor

<table>
<thead>
<tr>
<th>Service Name</th>
<th>Service Interface</th>
<th>Argument</th>
<th>Direction</th>
<th>G/W Acts as</th>
<th>External Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Door Control</td>
<td>Request &amp; Response</td>
<td>Door Position (FL/FR/RL/RR)</td>
<td>Vehicle</td>
<td>Service Consumer</td>
<td>MQTT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Target Status (Lock/Unlock)</td>
<td>Termination</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Cloud

Motion Control Application

Switch Control Application

Voice Control Application

SoA Adaptor

Door Control Service

Service-oriented Gateway

Door Control Service Consumer
Connected Car Service Example

- **Airbag Activation Alarm Function**
  - Utilizes existing “Emergency Alarm Service” provided by Service-oriented G/W

<table>
<thead>
<tr>
<th>Service Name</th>
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<th>Direction</th>
<th>G/W Acts as</th>
<th>External Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency Alarm</td>
<td>Request &amp; Response</td>
<td>Current Position</td>
<td>Vehicle</td>
<td>Service Provider</td>
<td>HTTP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alarm Reason</td>
<td>Origination</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Diagram:
- **Position Service**
- **AirBag Status Service**
- **SoA Adaptor**
- **Switch Control Application**
- **Automatic Emergency Application**
- **Emergency Alarm Service Provider**
- **Service-oriented Gateway**
- **Cloud**
Concluding Remarks

- SoA can be extended to End-to-End from legacy ECUs to Cloud.

- Service-oriented G/W can be introduced for efficient SoA extension to Cloud.

- It enables in-vehicle S/W to interact with Cloud in a service-oriented way.

- It efficiently handles external-network related issues like availability, delay, cost, and security, by performing protocol conversion, caching, filtering, network mapping, and access control.

- Its operation can be dynamically controlled as defined in the policy from Cloud.

- With SoA Adaptor and Service-oriented G/W, new connected car services can be developed and deployed with least time and effort.