A QoS Aware Approach to Service-Oriented Communication in Future Automotive Networks

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1. Introduction to In-Vehicle Networks

2. Automotive Service Classification

3. Middleware for QoS Aware Communication

4. Performance Evaluation

5. Conclusion & Outlook
Scenarios such as Autonomous driving and V2X pose new challenges on in-vehicle networks. Automotive services have heterogeneous communication requirements. Ethernet as high-bandwidth communication medium replaces legacy bus systems. SOME/IP introduces Service-Oriented Architecture (SOA) and promises flexibility. Time-Sensitive Networking (TSN) provides Quality-of-Service (QoS) with hard deadlines.

A mechanism is missing that merges the concepts of SOA and QoS-enhanced communication for dynamically changing communication relations.
Our Contributions

- We derived four QoS classes based on automotive service requirements
- We developed an automotive specific multi-protocol stack
- We designed a protocol for dynamic QoS agreements
- We evaluated the performance of our middleware in simulation
## Classification of Automotive Services

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web-based Services (WS)</td>
<td>Globaly accessible high-level services</td>
<td>Infotainment, Smart City</td>
</tr>
<tr>
<td>IP-based Services (IPS)</td>
<td>Non time-critical car control</td>
<td>Temperature, Windows Regulator</td>
</tr>
<tr>
<td>Real-Time Services (RTS)</td>
<td>Time-critical car control</td>
<td>Electronic Stability Control, Rear Camera</td>
</tr>
<tr>
<td>Static Real-Time Services (SRTS)</td>
<td>Safety- &amp; time-critical car control</td>
<td>Airbag, Brakes</td>
</tr>
</tbody>
</table>

An in—depth explanation can be found in the paper.
Multiprotocol Approach

- 7 Application
- 6 Presentation
- 5 Session
- 4 Transport
- 3 Network
- 2 Data Link

Services

QoS Middleware

WS

IPS

S/RTS

HTTP

SOME/IP (optional)

TCP

UDP

IP

Time-Sensitive Networking enabled Ethernet
QoS-Negotiation Protocol

Stage 1: Handshake
- Check Request
- QoSRequest
- [Service exists]

Stage 2: Connection
- ConnectionRequest
- Create Endpoint
- [Stage1 Success]
- ConnectionResponse
- Create Endpoint
- Finished

Publisher Side
- Publisher Application
- register
- Publisher Application
- deliver
- Middleware
- negotiate
- Endpoint
- publish

Subscriber Side
- Subscriber Application
- register
- Subscriber Application
- deliver
- Middleware
- Endpoint
- publish
Performance Evaluation

- Impact of cross-traffic on the latency of different QoS classes
- Scaling of setup time in relation to the number of services
- Setup time in a realistic automotive network with cross-traffic
Latency Behaviour of Mixing Different QoS Classes

Publisher Node

CT Node 1

Cross Traffic ≈ 950Mbit/s

CT Node 2

Switch 1

Critical Link

Switch 2

RTSSubscriber

IPSSubscriber

Linkspeed: 1Gbit/s
Latency Behaviour of Mixing Different QoS Classes

\[ L_{\text{AVB}_{\text{MAX}}} = t_{\text{MTU}} + 3 \cdot t_{\text{AVBFrame}} + 2 \cdot t_{\text{Switchdelay}} + IPG + 2 \cdot t_{\text{Nodedelay}} \]

Result: QoS can be guaranteed for heterogeneous client requirements
Setup Times with Increasing Numbers of Nodes

Publisher Node → Switch 1 → Switch 2 → IPSSubscriber

- Publisher Node
- Switch 1
- Switch 2
- IPSSubscriber

Linkspeed: 100Mbit/s
Setup Times with Increasing Count of Nodes

Result: The behaviour of the setup time is linear with the number of negotiations.

From 40 simultaneous negotiations the maximum bandwidth of 100 Mbit/s is exceeded and the network traffic becomes congested.
Setup Times in a Realistic Automotive Network with Cross-Traffic
Setup Times in a Realistic Automotive Network with Cross-Traffic
Maximum system setup time in cars is \( \approx 150 \text{ ms to } 200 \text{ ms} \). The measured setup time is well below the requirements.
Setup Times in a Realistic Automotive Network with Cross-Traffic

With cross-traffic of around 300 Mbit/s the setup time takes $\approx 1$ ms. From cross-traffic of around 700 Mbit/s the setup time rises exponentially.

Result: The setup time complies with automotive requirements of $\approx 150$ ms to 200 ms.
Conclusion & Outlook

Summary

• Introduced four QoS classes with a multi-protocol stack
• Presented a dynamic QoS negotiation protocol
• Showed successful support of mixed-critical communication
• Achieved acceptable setup-times in a realistic automotive network
• Implemented and evaluated with OMNeT++ Discrete Event Simulator
  Sourcecode available at: https://github.com/CoRE-RG/SOQoSMW

Future Work

• Determine real-world runtime delays with real car components
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