

Daniel Bischoff, Opel Automobile GmbH



IMAGinE

12 MAY 22

FINAL EVENT



V2X Simulation for Maneuver Coordination

Goal

- Analysis and improvement of the V2X communication protocol to coordinate cooperative maneuvers

Methodology

- Numerical and simulation analysis

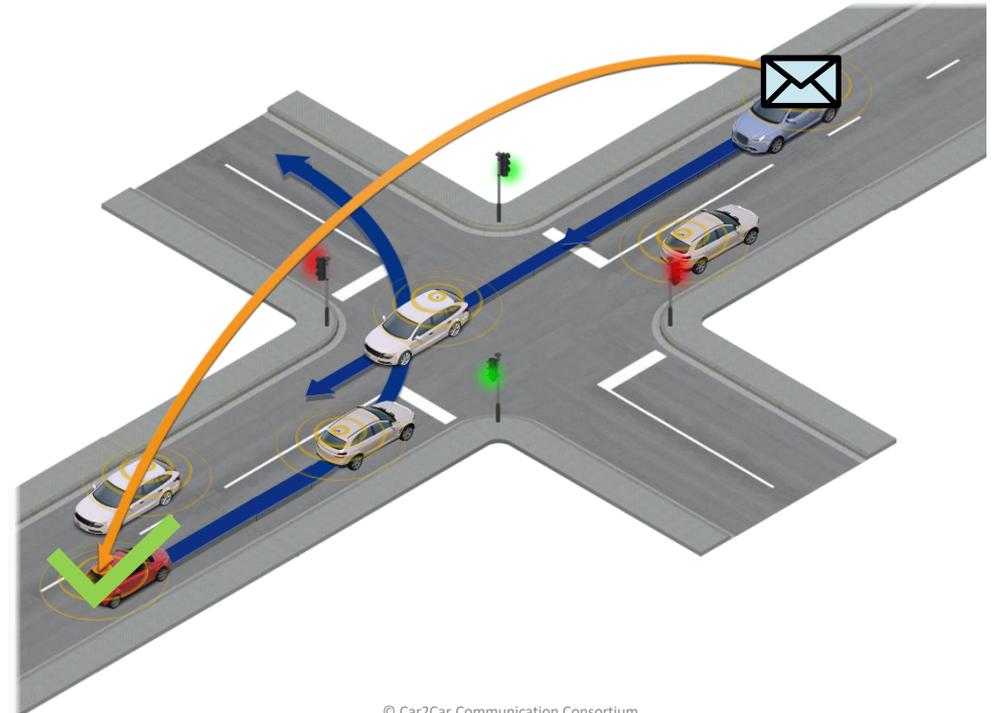
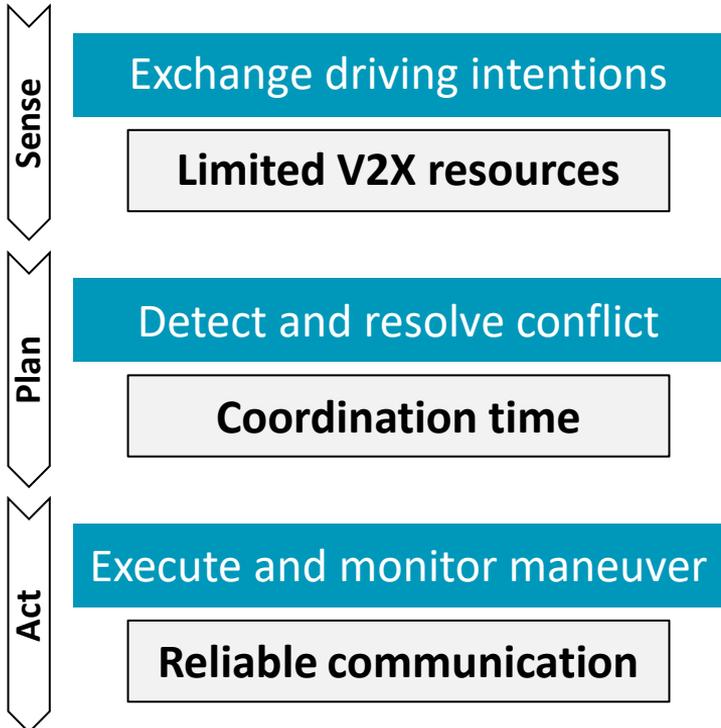
Academic Partner

- TU Braunschweig



V2X Simulation for Maneuver Coordination

Communication Challenges



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V2X Simulation for Maneuver Coordination

Simulation Environment

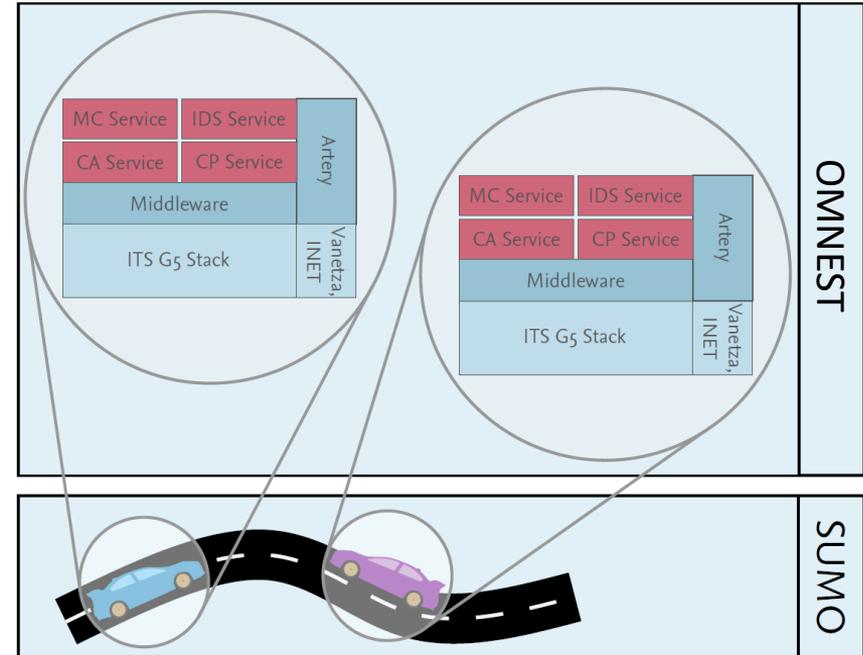
Network Simulation

- Message services in OMNEST
- Middleware abstracts services from communication layer

Traffic Simulation

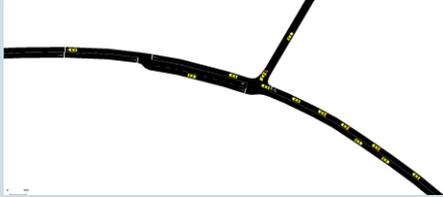
- Traffic modeled as flows in SUMO
- Traffic layout exported with OSM
- Coupled with OMNEST via TraCI

OSM: Open Street Map, SUMO: Simulation of Urban Mobility, TraCI: Traffic Control Interface



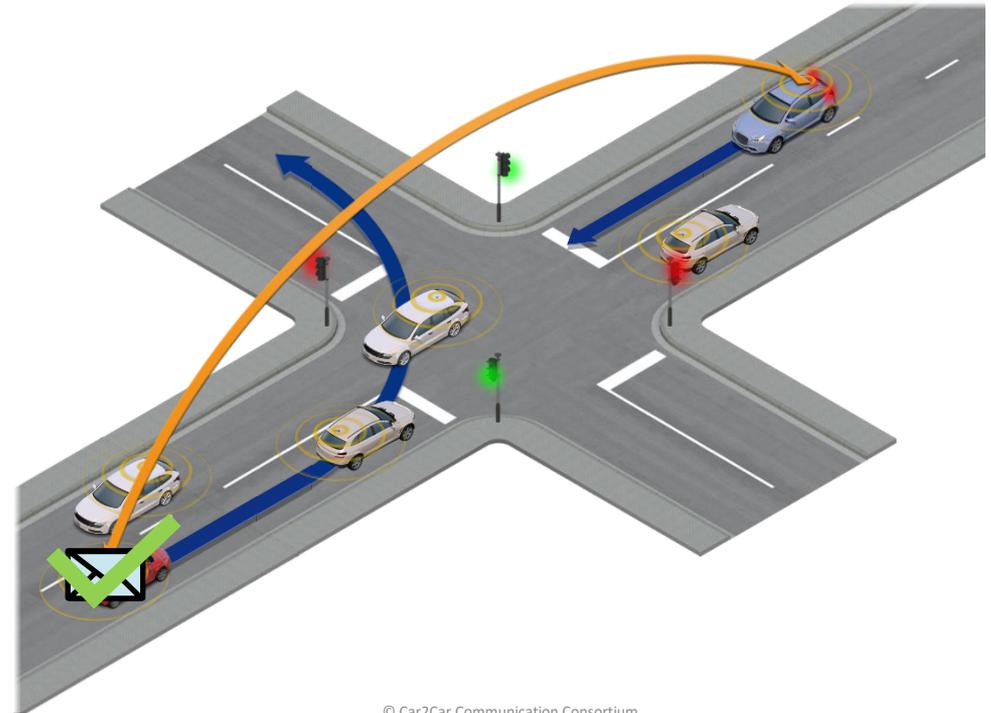
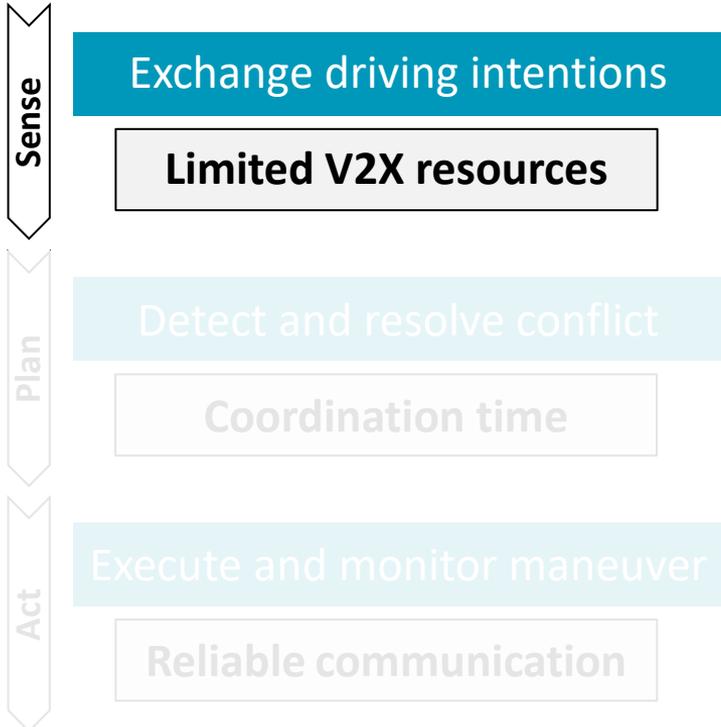
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V2X Simulation for Maneuver Coordination Scenarios

Description	Covered Use-Cases	Highlight	Scenario
Highway Frankfurt Kreuz	F1 – Merging on highways F2 – Longitudinal control F4 – Strategic traffic distribution F6 – Overtaking by trucks	> 30.000 veh/h	
Urban Junction Aschaffenburg	F5 – Turning at junctions	Analyzed in Ko-PER project	
Rural Junction	F3 – Overtaking on rural roads F5 – Turning at junctions	Different traffic distributions	

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V2X Simulation for Maneuver Coordination

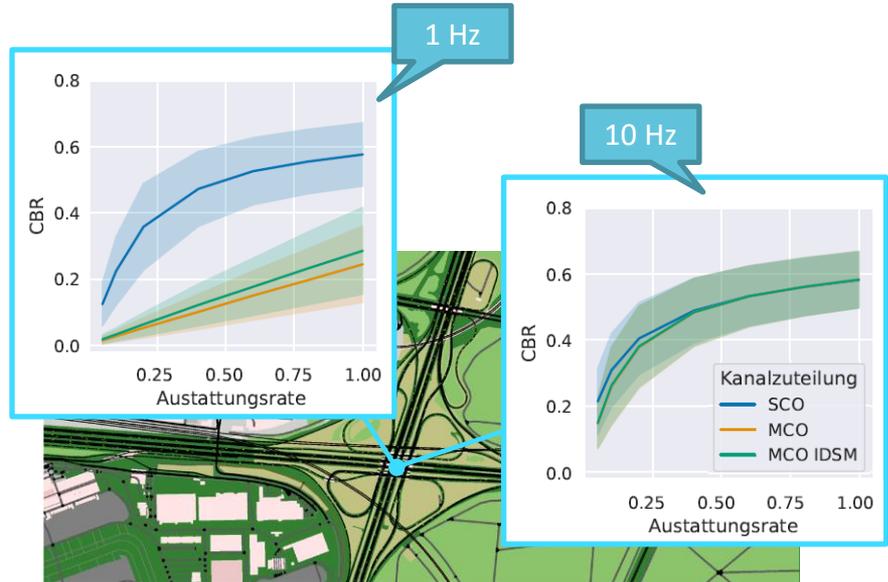
Limited V2X resources

Channel Busy Ratio (CBR)

- Fraction of time channel is busy
- Probing channel at specific locations and averaging over time

Results (Highway scenario)

- Channel saturates at 25% equip. rate
- Frequency causes channel congestion
- ETSI A-DCC limits channel load



V2X Simulation for Maneuver Coordination

Limited V2X resources

Channel Busy Ratio (CBR)

- Fraction of time channel is busy
- Probing channel at specific locations and averaging

SCO, message frequency, and high equipment rate lead to channel congestion

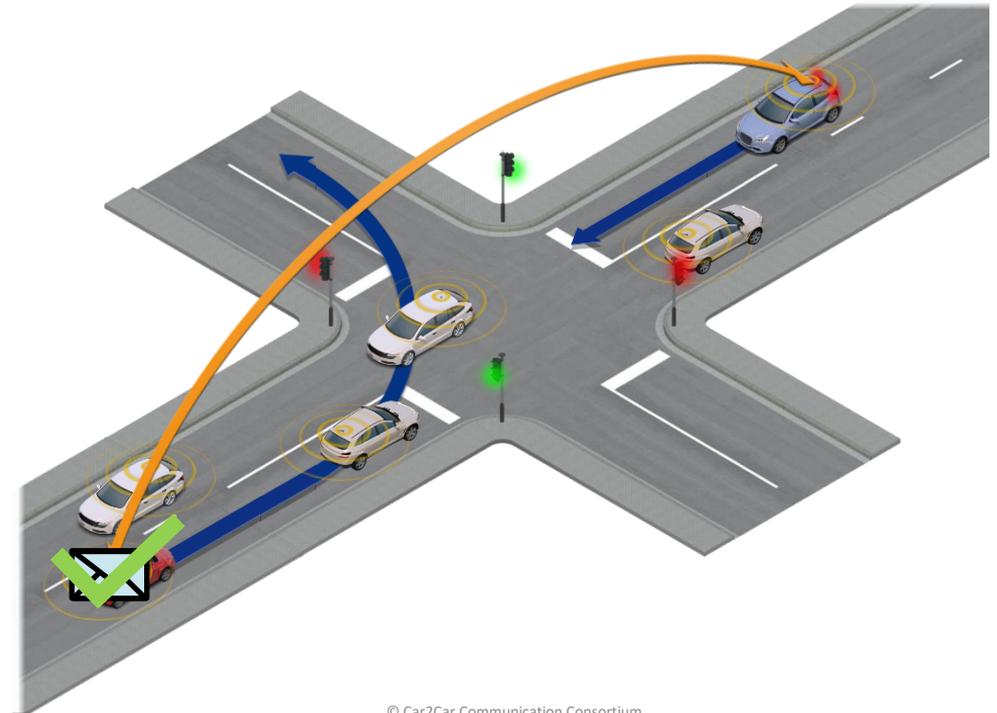
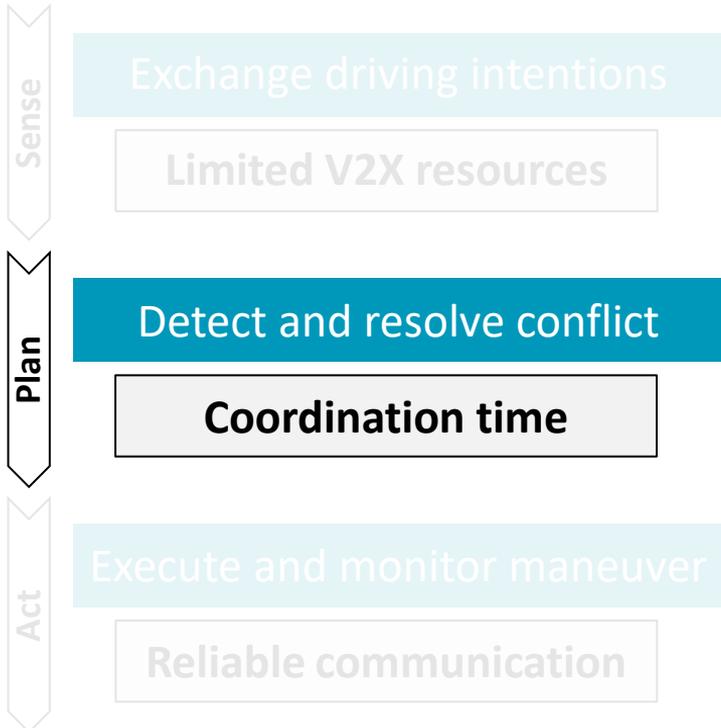
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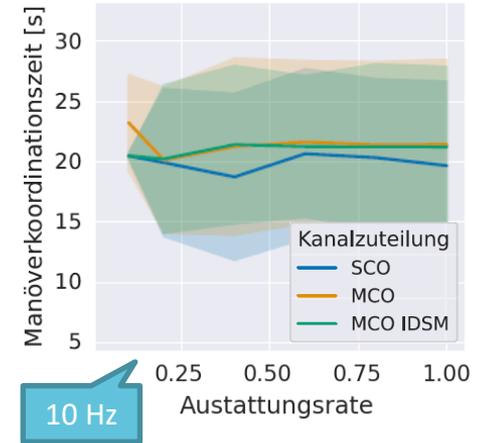
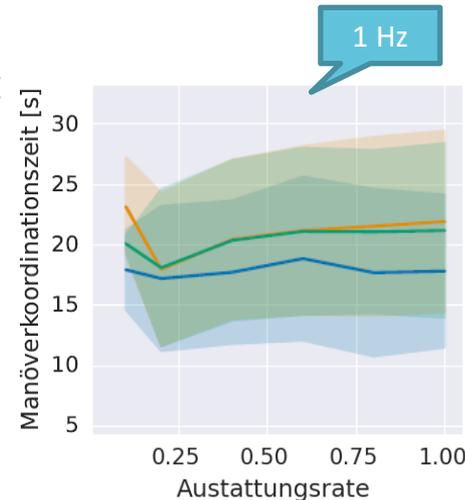
Coordination Time

Coordination Time

- Time left until two vehicles can coordinate a cooperative maneuver
- Difference between first received MCM and arrival at cooperation point

Results (Highway scenario)

- SCO degrades coordination time
- Equipment rate no significant impact
- Better results with low frequency



V2X Simulation for Maneuver Coordination

Coordination Time

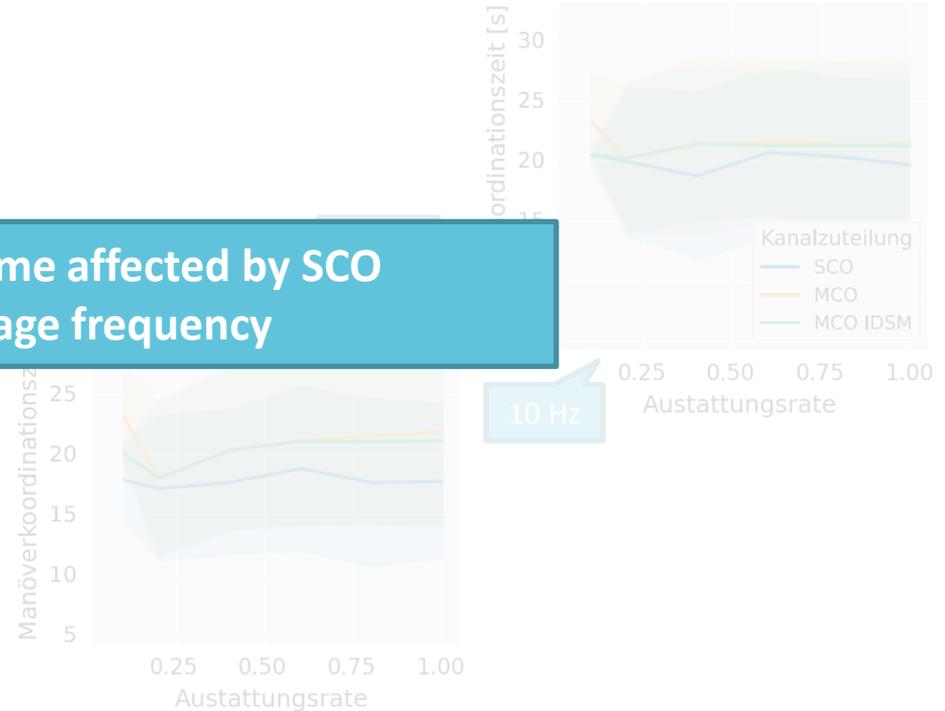
Coordination Time

- Time left until two vehicles can coordinate a cooperative maneuver
- Difference between MCM and arr

Coordination time affected by SCO and message frequency

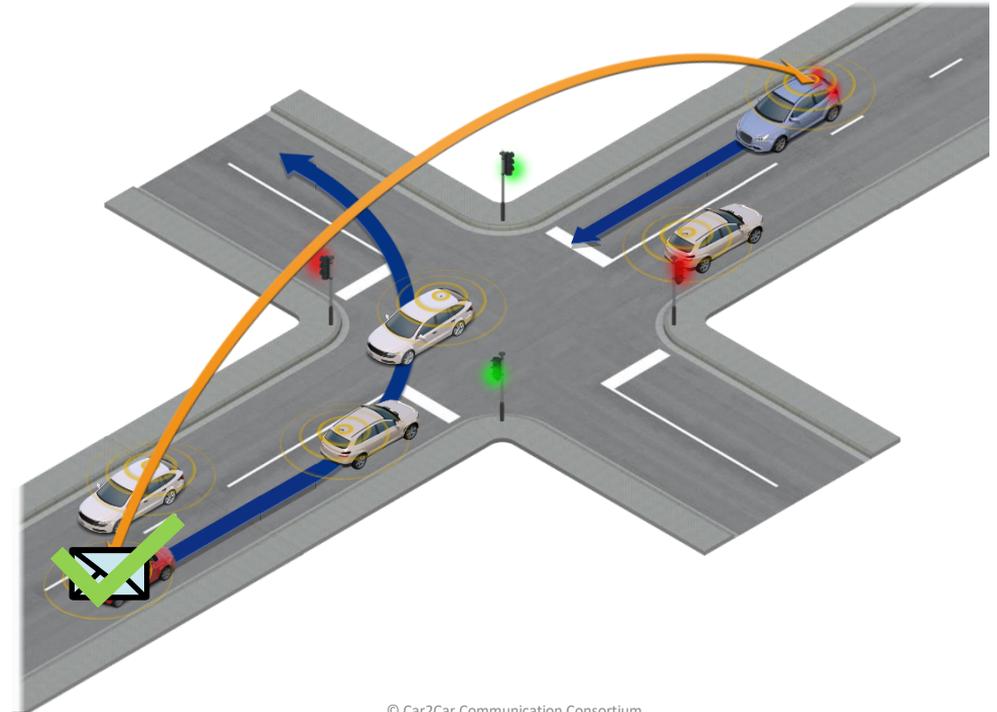
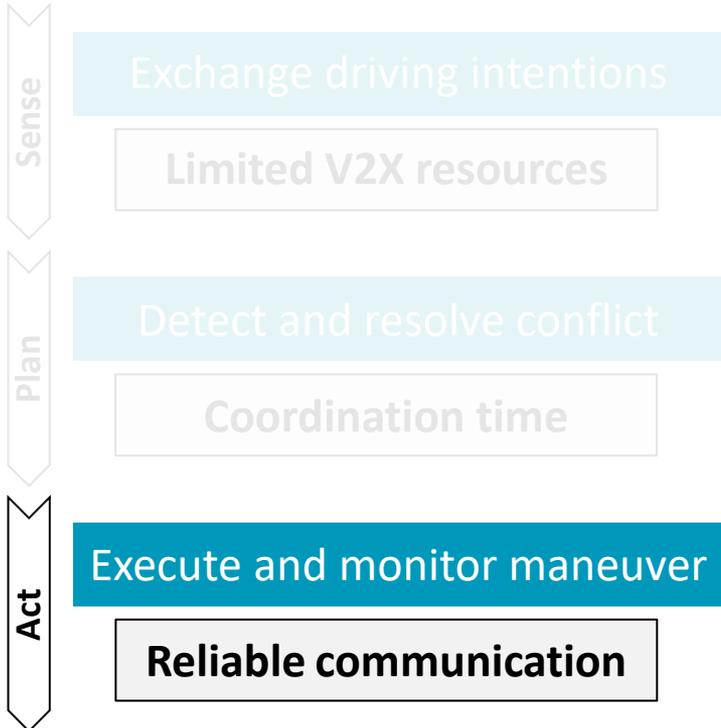
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V2X Simulation for Maneuver Coordination

Communication Challenges



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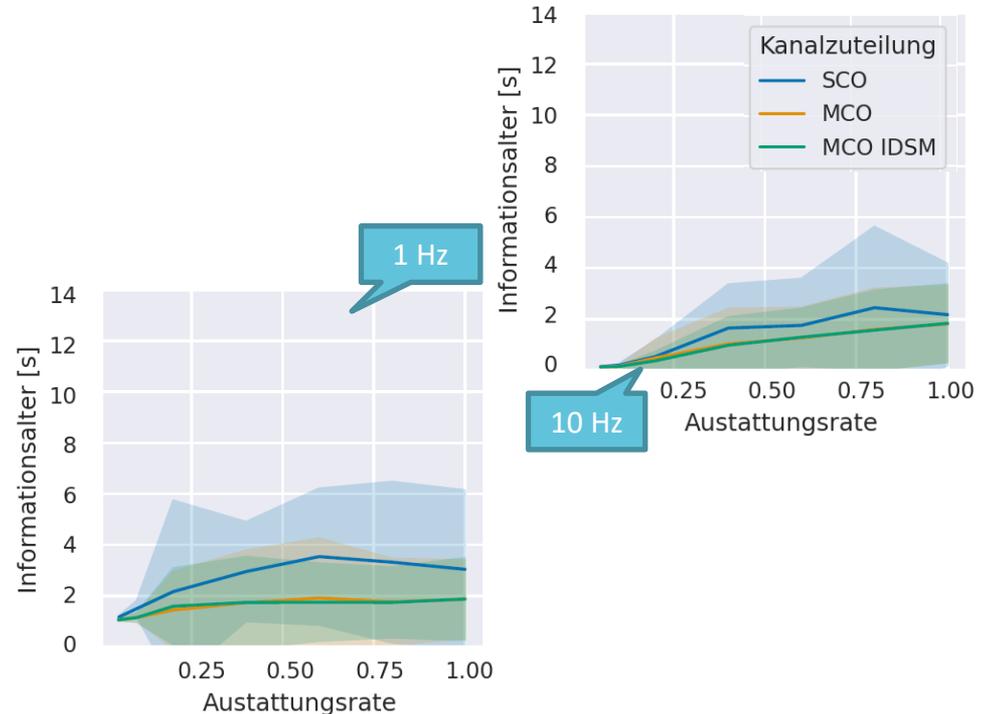
Reliable Communication

Age of Information (AoI)

- Time passed since message was created at transmitter
- Considers message reception rate, latency, and message frequency

Results (Highway scenario)

- AoI increases with channel load
- Higher AoI for 1 Hz frequency and SCO compared to 10 Hz and MCO



V2X Simulation for Maneuver Coordination

Reliable Communication

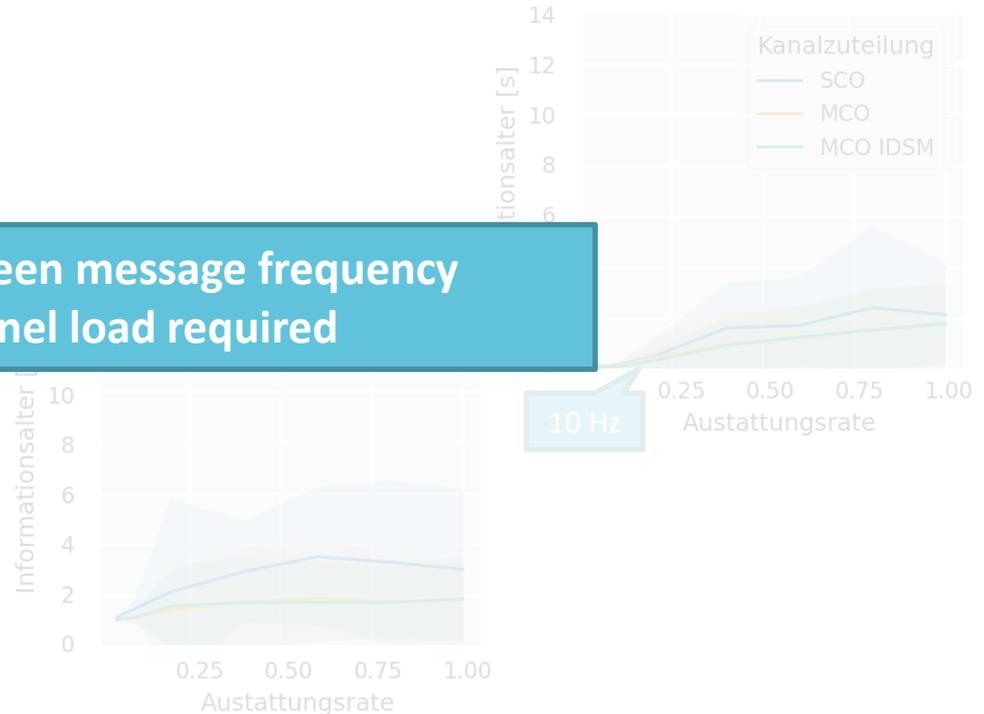
Age of Information (AoI)

- Time passed since message was created at transmitter
- Considers message latency, and message age

Trade-off between message frequency and channel load required

Results (Highway scenario)

- AoI increases with channel load
- Higher AoI for 1 Hz frequency and SCO compared to 10 Hz and MCO



V2X Simulation for Maneuver Coordination

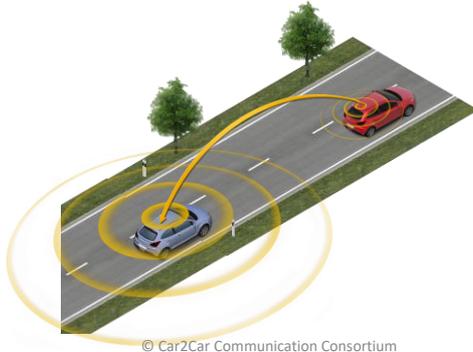
Transmission Control for Cooperative Driving

Transmission Control Mechanisms

Improve Age of Information for efficient and safe maneuver coordination

TPC

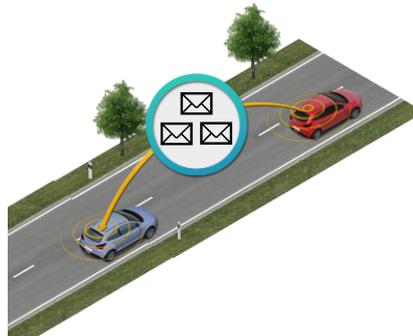
Transmission Power Control



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TRC

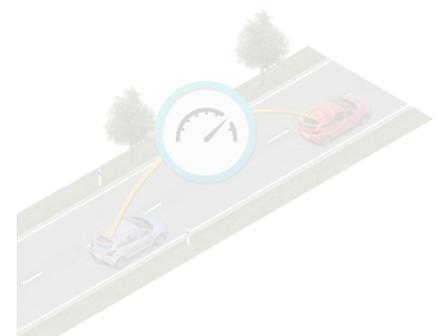
Transmission Rate Control



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TDRC

Transmission Data Rate Control



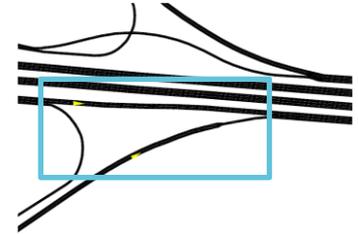
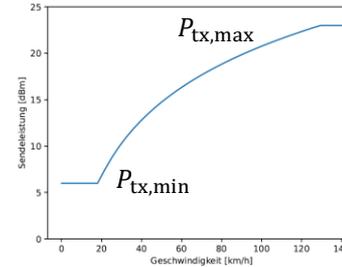
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V2X Simulation for Maneuver Coordination

Transmission Power Control

Transmission Power Control Adaptation

1. Based on vehicle velocity
2. Based on cooperative function



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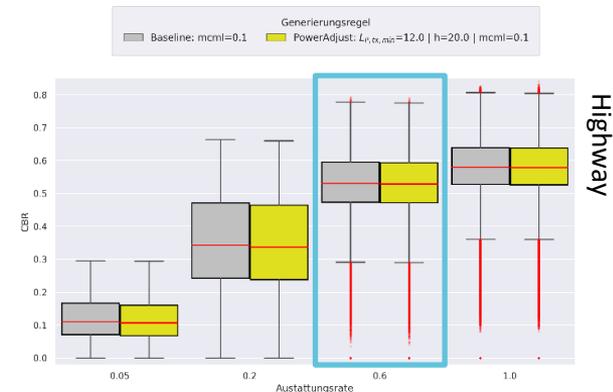
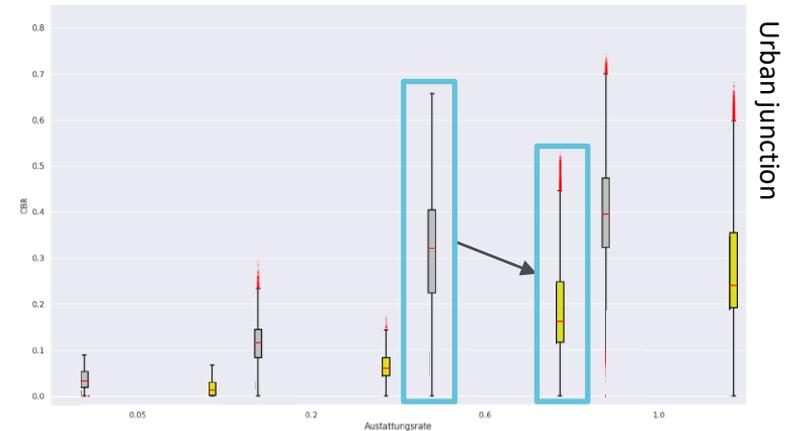
Transmission Power Control

Transmission Power Control Adaptation

1. Based on vehicle velocity
2. Based on cooperative function

Results

- Channel load can be lowered depending on the scenario and vehicle velocity
- Joint consideration of application needs and channel load required

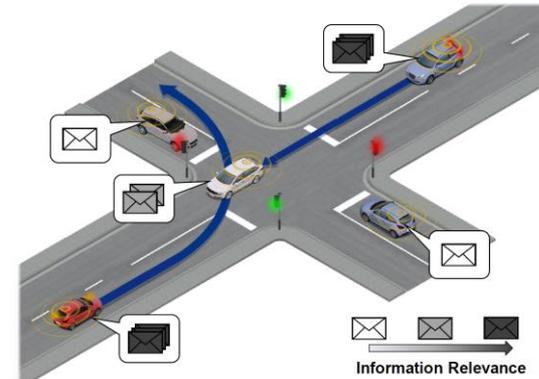


V2X Simulation for Maneuver Coordination

Transmission Rate Control

Transmission Rate Control Adaptation

1. Communication quality assessment
2. Information relevance assessment
3. Relevance-aware resource allocation



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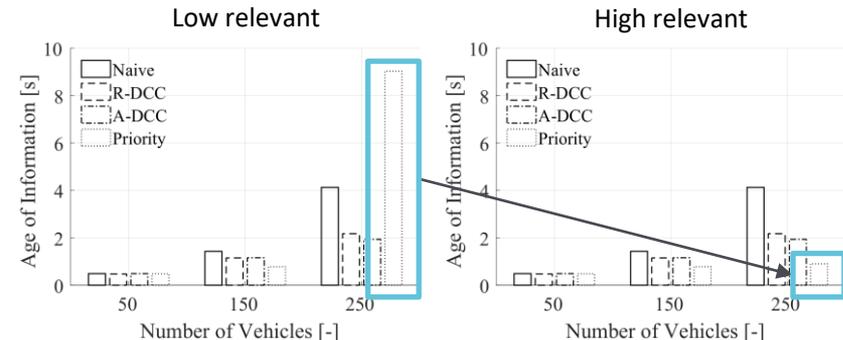
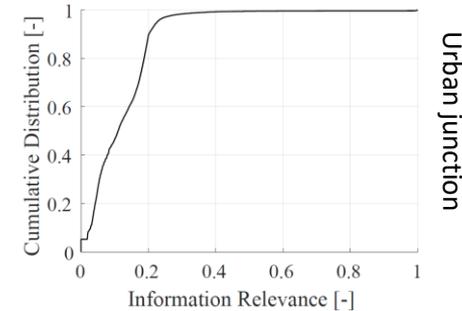
Transmission Rate Control

Transmission Rate Control Adaptation

1. Communication quality assessment
2. Information relevance assessment
3. Relevance-aware resource allocation

Results

- Only few information is highly relevant and needs to be prioritized
- AoI of highly relevant information can be significantly reduced



Velocity-dependent power control **depends** on scenario

Rate control based on relevance **prioritizes** information for vehicles coordinating cooperative maneuvers

Joint consideration of **network and application** addresses communication demands of maneuver coordination

THANK YOU

Daniel Bischoff, Opel Automobile GmbH

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