

CReTS-Co-simulation Framework for Control, Communication and Traffic for Vehicle Platoons

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Introduction

Vehicle platooning:

A convoy of vehicles travelling together safely at high speed while keeping a short distance between them.

Vehicles communicate wirelessly over:

- Wireless communication standard e.g. IEEE802.11p for sharing information between vehicles such as: acceleration, velocity, position, braking actions, road and intersection status)
- Other sensors e.g. radar and lidar, camera (measuring position of the preceding vehicle).



Figure 1. vehicle platooning
Image source: Scania Newsroom

Challenges

The design of a platoon system depends on:

1. Network behavior:

- Number of vehicles equipped with V2V communication devices
- Simulating V2V communication using realistic simulator
- Designing the control system according to different packet reception ratios and delays occur depending on the network congestion level.

2. Traffic behavior:

- Generating real driving behavior on highways or urban areas.
- Considering different traffic densities

3. Control design: Analysis and evaluation of different control architectures under:

- different network congestion levels and traffic densities
- different sampling rates of the inter-vehicle (1-10 Hz, 802.11p) and intra-vehicle network (20 Hz or 50 Hz over FlexRay or Ethernet)

Co-simulation Framework Components

1. Network simulator ns-3¹

- Event based discrete simulator
- Realistic network simulator
- Implements the architecture for IEEE802.11p

2. Traffic simulator SUMO²

- open source, microscopic road traffic simulator
- generate real driving behavior
- Provide graphical user interface (GUI) to observe the motion of the vehicles

3. Matlab for control design

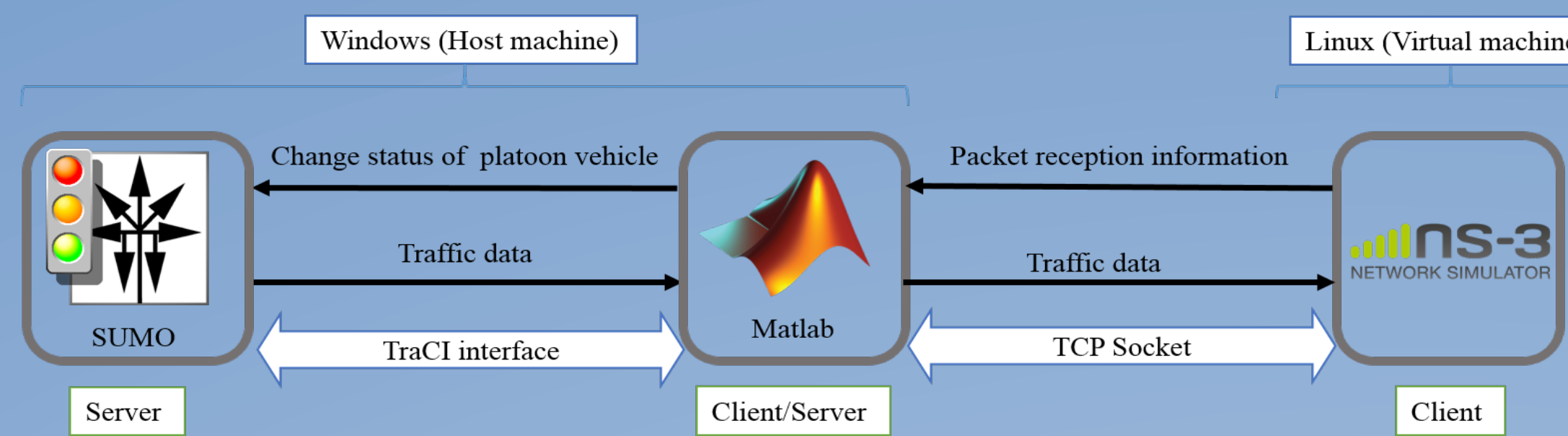


Figure 3. Interaction between tools

How it works?

1. Connecting the tools:

TCP connection is established between tools:

- Between Matlab and SUMO using TraCI (Traffic Control Interface).
- Between Matlab and ns-3 using socket programming

2. Interaction is based on client-server model:

- SUMO acts as a server and is responsible of viewing all the vehicles (platoon vehicles and other vehicles) through GUI.
- SUMO allows Matlab to modify and retrieve states of the simulated vehicles
- The control algorithm is computed on Matlab which acts as the interface between SUMO and ns-3
- Matlab acts as server for ns-3 and client for SUMO
- ns-3 simulates V2V communication between all vehicles based on the state information of each vehicle received from Matlab.
- ns-3 updates matlab with the packet reception information of the platoon vehicles

3. Synchronization is considered between tools:

- SUMO waits to receive the new information of the platoon vehicles from Matlab
- Then SUMO simulates and update the whole traffic members.
- Then, the states of the whole traffic members are sent to ns-3 through Matlab which simulates V2V communication between vehicles.
- ns-3 simulates packet broadcast of every vehicle using a uniform velocity mobility model. That is, ns-3 simulates constant speed motion of every vehicle.
- ns-3 finds the packet reception information between platoon vehicles.
- Hence, Matlab waits to receive packet reception details from ns-3 and then it runs the control algorithm based on this information.
- In reality, synchronization can be achieved with acceptable accuracy via GPS with the state-of-the-art 802.11p devices e.g. MK5 On-Board Unit (OBU) from Cohda Wireless³

Case study

- Low, medium and high congestion levels are considered
- 3 km road segment (4 lanes in each direction), lane 1 is dedicated to platoon members

Multi-layer control design

Upper-layer:

- receives information of the preceding platoon member
- Generate the acceleration setpoint ensuring safety and efficiency
- the message could be received every 100ms (10 Hz message rate) assuming channel load < 70% (complying with IEEE 802.11p standard)
- Message rate could be lower (i.e. < 10 Hz) if the channel load > 70 % (controlled via Decentralized Congestion Control (DCC) algorithm)
- Model Predictive Control (MPC) is chosen for its ability to handle constraints and its predictive behavior relevant to deal with packet losses

Lower-layer:

- Reach the acceleration setpoint as soon as possible
- State-feedback control is used at higher sampling rate e.g. 50 Hz, 20 Hz (i.e. 2ms or 5ms), supported by common automotive operating systems.

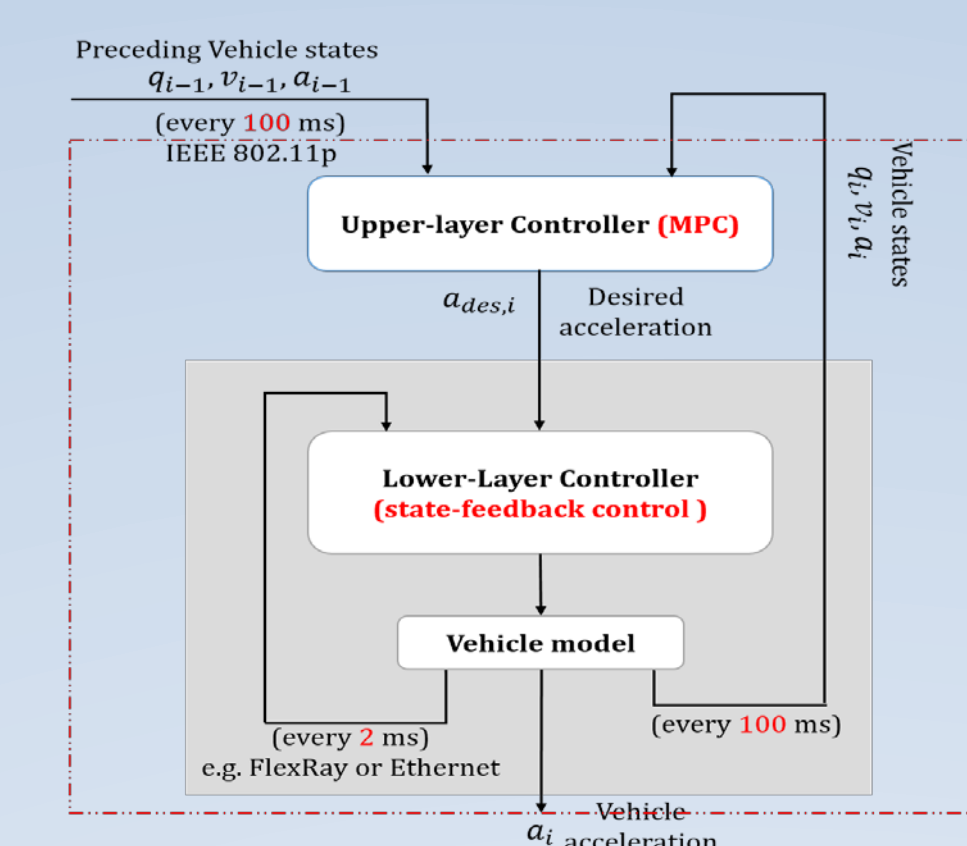


Figure 4. Multi-layer multi-rate control structure of vehicle i

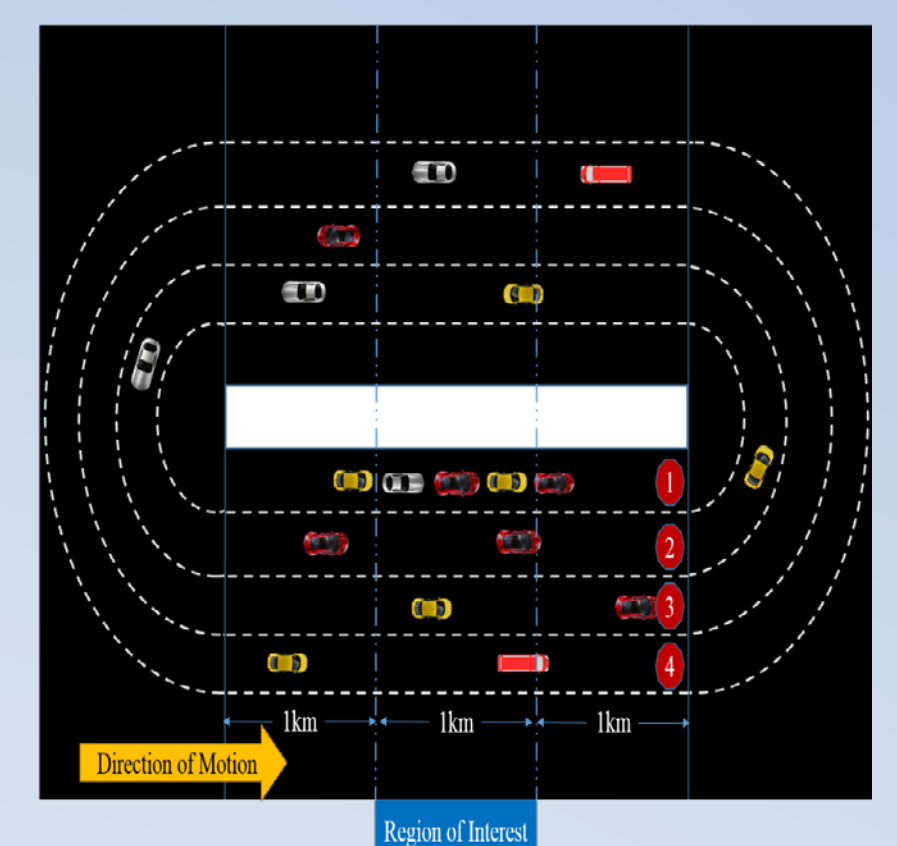
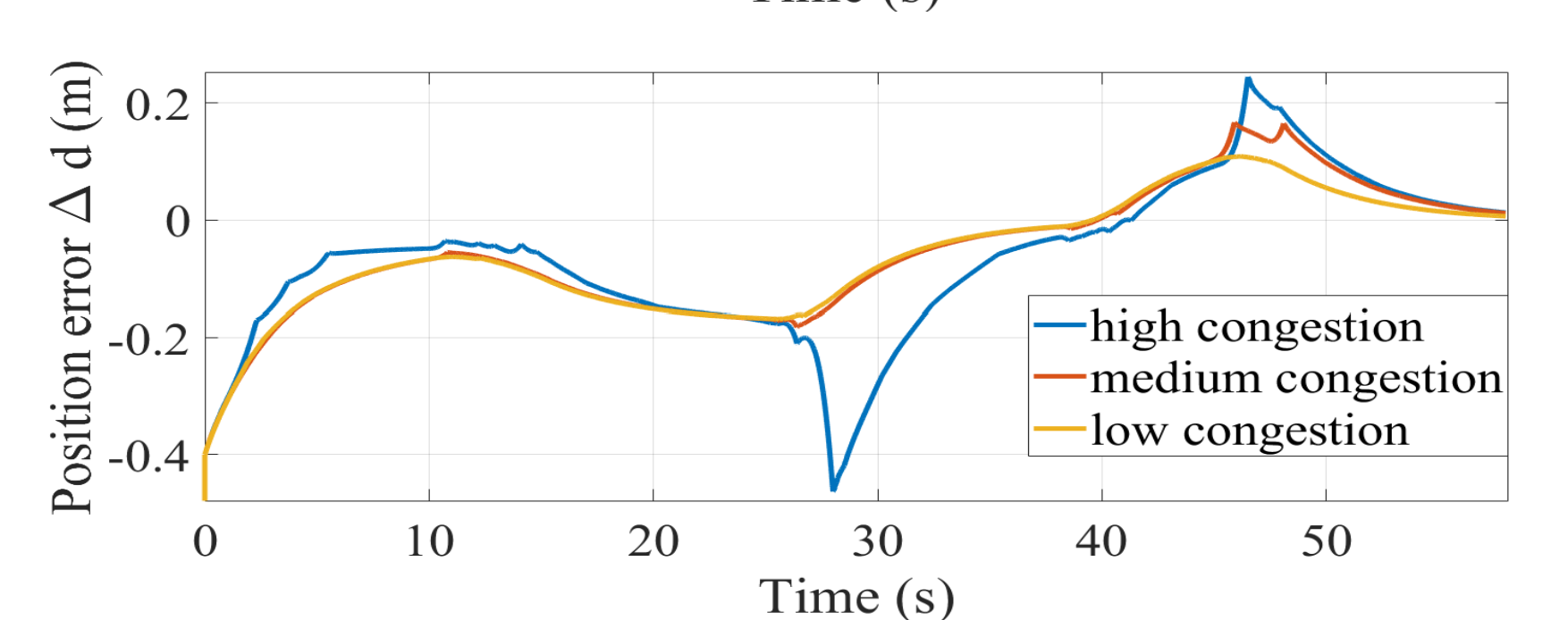
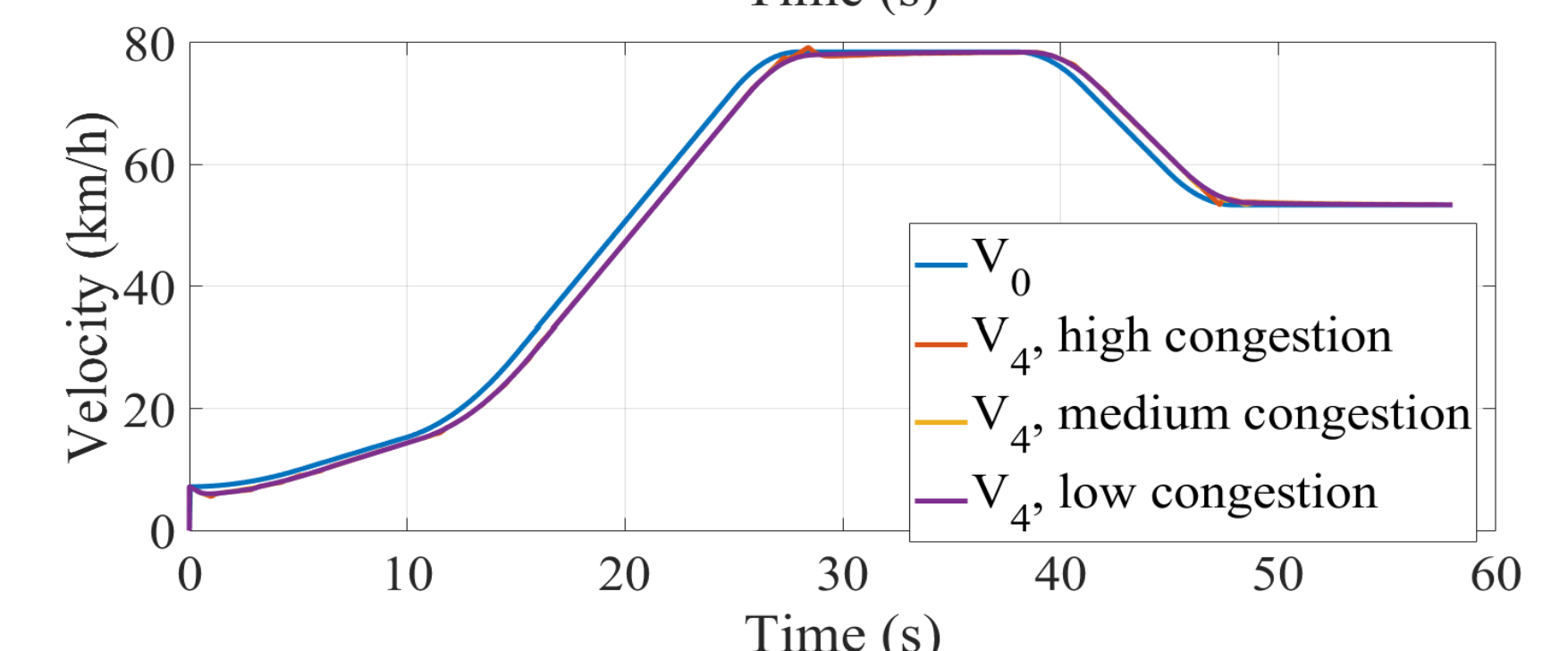
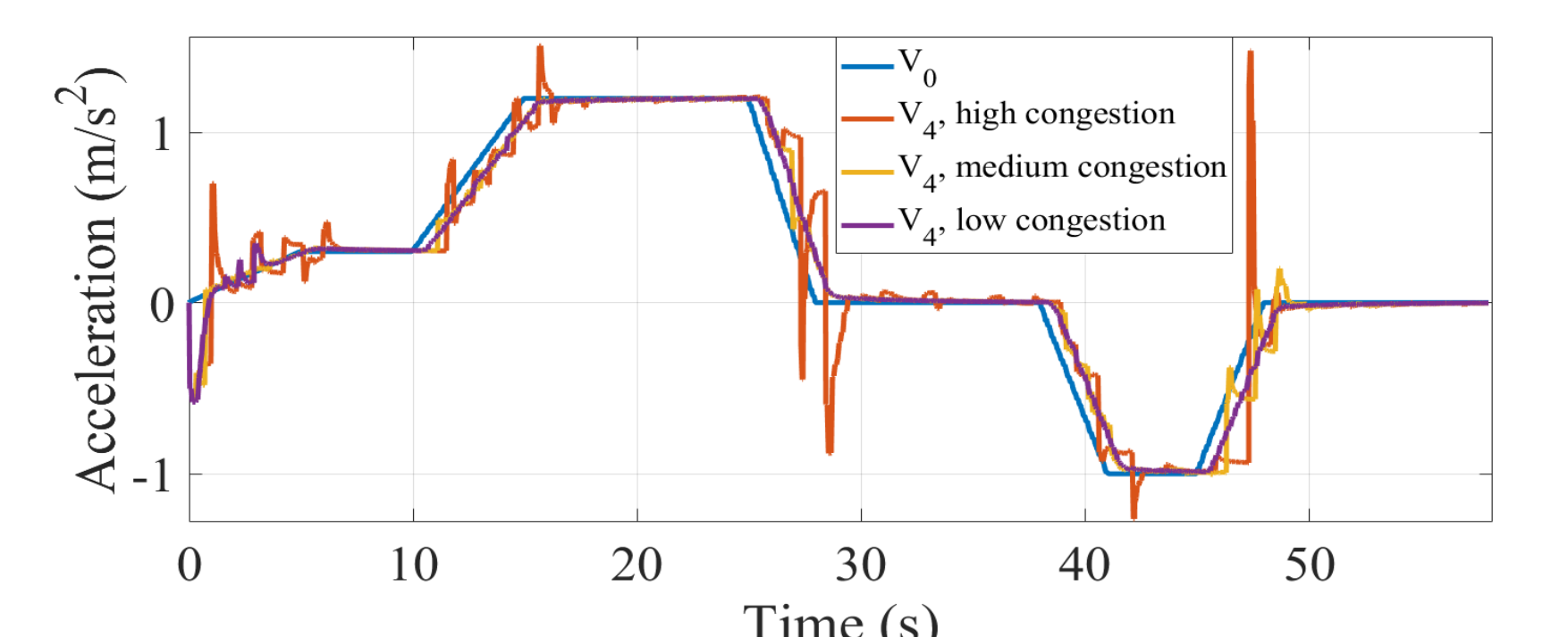


Figure 5. traffic scenario considered on SUMO

Results



Scenario	Configuration	Average PRR %	Average Delay (ms)
Scenario 1	600 vehicles, Low congestion, channel load <70%	83.41	6.69
Scenario 2	800 vehicles, Medium congestion, channel load = 70%	67.33	11.44
Scenario 3	1000 vehicles, High congestion, channel load > 70%	51.43	20.15

Table 1. Average Packet Reception Ratio (PRR) and average delay in different traffic scenarios

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This research was partially funded by the European Union's Horizon 2020 Framework Programme for Research and Innovation under grant agreement no 674875 (oCPS Marie Curie Network).

Conclusion

- Our framework provides a design and testing template for all three relevant components (network behavior, traffic density, control design).
- This framework can be used for development, testing and validation of both platoon control and communication in different traffic scenarios.



Figure 2. SUMO GUI

References

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