NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

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Analytical analysis of the effect of maximum CAV platoon size in mixed traffic

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Outline

- Introduction
- Effect on capacity
- Effect on traffic stability
- Conclusions

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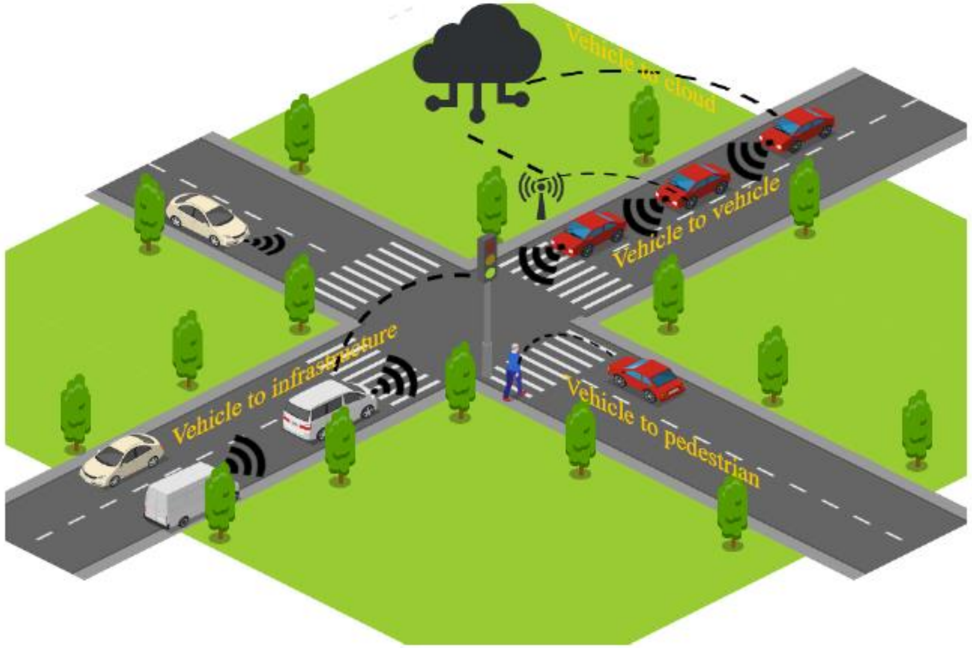
Introduction

Connected and Automated Vehicle (CAV) platooning:

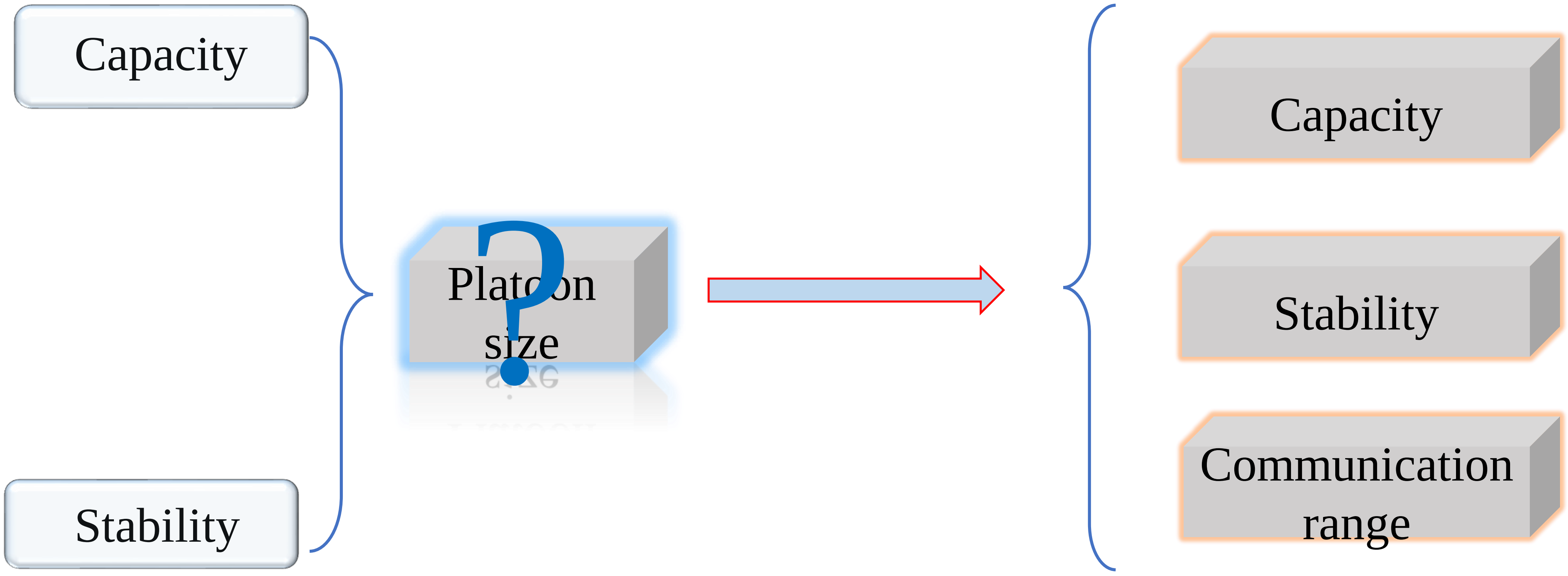
- Shorter spacing (or headway)
- Higher roadway **capacity**
- Higher **flow stability**



CAV Platoon configurations:

- Inter-platoon headway
- Intra-platoon headway
- **Maximum platoon size**

Introduction



Research objective

The effect of maximum platoon size on:

- capacity
- traffic stability

Problem statement

Basic segment of highway

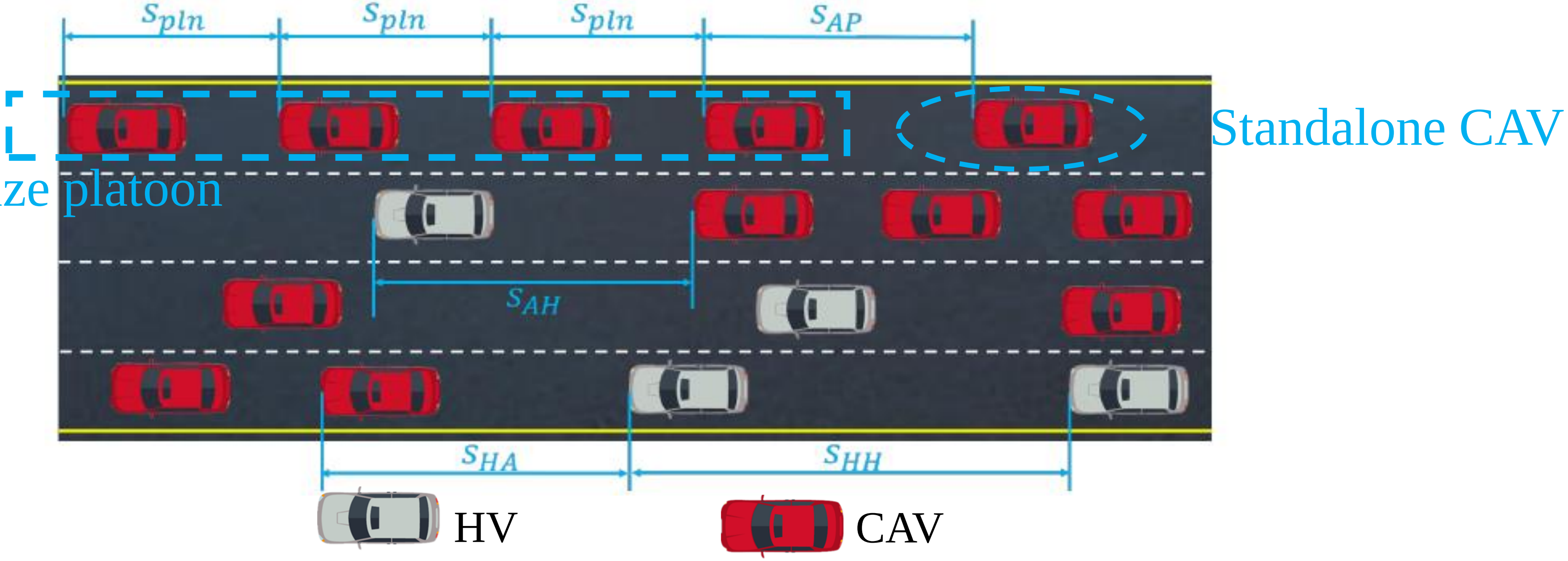


Figure 1: Five types of spacings

Mixed traffic:

- CAV
- human-driving vehicle (HV)

Assumption:

$$\frac{s_{pln}}{\beta_{pln}} = \frac{s_{AP}}{\beta_{AP}} = \frac{s_{AH}}{\beta_{AH}} = \frac{s_{HA}}{\beta_{HA}} = s_{HH}$$

$$\beta_{pln} < \beta_{AP} \leq \beta_{AH} \leq \beta_{HA} \leq 1$$

Model parameters

Table 1. Model parameters

N	maximum allowable platoon size
P_A	CAV market penetration ($P_A \in [0,1]$)
P_H	HV market penetration ($P_H \in [0,1]$)
O	platooning intensity ($O \in [-1,1]$)
s_{pln}	intra-platoon spacing (km)
s_{AP}	inter-platoon spacing (km)
s_{AH}	spacing between a following CAV and a leading HV (km)
s_{HA}	spacing between a following HV and a leading CAV(km)
s_{HH}	spacing between two HVs (km)

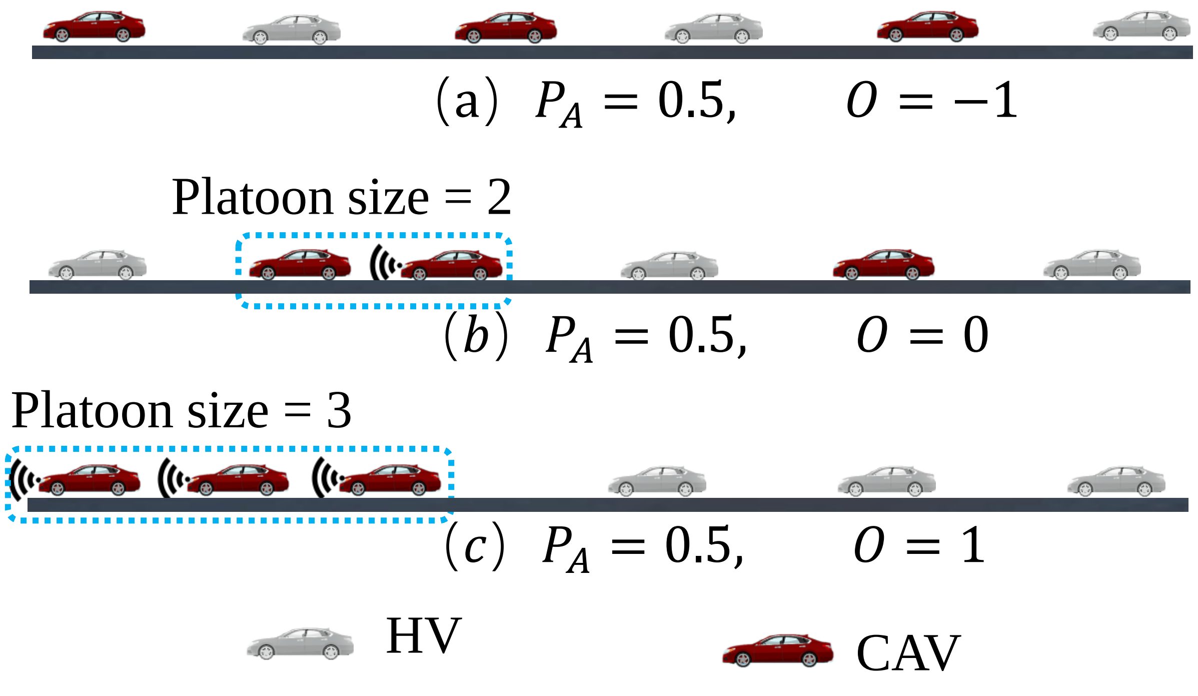


Figure 2: The illustration of P_A and O

Effect on capacity

1. Capacity model

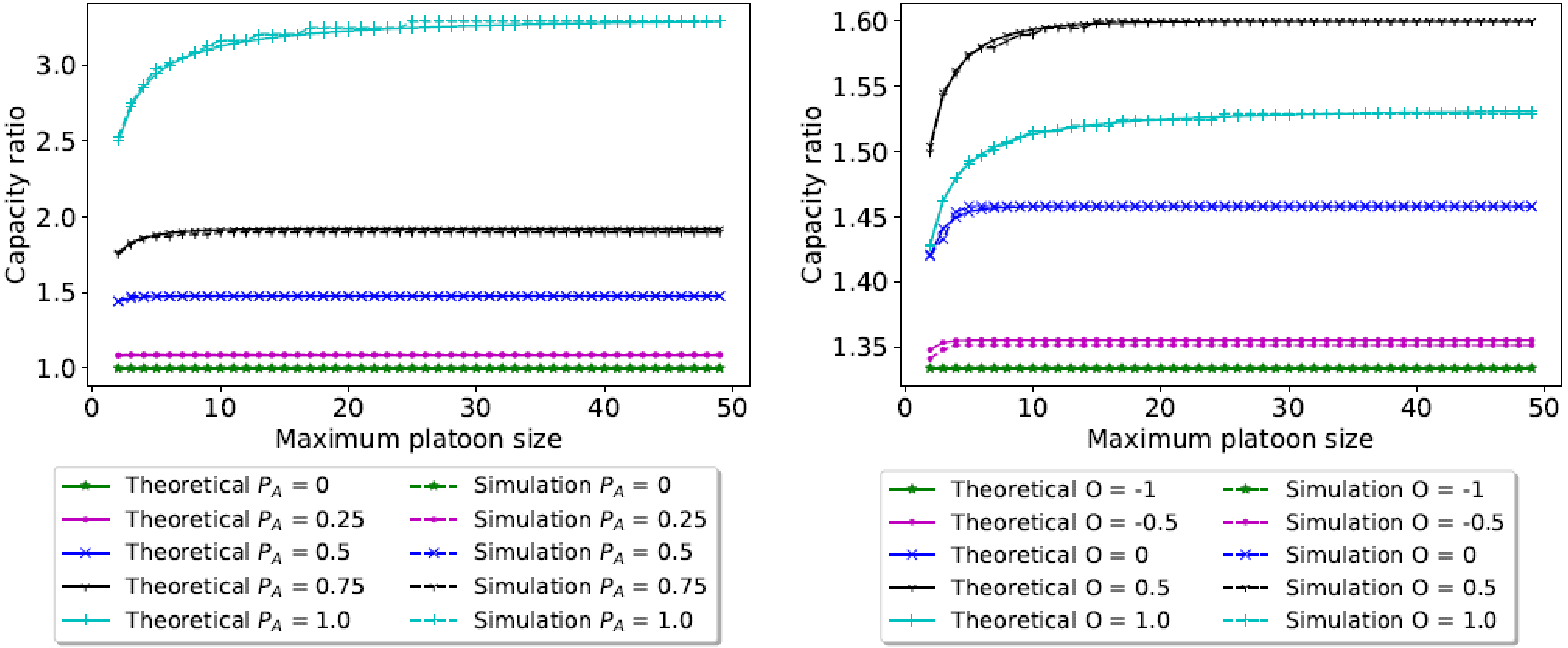
Average spacing: $\bar{s} = f\left(N, P_A, O, \beta_{pln}, \beta_{AP}, \beta_{AH}, \beta_{HA}, \beta_{HH}\right) s_{HH}$

Lane capacity: $C = \dfrac{1}{\bar{s}/v_f} = \dfrac{v_f}{f(N, P_A, O, \beta_{pln}, \beta_{AP}, \beta_{AH}, \beta_{HA}, \beta_{HH})s_{HH}}$

Let $C_0 = \frac{v_f}{s_{HH}}$ denotes the capacity of pure HV traffic, then the capacity is:

$$C = \frac{1}{f(N, P_A, O, \beta_{pln}, \beta_{AP}, \beta_{AH}, \beta_{HA}, \beta_{HH})} C_0$$

2. Capacity model verification



(a) $O = 0$ (b) $P_A = 0.5$

Figure 4: Capacity ratio vs maximum platoon size

Parameter setting: $\beta_{pln} = \frac{0.6}{2.0}; \beta_{AP} = \frac{1.0}{2.0}; \beta_{AH} = \beta_{HA} = \frac{1.5}{2.0}$

1. *N* ↑ ⇒ capacity ↑

2. *N* ↑ ⇒ marginal effect ↓

(platoon size does not necessarily need to be set too large)

Effect on traffic stability

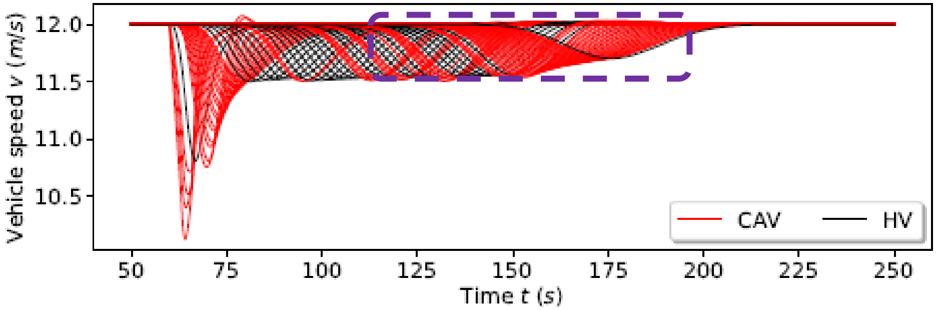
1. Linear stability analysis (through car-following model linearization)

Proposition 1. The maximum platoon size N contributes negatively to the mixed traffic stability.

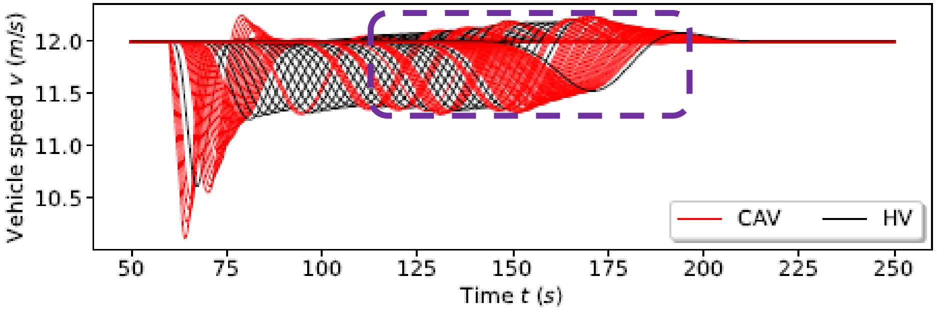
2. Simulation

Linearization **can not** fully capture the car-following dynamics.
The traffic that is linearly stable might still be non-linearly unstable.

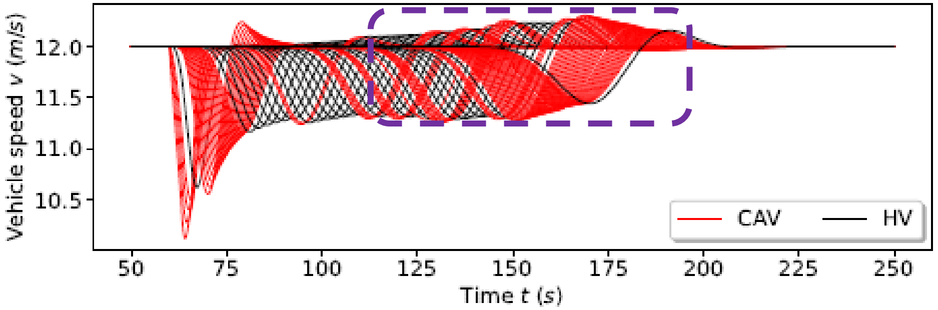
⇒ simulation



(a) $N = 2$

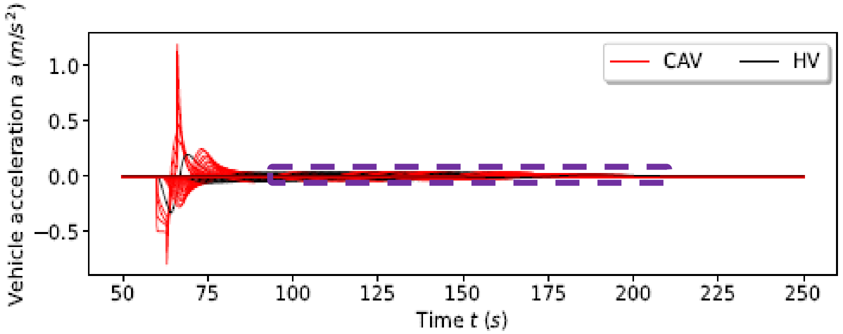


(b) $N = 6$

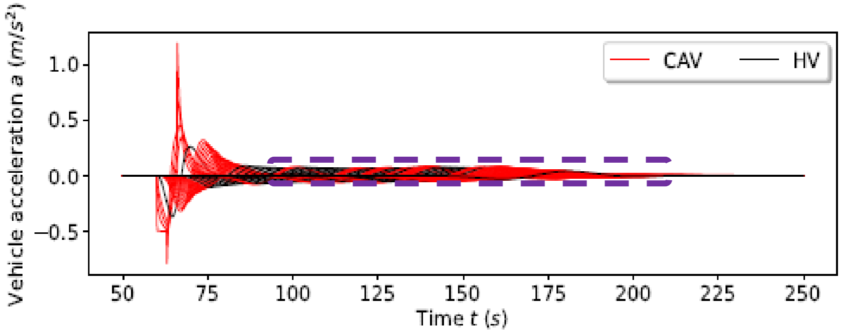


(c) $N = 20$

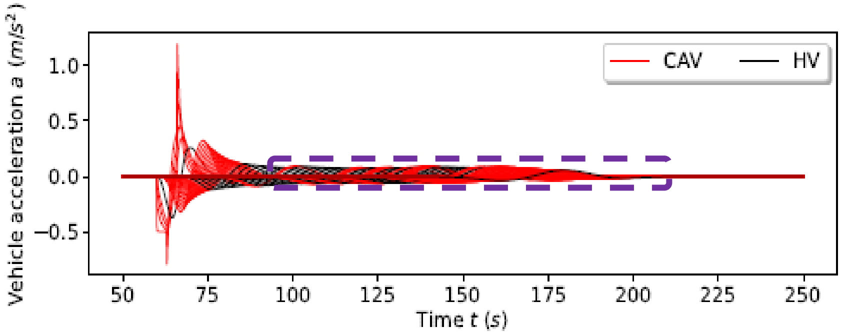
Figure 7: The speed profile



(a) $N = 2$



(b) $N = 6$



(c) $N = 20$

Figure 8: The acceleration profile

N ↑ stability ↓ ⟸ Smaller N leads to more inter-platoon followings

Dampen wave: inter-platoon > intra-platoon

Conclusion and future work

Discussion

- The maximum size of CAV platoon does not necessarily need to be too large.
- A moderate platoon size limit is suggested considering various stakeholders.

Contribution

- The understanding of impacts of CAV platoon size configuration
- Insights in the configuration of CAV platoon operation for future research

Reference

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Comments and suggestions ?

Thank you!