2020 IEEE SA
ETHERNET & IP AUTOMOTIVE TECH WEEK

A FRAMEWORK TO VIRTUALLY VALIDATE QUALITY OF SERVICE CONTRACTS IN ETHERNET-BASED VEHICLE DATA INFRASTRUCTURES FOR AUTOMOTIVE CYBER-PHYSICAL SYSTEMS

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Agenda

1. Introduction
2. Quality of Services
3. Framework to virtually validate Quality of Service contracts
4. Use Case: Autonomous Emergency Braking (AEB)
5. Conclusion
6. References

INTRODUCTION

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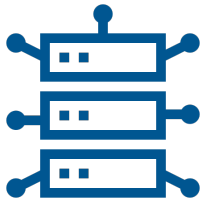
Introduction
E/E Architecture (R)evolution. Trends in the Automotive Industry

- **Today:** Increasing system complexity & number of functions due to several new features introduced to the automotive market.

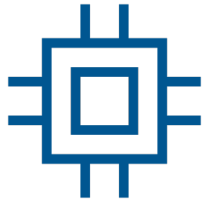
Connected Infotainment

High Autonomous Driving Functions

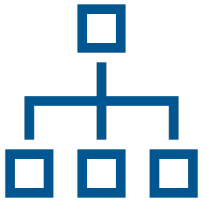
- **Tomorrow:** New solutions for the E/E architecture will appear to handle the new features, reducing the complexity and costs.



Service Oriented Architecture



Vehicle Computer



Cross-domain Zone architecture

Automotive Ethernet

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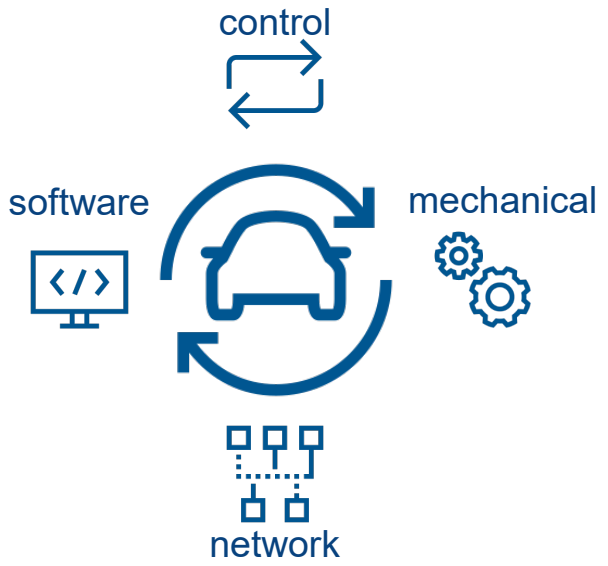
Introduction
Challenges in Automotive Cyber-Physical Systems (CPS)

Automotive CPS design requires co-engineering between multi-domain fields of expertise, where many system properties can effect more than one discipline.[1]

The cross-cutting concerns (CCC) between the domains is not always clearly defined, challenging the automotive industry in effectively handling the upcoming trends.

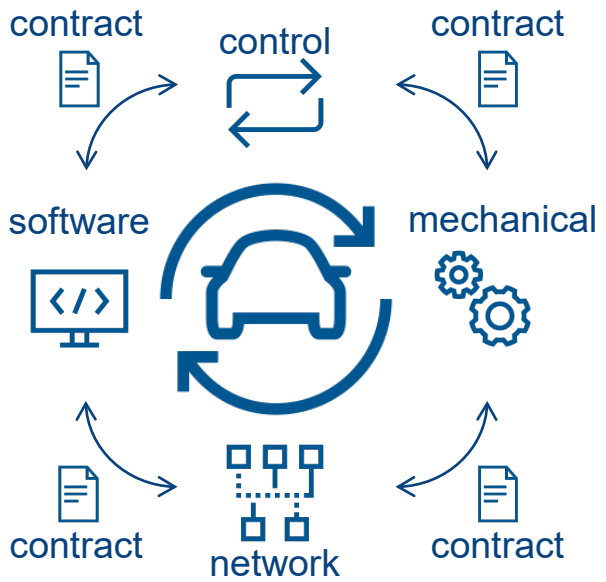


Automotive CPS interactions

Introduction
Closing the gaps using Design Contracts

The usage of “design contracts” can bridge the gap between the discipline interfaces enhancing the system design by giving a clear view of the interactions and collaborations. [1]

The design contract defines an agreement on certain system properties, being the central point for inter-domain exchange and negotiation. [1]



Automotive CPS interactions with Contracts

Introduction
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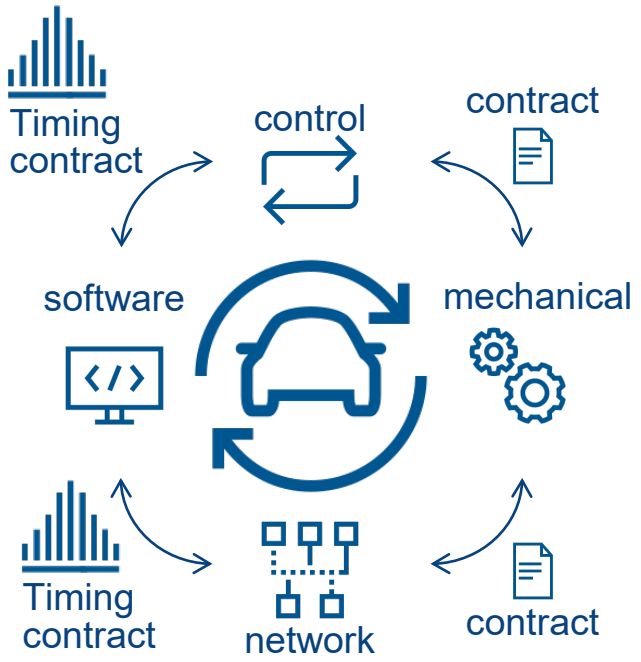
An example of design contract could be the timing agreements between the controls design and the runtime environment (software and network).



Automotive CPS interactions with Contracts

QUALITY OF SERVICES

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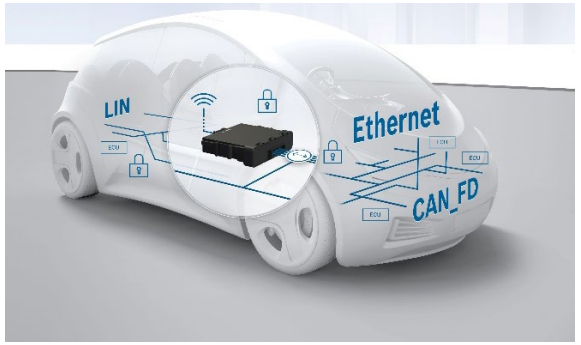
Quality of Service (QoS)
Contracts for In-Vehicle Communication Networks

“Quality of Service (QoS) is a measure of the ability of network and computing systems to provide different levels of services to selected applications and associated network flows.” [2]

The QoS is composed by **Inter-ECU-Communication** and **Intra-ECU-Communication**, where the non-functional requirements (timing) are a composition of their interactions.

Quality of Service and corresponding contracts:

QoS	Contract
Bounded latency	Worst case latency in end-to-end messaging delivery from the source to the destination
Delivery Guarantee / Loss Ratio	Reliable transmission with an upper bound for packet losses
Delay Variation	Jitter for cycle, event, and time triggered transmission
Ordered delivery	Delivery sequence of stream of data and/or the ability to re-order
Authenticity	Data and source authenticity
Data integrity	Data correctness



FRAMEWORK TO VIRTUALLY VALIDATE QoS CONTRACTS

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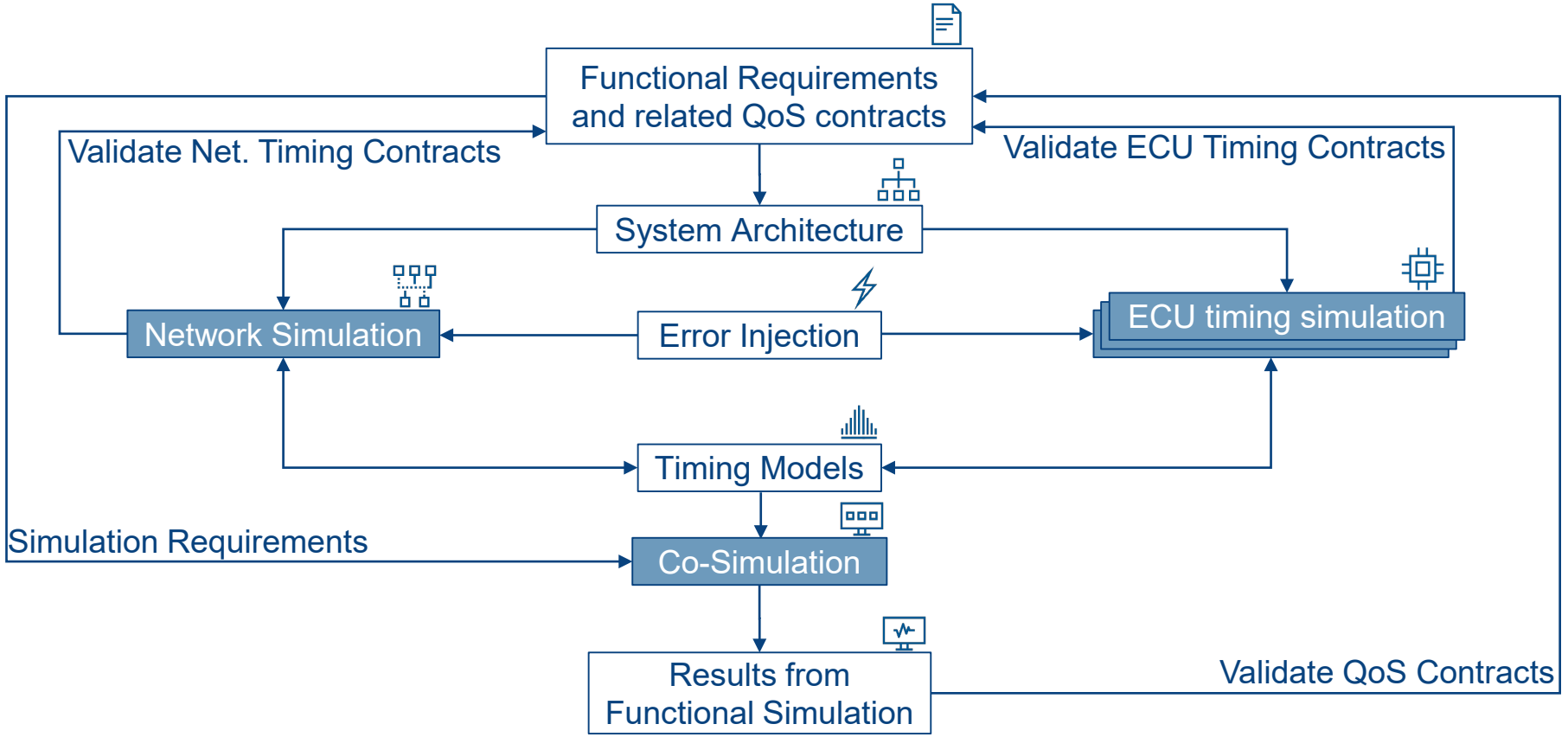
Framework to Virtually Validate QoS Contracts
X-Domain Simulation



USE CASE

AUTONOMOUS EMERGENCY BRAKING

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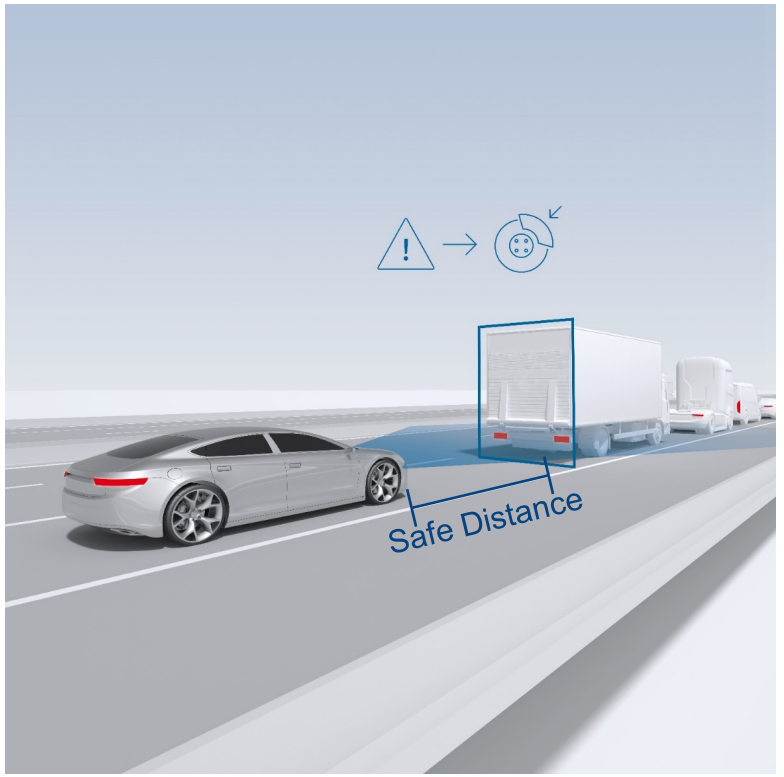
Use Case: Autonomous Emergency Braking (AEB)
Feature and Test Scenario

Feature:
AEB systems activate the vehicle brakes when a collision is imminent despite any reaction by the driver. [3][4]

Scenario:
The ego-vehicle with the AEB feature should maintain a minimum safe distance from a vehicle in front moving slowly.

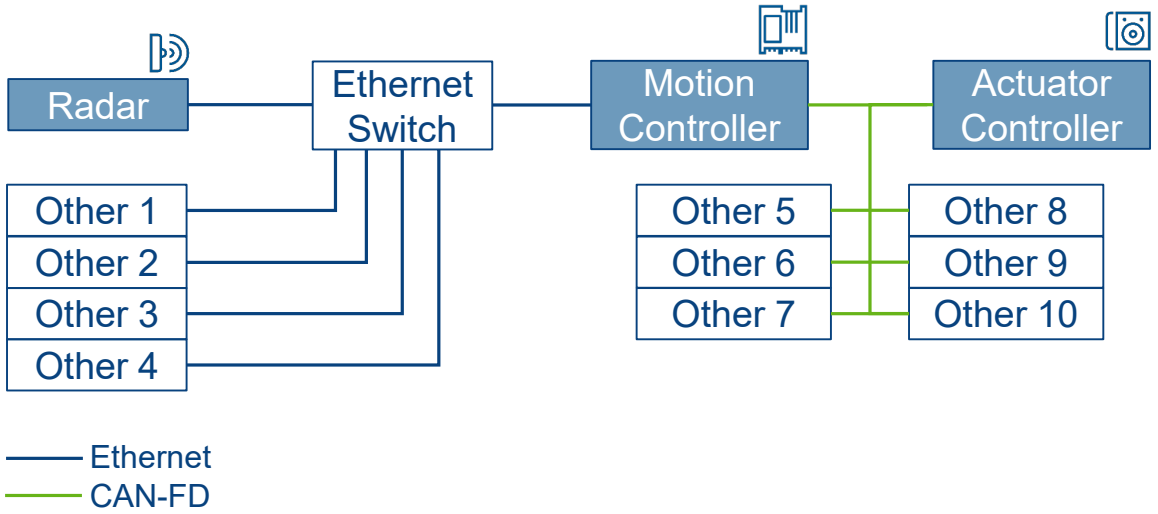
Functional Requirement:
During the AEB maneuver the safe distance shall be above 5 meters.

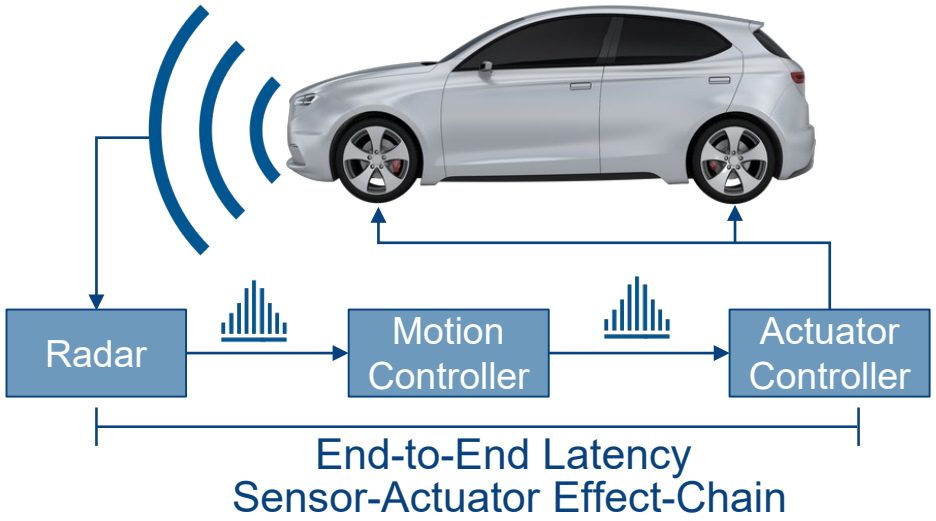
Non-Functional Requirement:
Timing properties that could lead to a violation of the functional requirement.



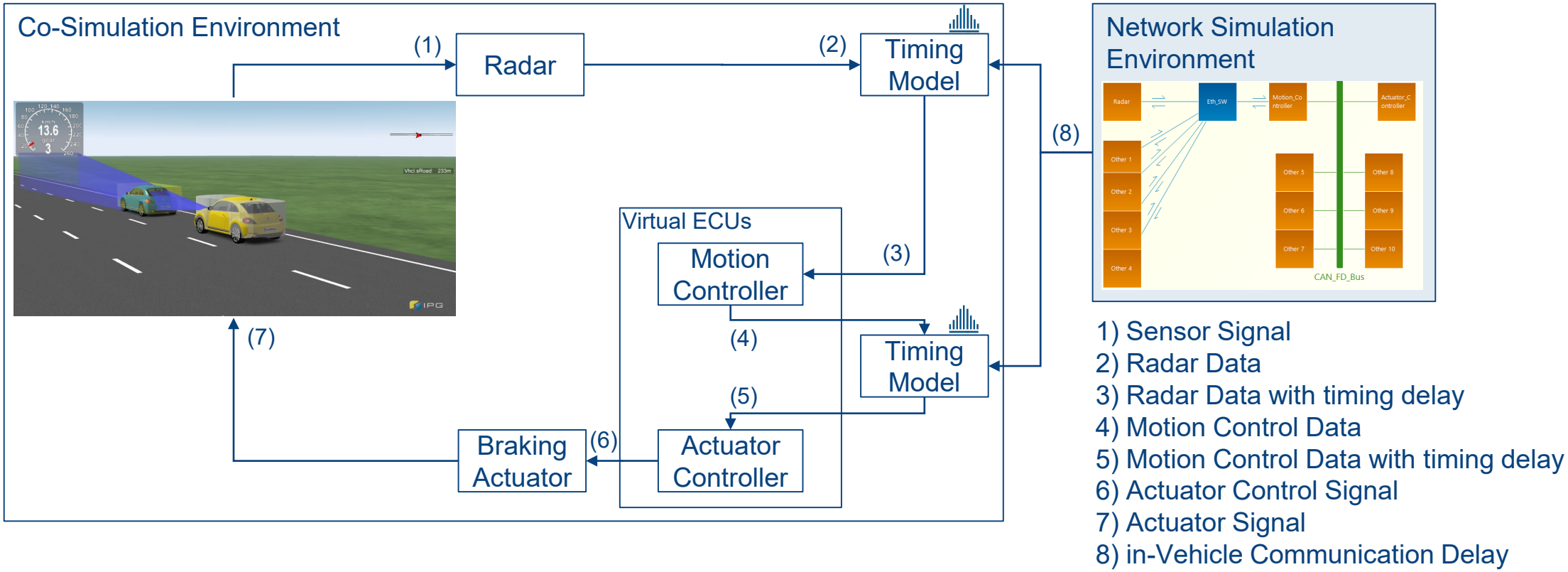
AEB Feature

Use Case: Autonomous Emergency Braking (AEB)
System Architecture and Timing Effect Chain





Use Case: Autonomous Emergency Braking (AEB)
Simulation Environment Set-Up

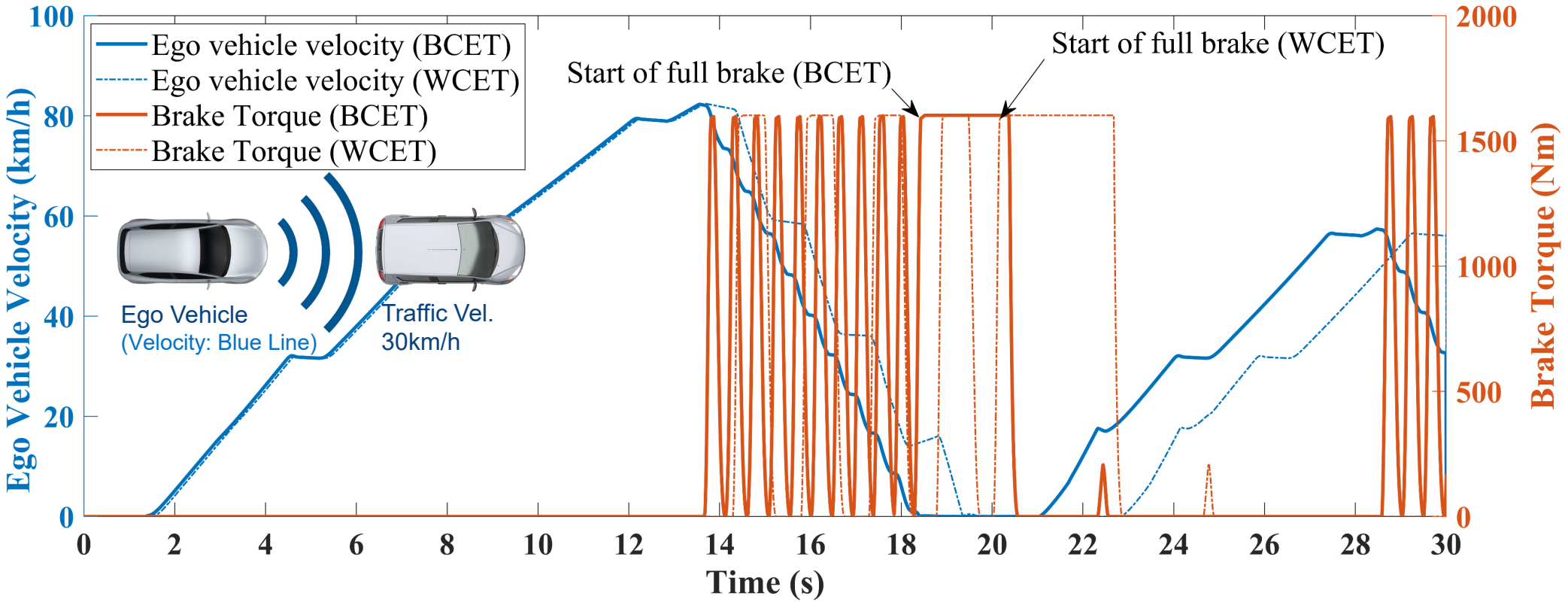


1) Sensor Signal
2) Radar Data
3) Radar Data with timing delay
4) Motion Control Data
5) Motion Control Data with timing delay
6) Actuator Control Signal
7) Actuator Signal
8) in-Vehicle Communication Delay

RESULTS

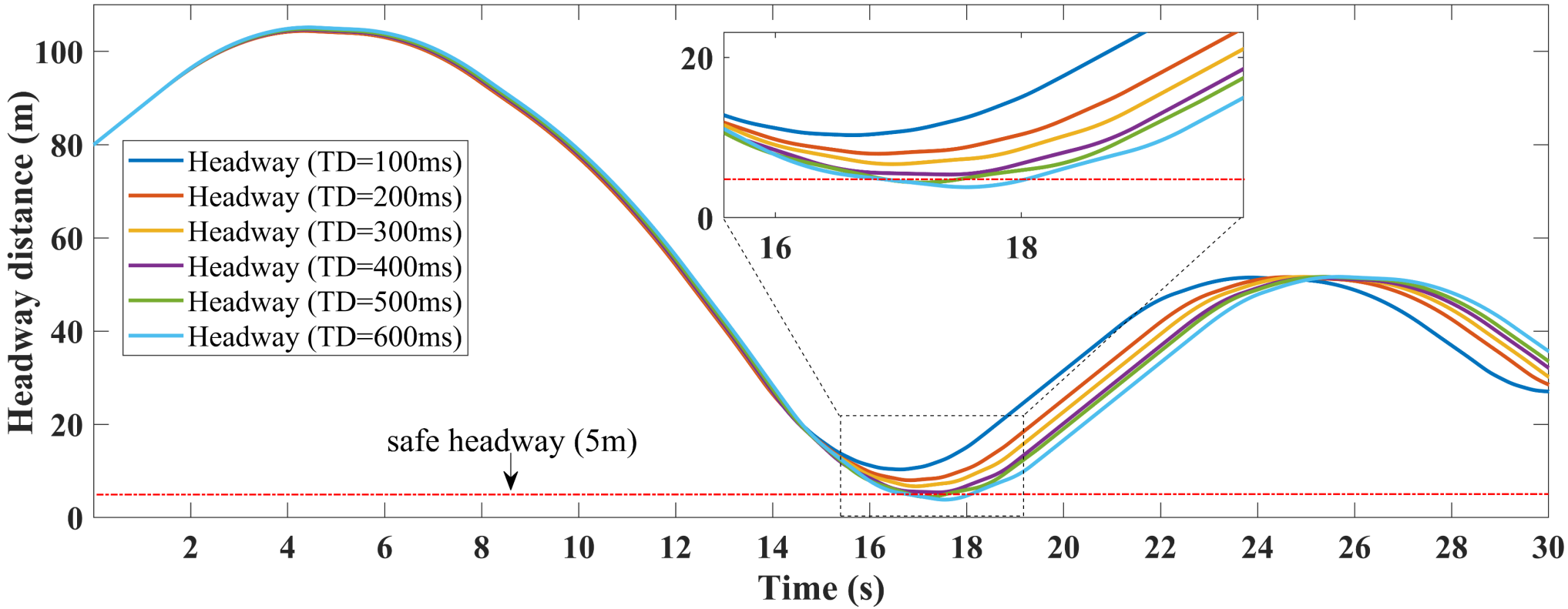
Use Case: Autonomous Emergency Braking (AEB)
Simulation Results

Deviation of Ego-Vehicle Velocity and Brake Torque for Best and Worst Case Execution Time (BET/WET)



Use Case: Autonomous Emergency Braking (AEB)
Simulation Results

Comparison of headway distance for different time delays (TD)



CONCLUSION

Conclusion

- This work proposed a framework to virtually validate Quality of Service timing contracts for automotive cyber-physical systems.
- The vehicle is a multi-domain Cyber-Physical System with rich interactions.
- The new trends coming to the automotive sector will increase even more the complexity of the vehicle systems, making necessary new approaches for system validation.
- The usage of design contracts could help the system development, bridging the gap between the plural vehicle domains.
- For the timing properties related to the in-vehicle network communications, the usage of Quality of Service contracts can aid the validation of the systems effect-chains.

References

[1] P. Derler, E. A. Lee, M. Törngren and S. Tripakis, "Cyber-physical system design contracts“, 2013 ACM/IEEE International Conference on Cyber-Physical Systems (ICCPS), Philadelphia, PA, 2013, pp. 109-118, doi: 10.1145/2502524.2502540

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[4] European New Car Assessment Programme (Euro NCAP), Test Protocol – AEB Systems, Version 1.1, June 2015. Retrieved from https://cdn.euroncap.com/media/17719/euro-ncap-aeb-test-protocol-v11.pdf

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Thank you for your attention.
Questions?

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AUTHORS BIOGRAPHY

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