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Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

Università di Pisa

FORESEEN Project

PRIN 2022 PNRR

FORmal mEthodS for attack dEtEction in autonomous driviNg systems

https://forseen.dii.unipi.it

Severity of attacks in a vehicle platoon by model-based simulation

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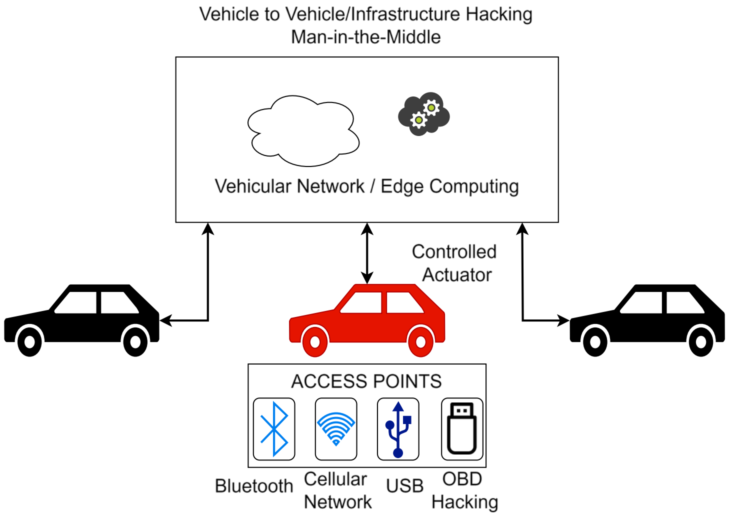
Introduction

The goals of our work:

1. Enhancing security of *connected autonomous vehicles* (CAV) by developing run-time local monitors for attack detection: the case of vehicle platoon
2. Model-based design security analysis
3. Traces analyses for anomaly detection
4. Model checking & abstract interpretation to identify patterns suggesting the possibility of an impending attack

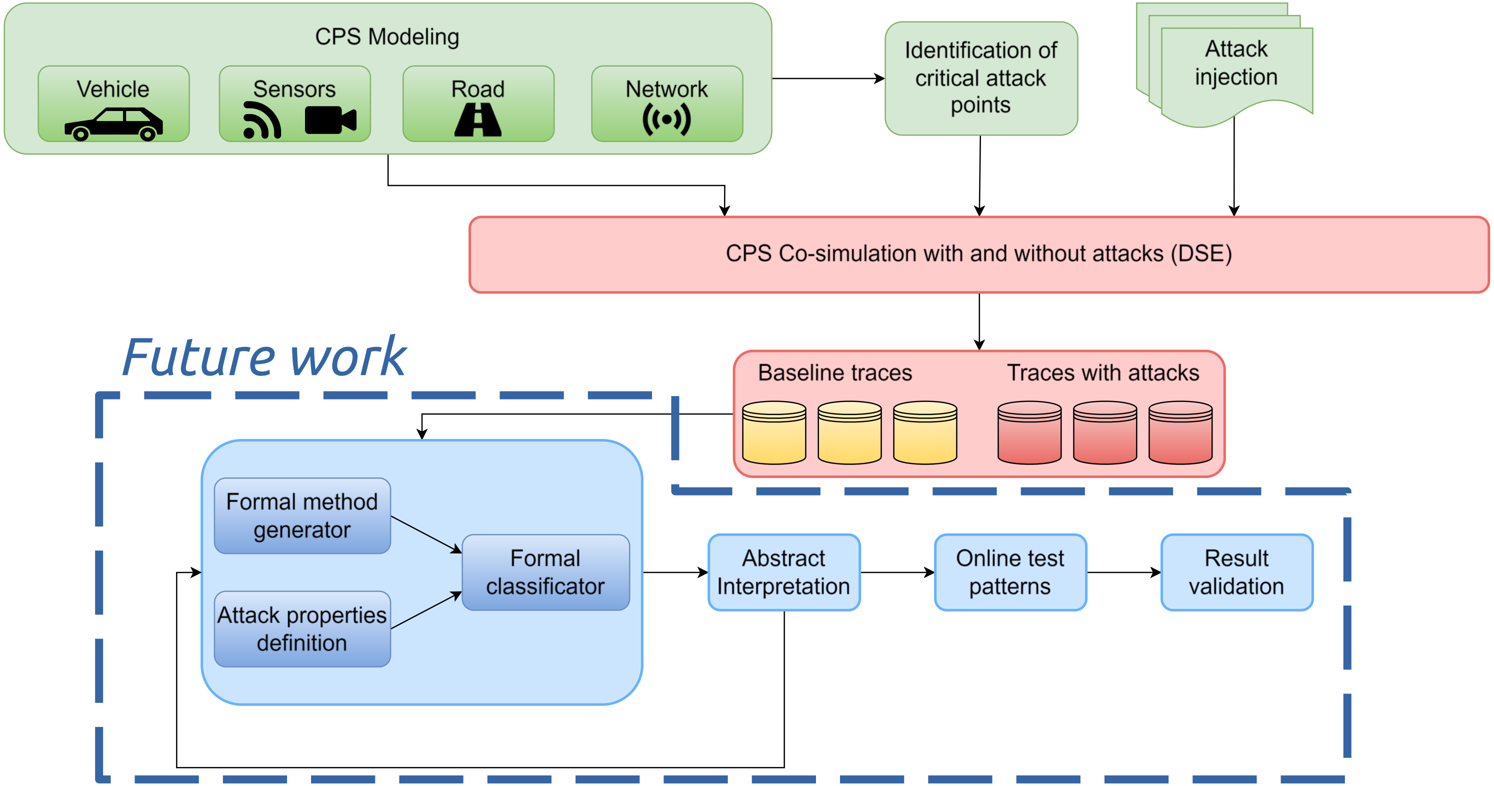


Motivations:

Vulnerability in vehicle ecosystems

GPS, OBD, CAN etc… etc…

Introduction – Project's goal



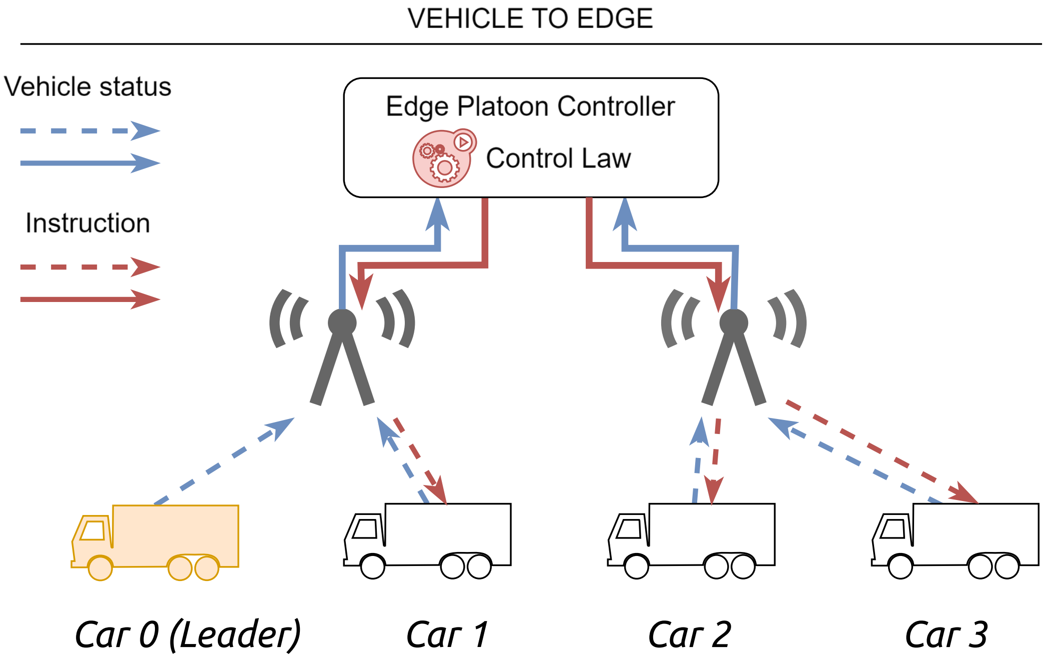
Vehicle platoon

The platoon's main objective is to keep an inter-vehicular distance D=11 meters between each pair of cars.

We study two kind of configurations:

1. Vehicle-to-edge
2. Vehicle-to-vehicle

The *Cooperative Adaptive Cruise Control* (CACC) is used to control the platoon

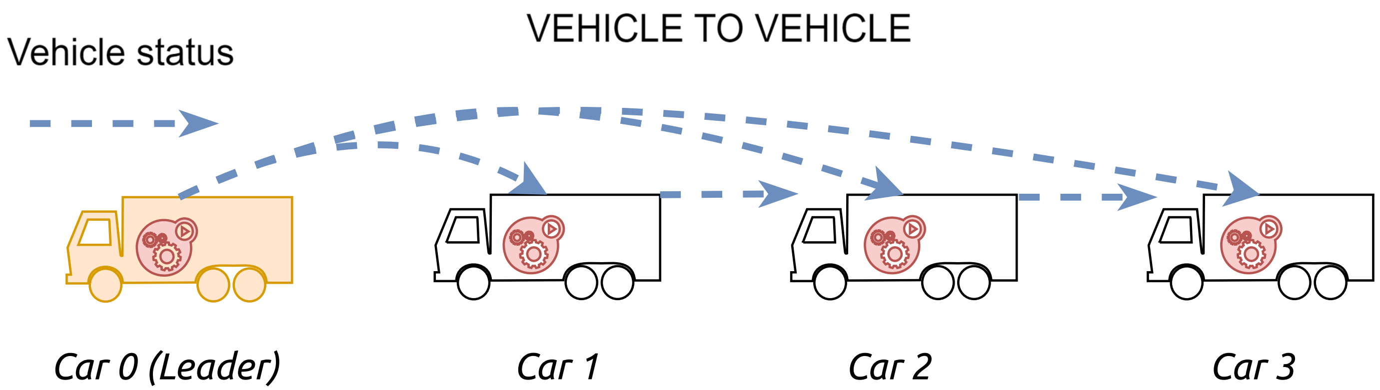


Vehicle platoon – V2V

The V2V counterpart is similar but there's a pair of edge of each pair of cars (i, i - 1) and (i, 0).

The IEEE 802.11p protocol is implemented as the network medium.

[1] was used to simulate the rate of packet drops in function of distance, vehicle distance and network traffic



[1] M. Sepulcre, M. Gonzalez-Martín, J. Gozalvez, R. Molina-Masegosa and B. Coll-Perales, "Analytical Models of the Performance of IEEE 802.11p Vehicle to Vehicle Communications," in *IEEE Transactions on Vehicular Technology*, vol. 71, no. 1, pp. 713-724, Jan. 2022

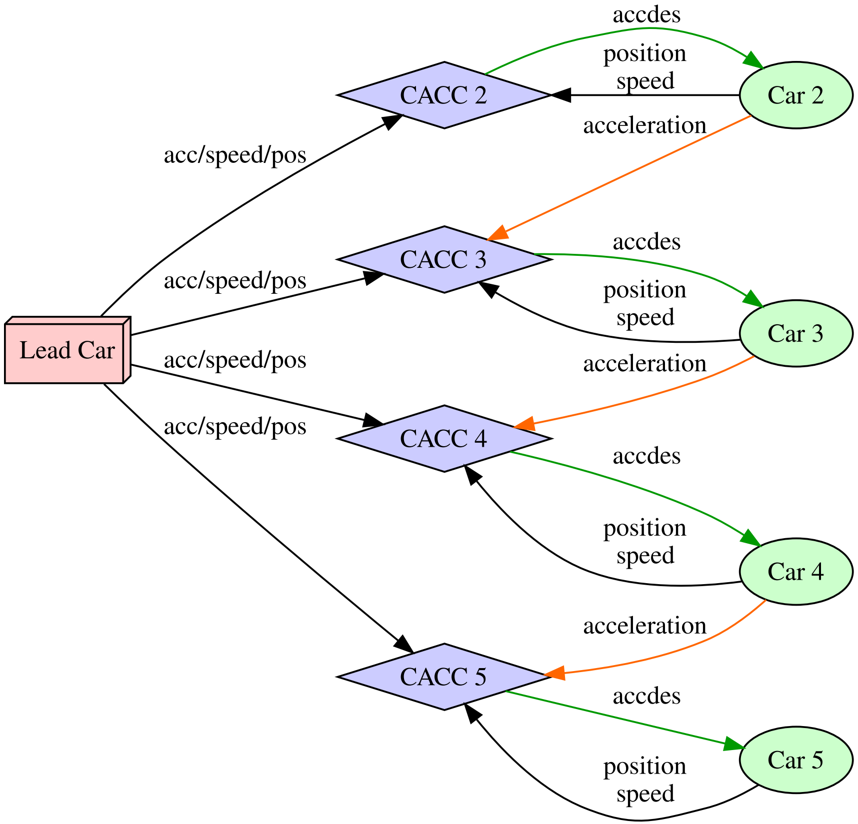
Co-simulation

We have the following FMUs:

Name	Language
Car's physics	MATLAB
[V2E] Network medium + CACC Controller	Python
[V2V] Network Medium	C++
[V2V] CACC Controller	C

INTO-CPS is used as the COE

http://into-cps.org



How the FMUs are connected in the V2V scenario

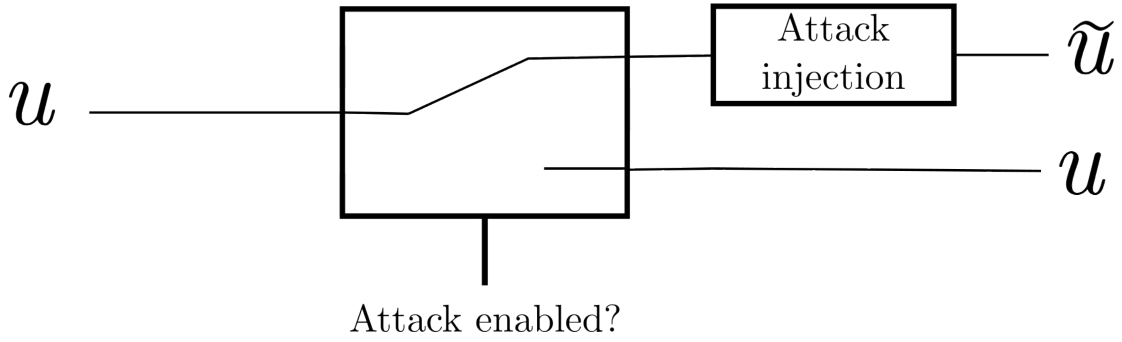
Attack injection

We study two kinds of *data alteration* attacks:

1) **Actuator alternation** (i.e. on the value of desired acceleratoin u sent by the CACC to the car's physics)

2) **Physical values alteration** (i.e. on the x,v,a values sent by vehicle to the edge/other vehicles)

They're implemented by **adding a switch** in the car's physics' FMU



Attack injection for the 1st case

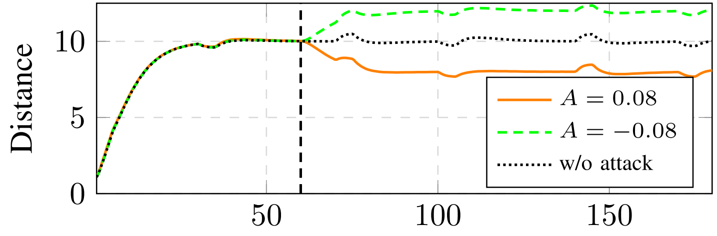
For the 2nd attack is analogous

Actuator alteration

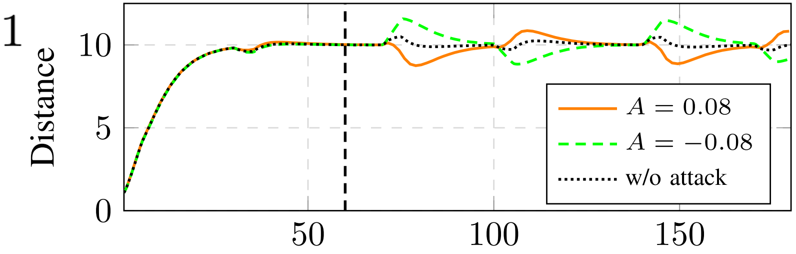
Attack on the actuator with a certain parameter A

$$\tilde{u}_1 = u_1 + A$$

$$\tilde{u}_1 = (1 + A) \cdot u_1$$



(a) d_1, gap between car 1 and the leader



Physical values alteration

$$\tilde{a}(t) = a(t) + A \sin(2\pi f t)$$

$$\tilde{v}(t) = v(t_0) + \int_{t_0}^{t} \tilde{a}(\tau) d\tau$$

$$\tilde{x}(t) = x(t_0) + \int_{t_0}^{t} \tilde{v}(\tau) d\tau$$

Ranges under study

Examples of possible values of A:

±0.08, ±0.04, ±0.5, etc…

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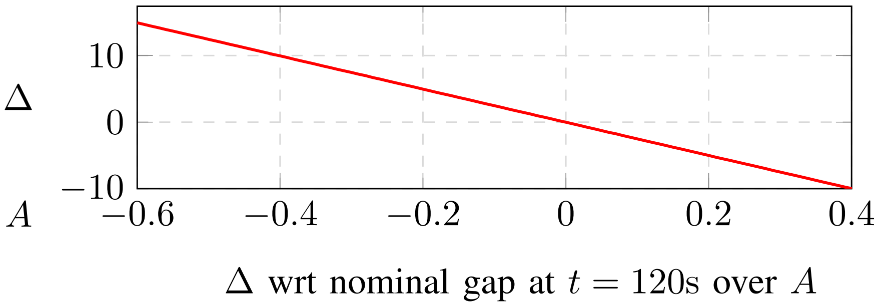
Assumptions

- The CACC control law is assumed to be the same between the two scenario
- Packet latency are drawn from an exponential distribution
- V2V
  - Simulation of highly congested radio channel
- V2E
  - Reliable link (no packet loss)
  - RTT within 30 ms

Some results & Conclusions

We tested many parameter combinations.

- Attacks **data-alteration** are most dangerous
- Attacks on **actuators** mainly result in a reduced inter-vehicular distance.



Example of possible data aggregation

These figures are relative to V2E. (similar to V2V)

***P1**: Physical values alteration attacks*

***P2**: actuator alteration attacks*

Label class	*No attack*	*Attack leader P1*	*Attack on car 1 - P1*	*Attack on car 1 - P2*	*Attack on car 4 - P1*	*Attack on car 4 - P2*
OK	100.00%	33.33%	33.33%	50.00%	33.33%	75.00%
TOO CLOSE	0.00%	0.00%	0.00%	50.00%	0.00%	25.00%
COLLISION	0.00%	66.67%	66.67%	0.00%	66.67%	0.00%
# TRACES	*96*	*576*	*288*	*384*	*288*	*384*

Further work

- More attacks
- Extract models of the cars' behaviors from the traces
- Extract properties from the traces
- Generate online tests to check against attacks on the vehicle

FIN
Thank you for the attention

This work is part of the FORSEEN project

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