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

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Outline

In-Vehicle Networks - State of the Art

- 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

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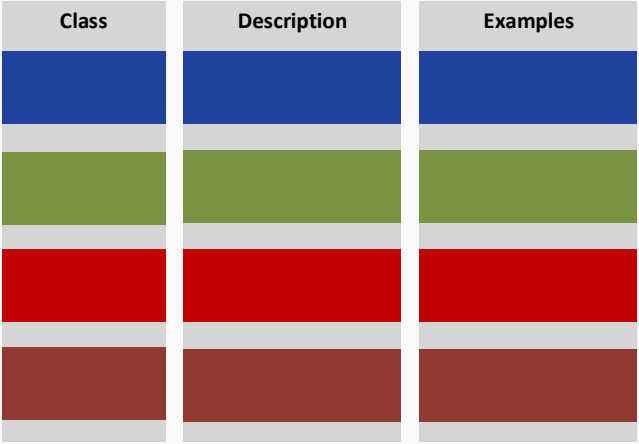
A mechanism is missing that merges the concepts of SOA and QoS-enhanced communication for dynamically changing communication relations.

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



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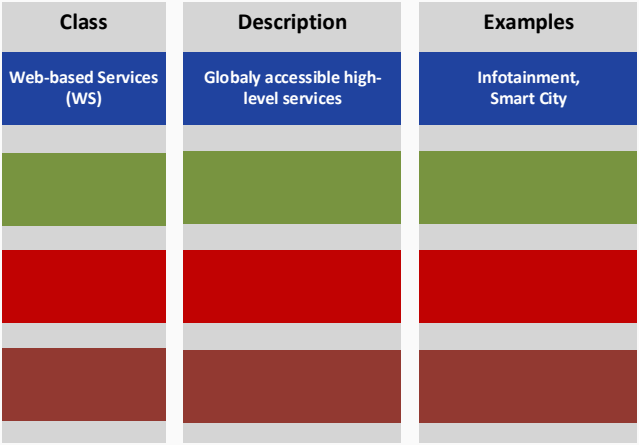

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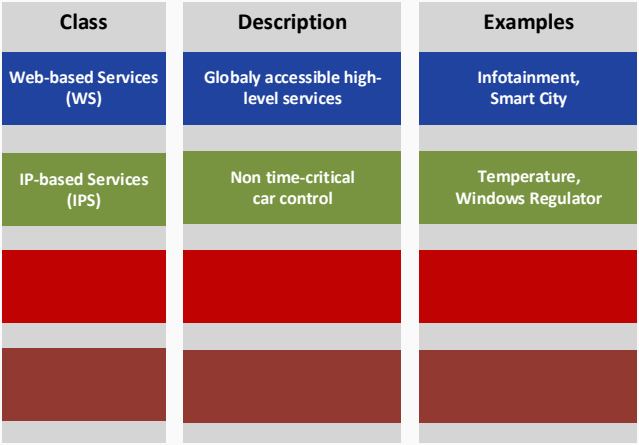

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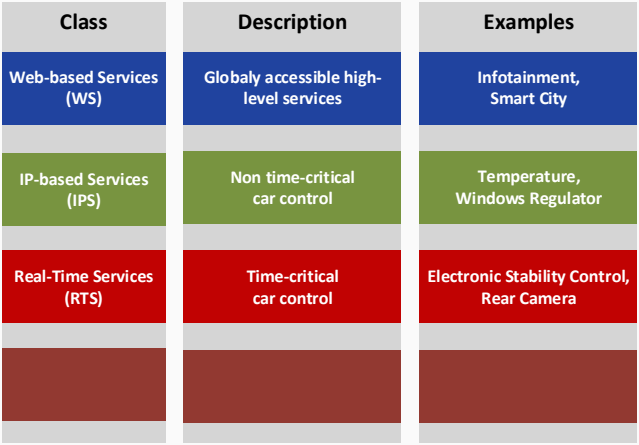

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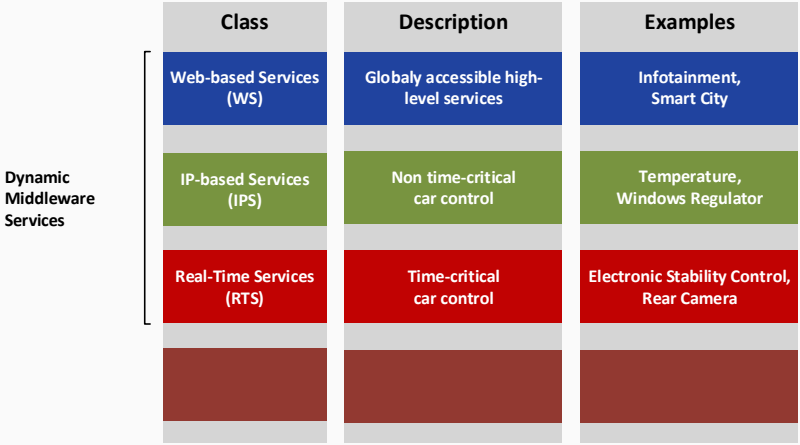

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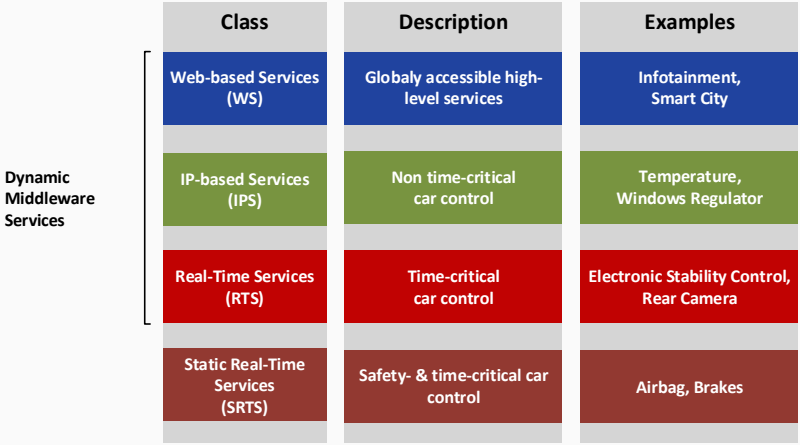

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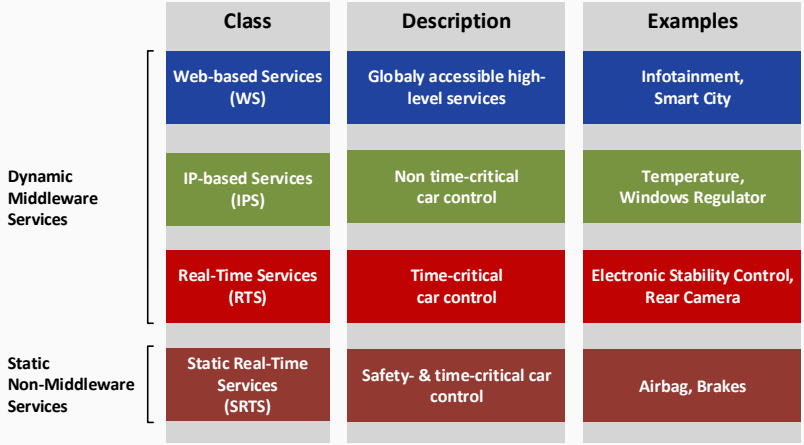
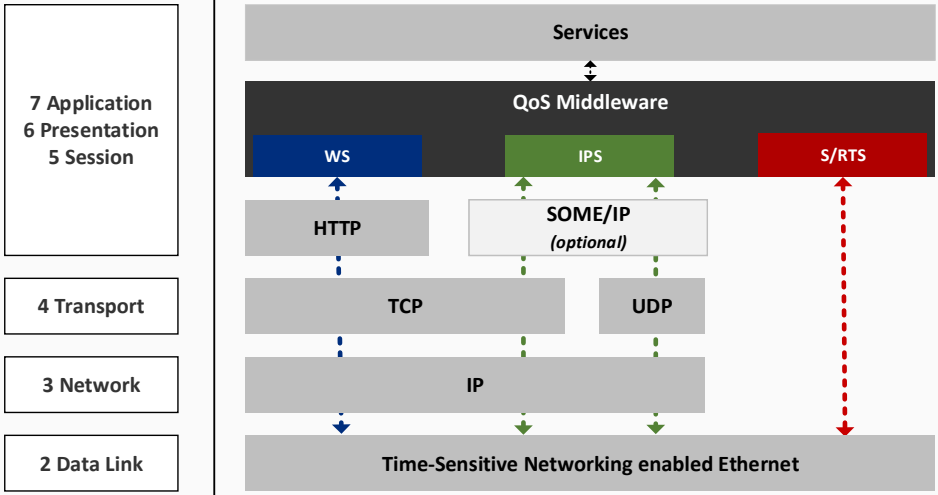
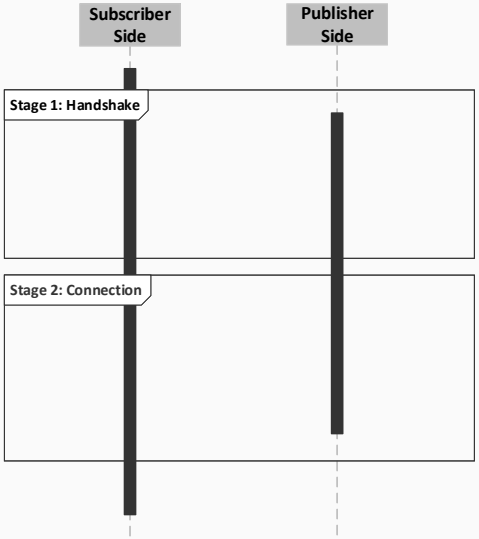


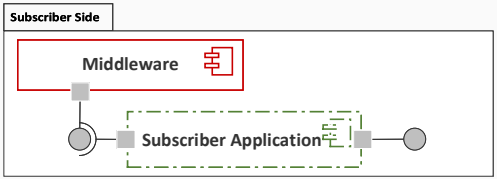
An in−depth explanation can be found in the paper.

Multiprotocol Approach



QoS-Negotiation Protocol





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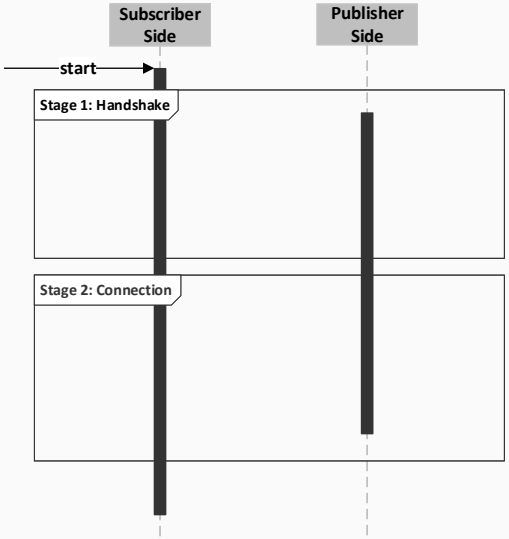

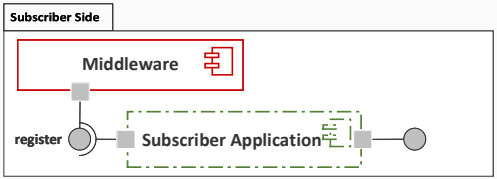

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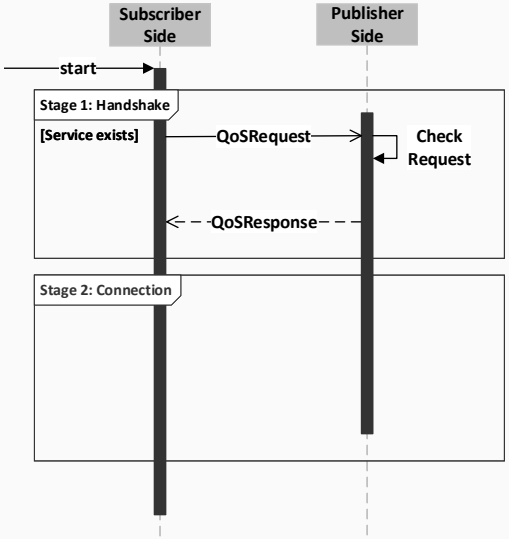

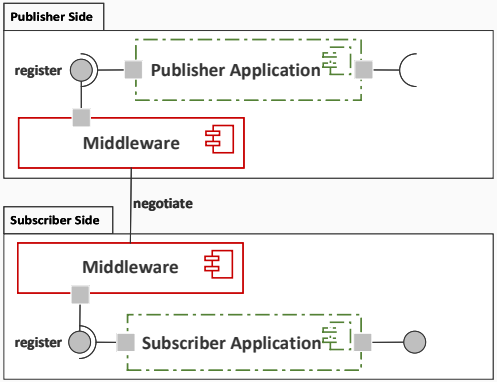

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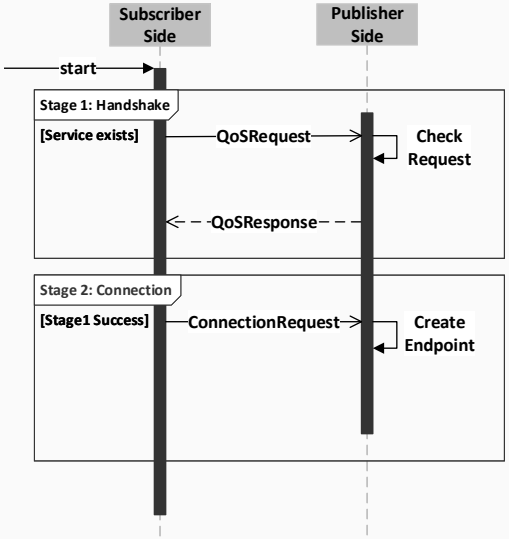

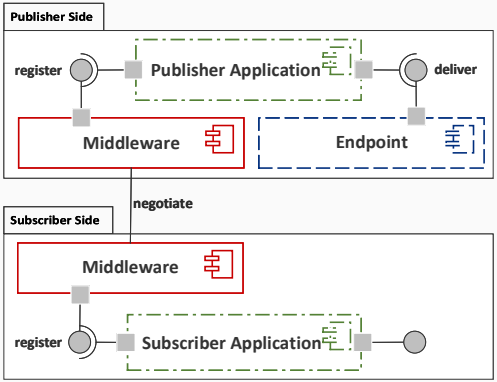

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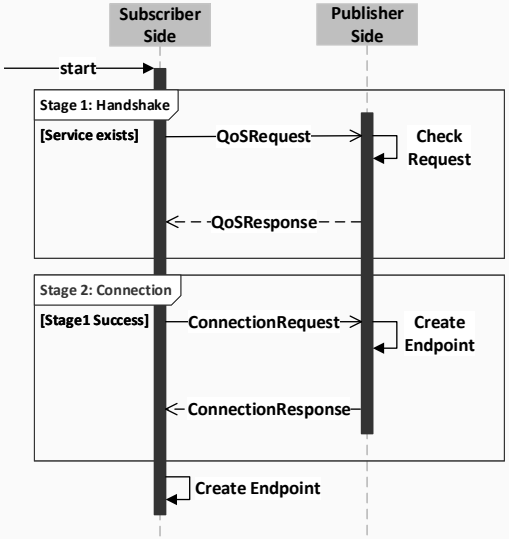

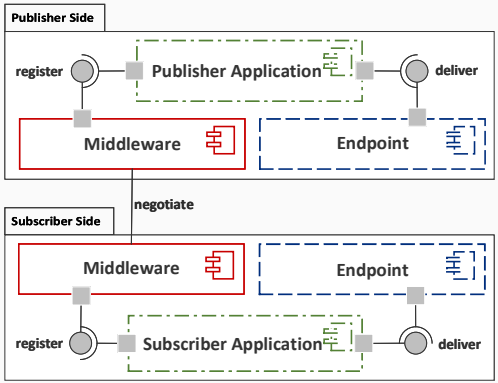

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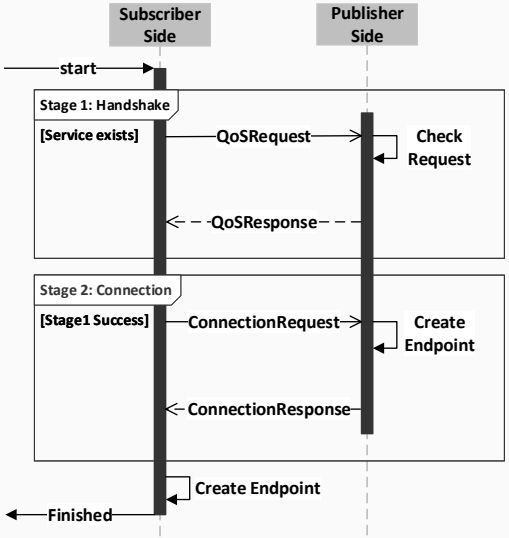
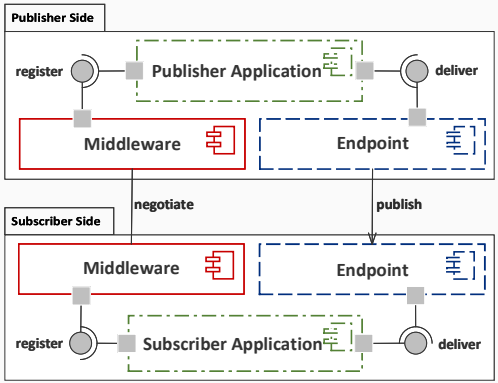
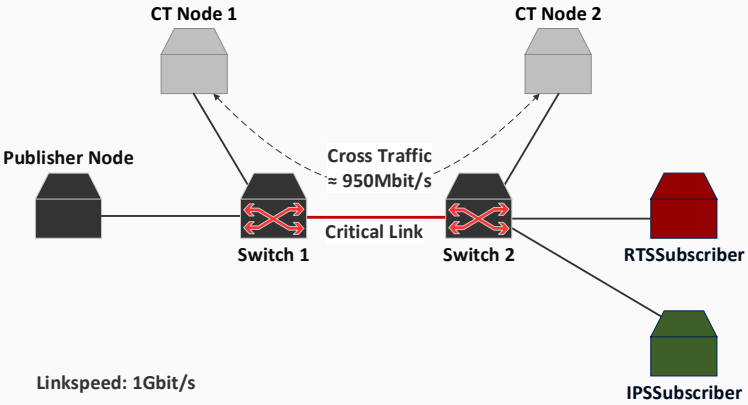




Performance Evaluation

- 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



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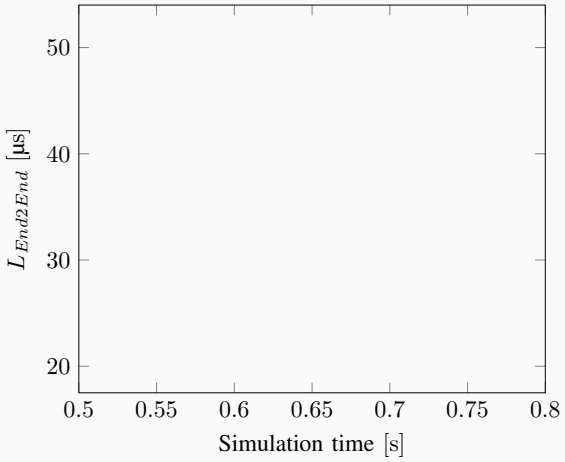

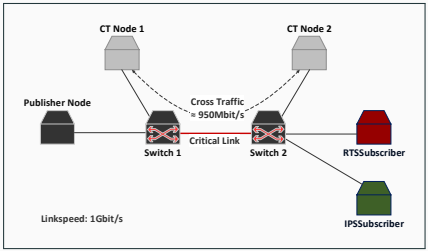

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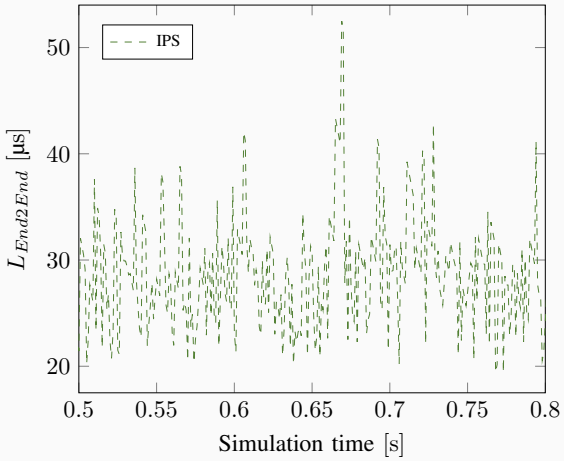

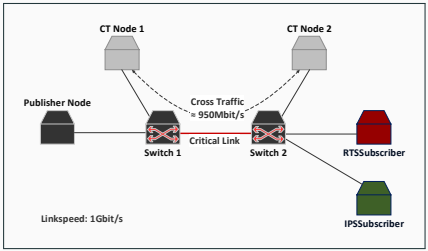

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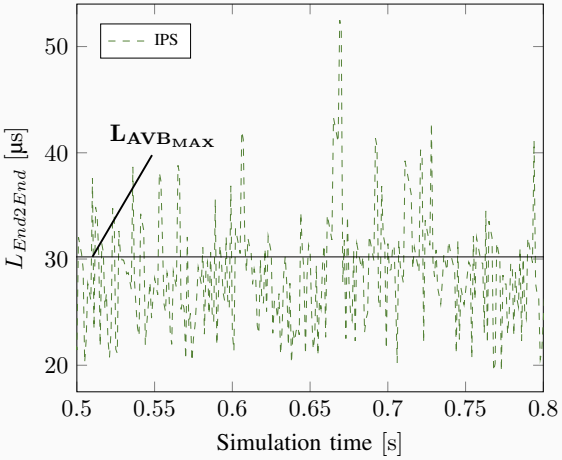

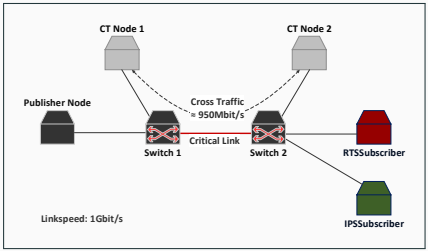

$$L_{AVB_{max}} = t_{MTU} + 3 \cdot t_{AVBFrame} + 2 \cdot t_{Switchdelay} + IPG + 2 \cdot t_{Nodedelay}$$

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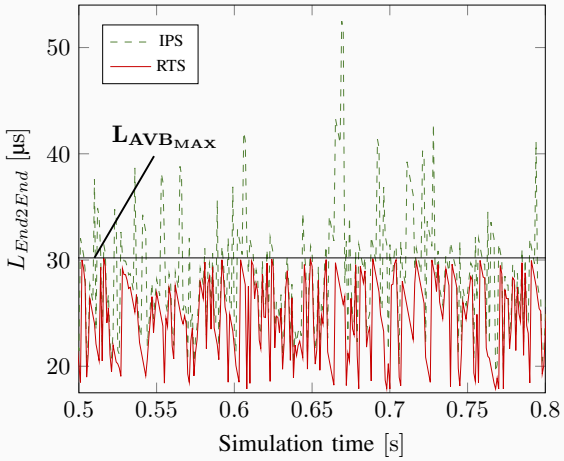

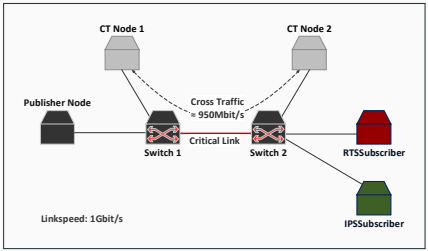

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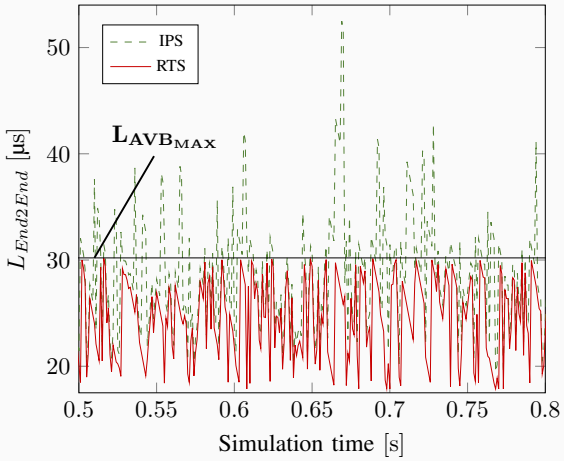

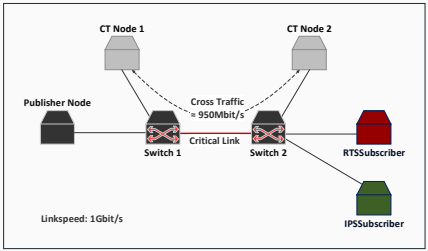

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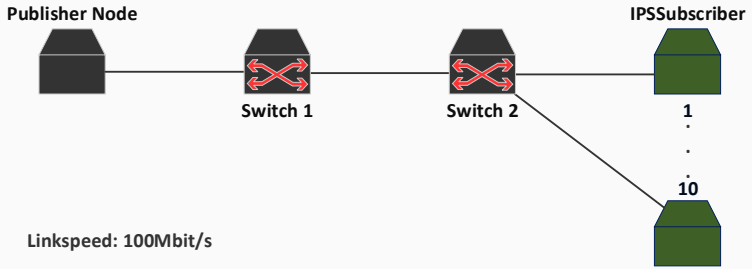
Result: QoS can be guaranteed for heterogeneous client requirements

Setup Times with Increasing Numbers of Nodes



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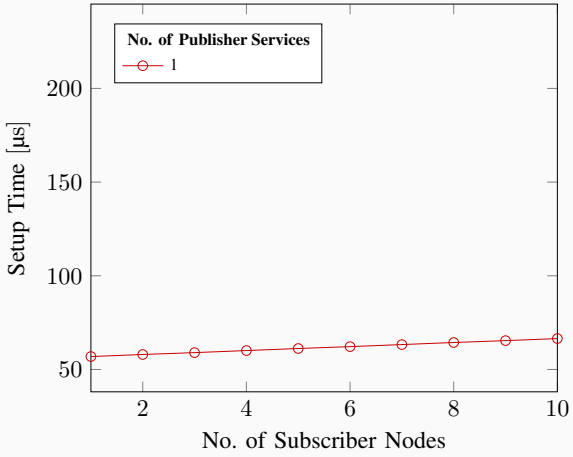

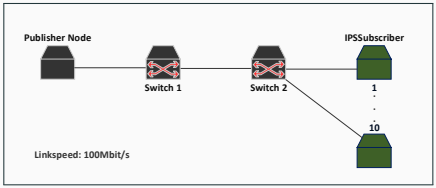

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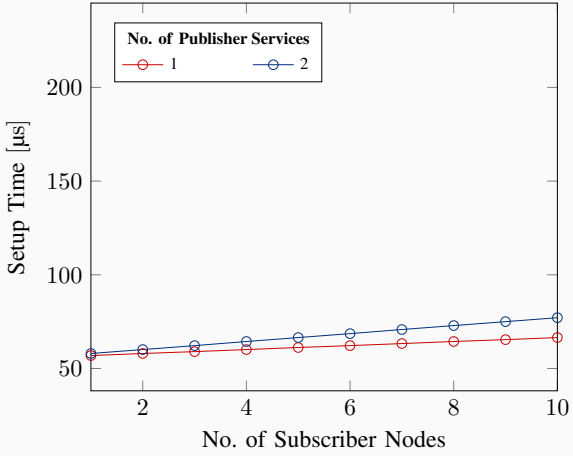

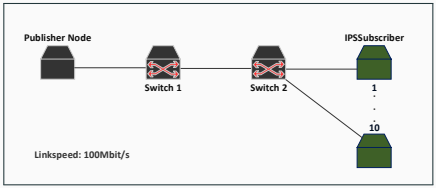

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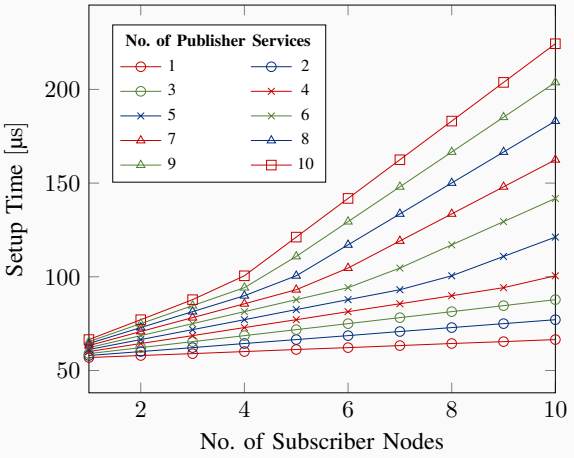
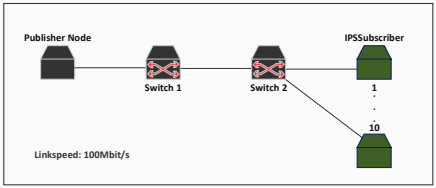
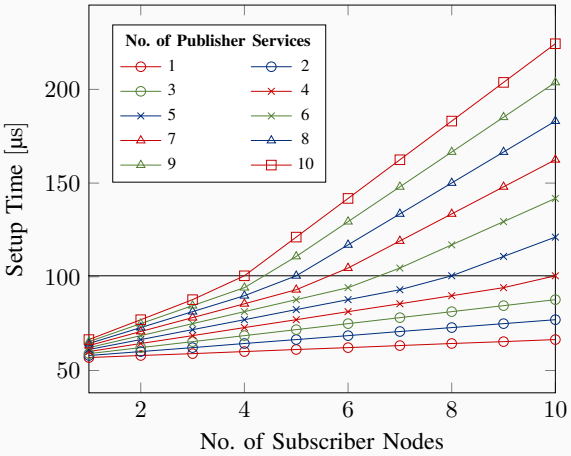
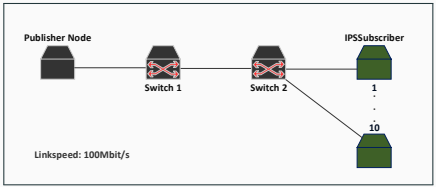




Result: The behaviour of the setup time is linear with the number of negotiations

Setup Times with Increasing Count of Nodes

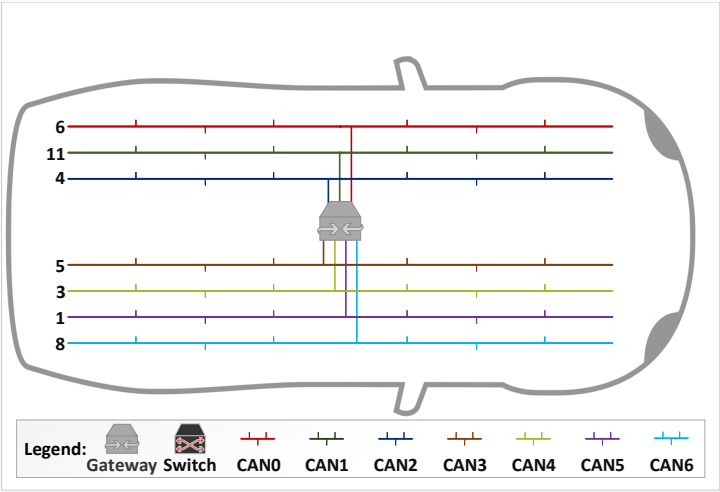




From 40 simultaneous negotiations the maximum bandwidth of 100 Mbit/s is exceeded and the network traffic becomes congested.

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

Setup Times in a Realistic Automotive Network with Cross-Traffic



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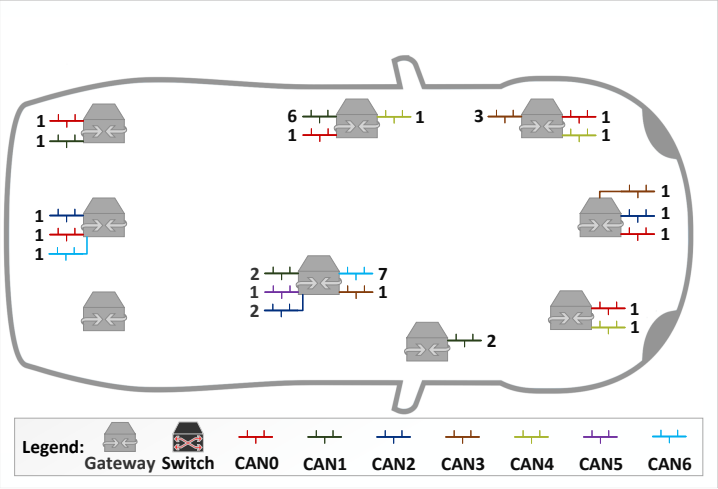

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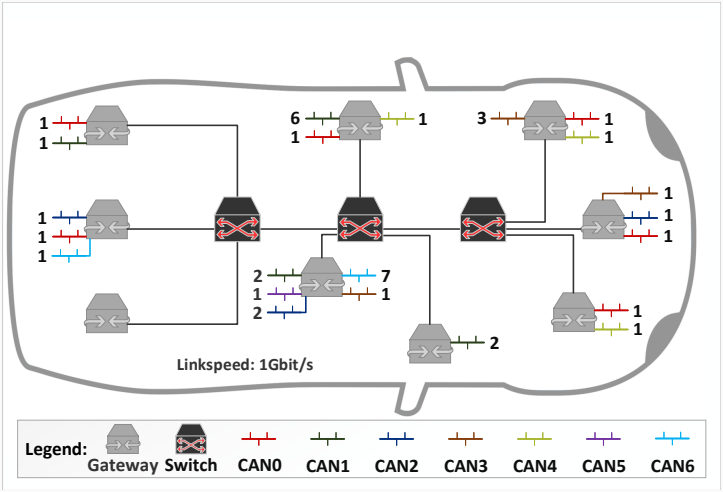

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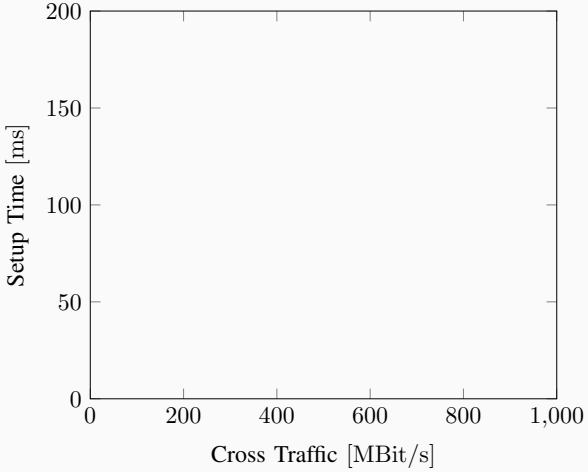

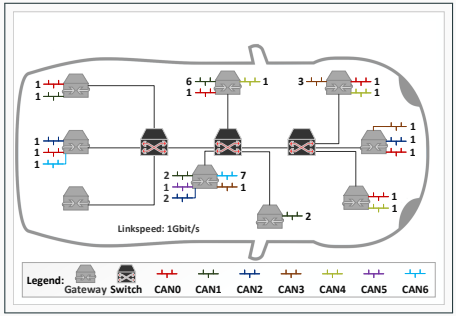

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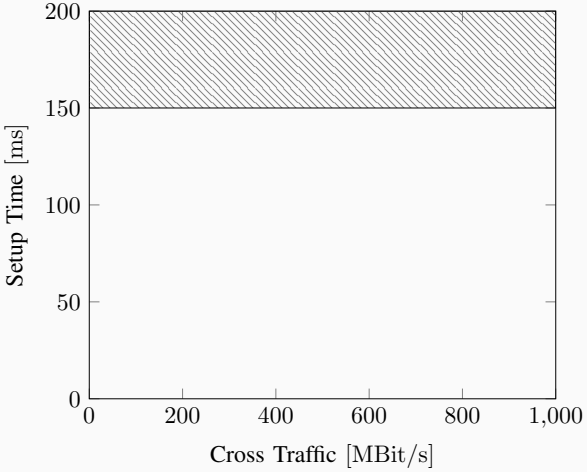
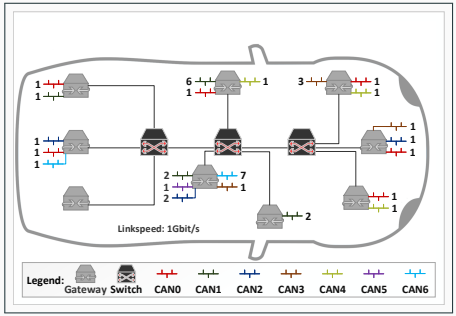
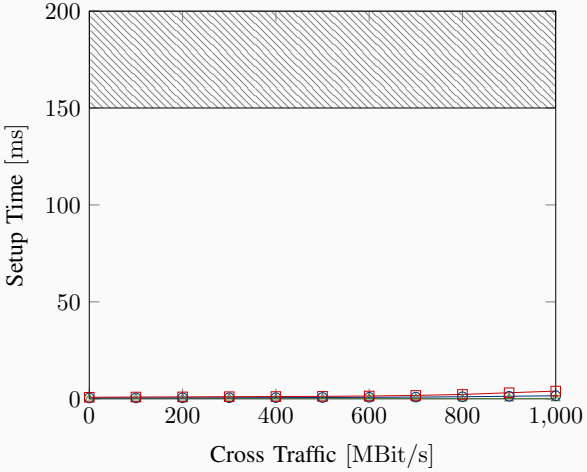
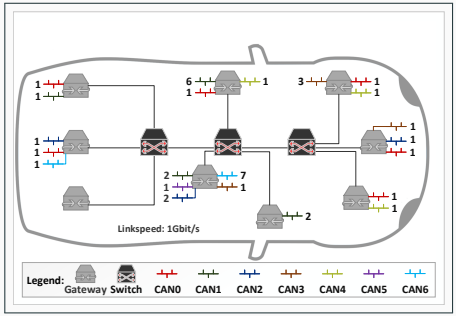




Maximum system setup time in cars is $\approx$ 150 ms to 200 ms.

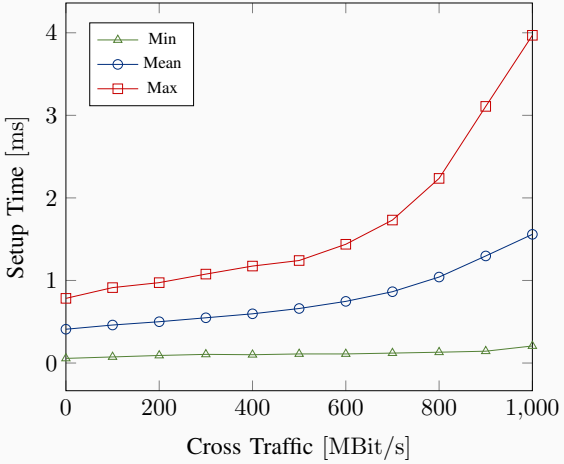
Setup Times in a Realistic Automotive Network with Cross-Traffic

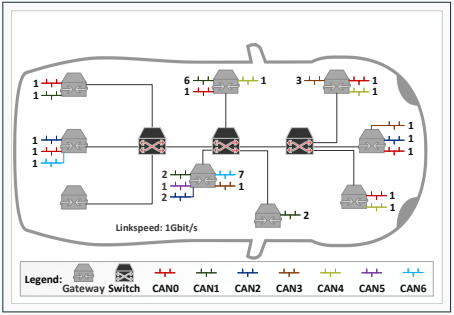




The measured setup time is well below the requirements.

Setup Times in a Realistic Automotive Network with Cross-Traffic





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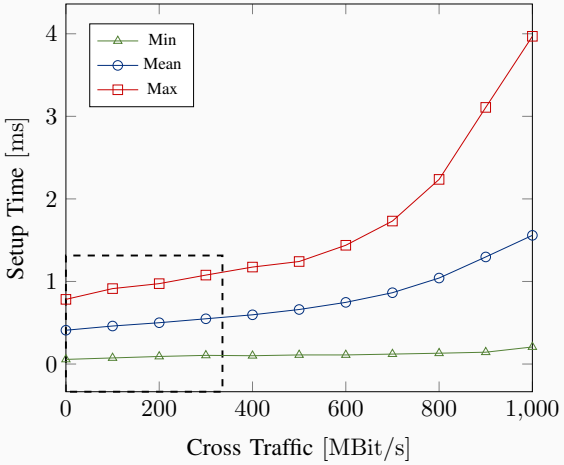
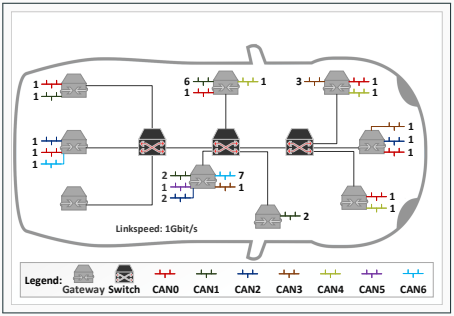
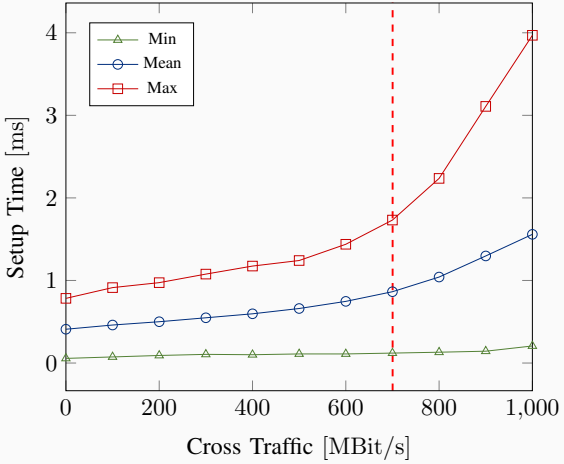
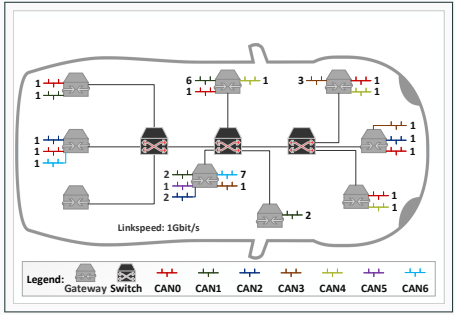




With cross-traffic of around 300 Mbit/s the setup time takes $\approx$ 1 ms.

Setup Times in a Realistic Automotive Network with Cross-Traffic





From cross-traffic of around 700 Mbit/s the setup time rises exponentially and negotiations might not finish in time.

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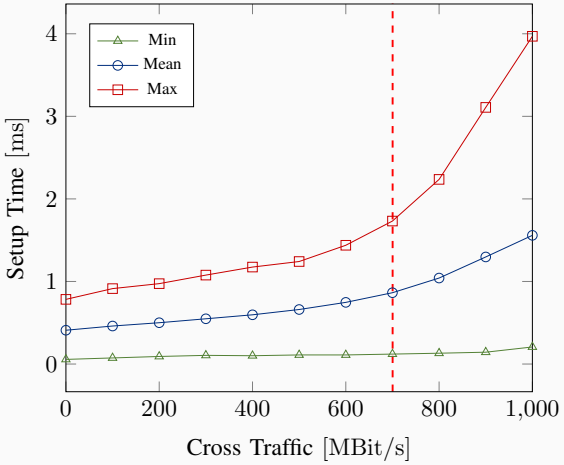

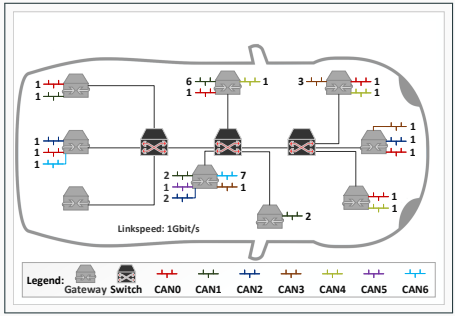

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Result: The setup time complies with automotive requirements of $\approx$ 150 ms to 200 ms

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

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

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