A Pricing Rule for Third-Party Platoon Coordination Service Provider

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Ting Bai, Alexander Johansson, Shaoyuan Li, Karl Henrik Johansson, Jonas Mårtensson

KTH Royal Institute of Technology, Stockholm, Sweden
Shanghai Jiao Tong University, Shanghai, China

What is truck platooning?

Trucks drive one after another on the road with small inter-truck distances.

Benefits of truck platooning:

1) Save fuel
2) Reduce greenhouse gas exhaust
3) Increase road capacity
4) Cut human labor cost
5) Positive for driving safety

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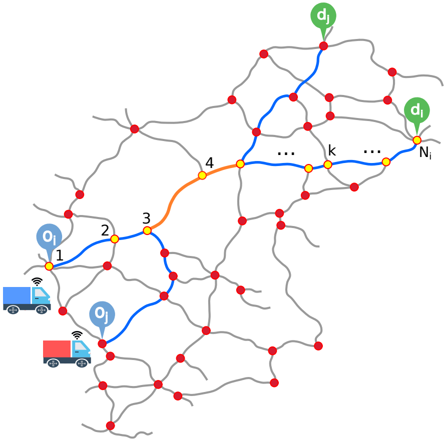
Platoon coordination



Motivation:

- Trucks with different OD-pairs, routes, time schedules need coordination to form platoons.
- Trucks from different carriers may not share information due to privacy concerns.

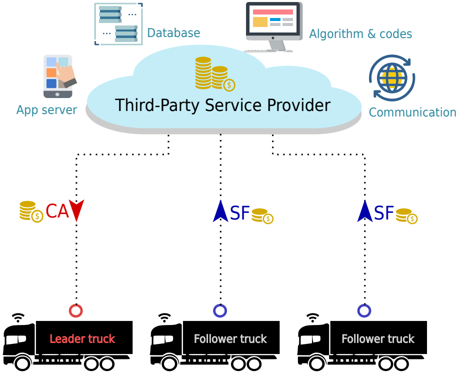
→ *A Third-Party Service Provider*

Third-party service provider

Service provided to trucks:

1) Data collection and communication
2) Platoon coordination at hubs
3) Sharing of platooning benefit

The service provider charges a service fee



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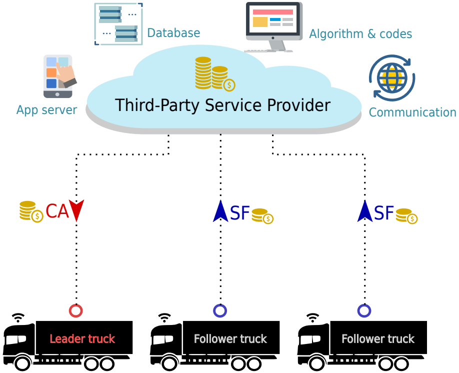
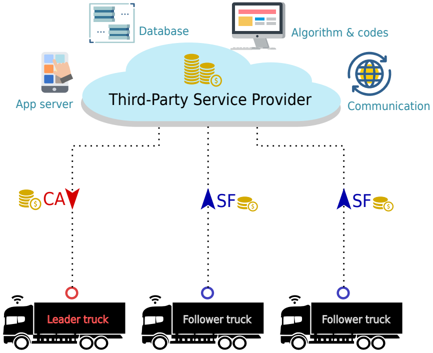
A pricing rule for third-party service provider



Pricing rule of the third-party service provider

- Charging rule:



The service fee of each follower truck:

$$F_f = R_{s,f} + R_{c,f}$$

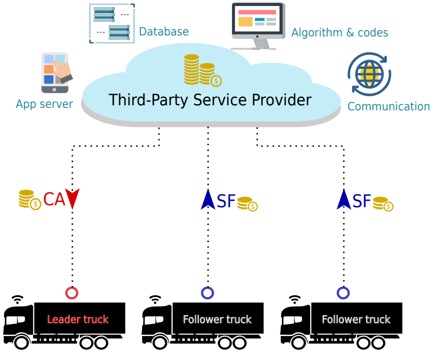
$$R_{c,f} = \frac{(P_f - R_{s,f})}{n}$$

P_f: the platooning benefit of each follower truck
n: the number of trucks in a platoon

SF: Service Fee
CA: Compensation Allowance

Pricing rule of the third-party service provider

- Compensation rule:



SF: Service Fee
CA: Compensation Allowance

The compensation of the leader truck:

$$R_c = (n-1)R_{c,f} = P_f - F_f$$

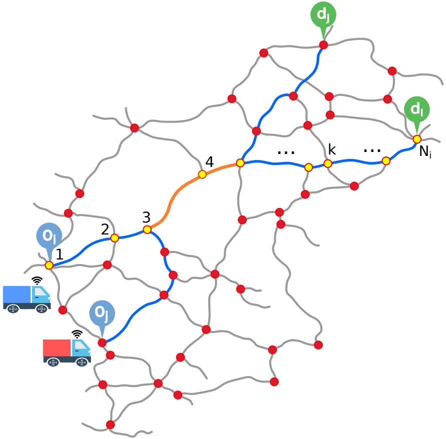
$\rightarrow$ The platooning benefit is shared evenly.

The service fee kept by the service provider:

$$F = (n-1)R_{s,f}$$

$\rightarrow$ Assume that $R_{s,f} = \alpha P_f$, where $0 \leq \alpha \leq 1$.

Platoon coordination method



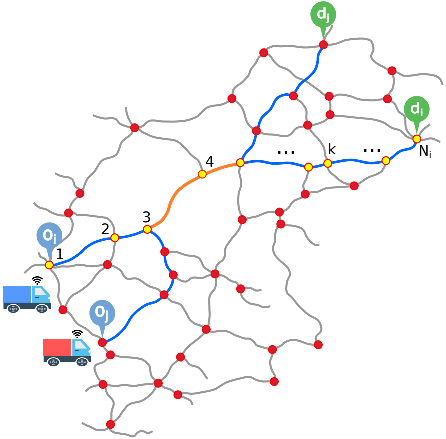
- Dynamics of truck i:

$$a_i(k+1) = a_i(k) + w_i(k) + c_i(k)$$

- Waiting times of truck i:

$$\mathbf{w}_i(k) = [w_i(k|k), w_i(k+1|k), \ldots, w_i(N_i-1|k)]$$

Platoon coordination method



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- The utility of truck i:

$$J_i(k) = \sum_{h=0}^{N_i-1-k} \left(R_i(k+h|k) - \epsilon_i w_i(k+h|k) \right)$$

where $R_i = (1-\alpha)P_f \frac{n-1}{n}$

Platoon coordination method

- Distributed MPC problem:

$$\max_{\mathbf{w}_i(k)} \quad J_i(k) = \text{Platooning reward} - \text{Waiting loss}$$
$$\text{s. t.} \quad \text{Dynamics of truck } i$$
$$\text{Delivery deadline} \qquad \rightarrow \textit{Mixed Integer Nonlinear Programming Problem}$$

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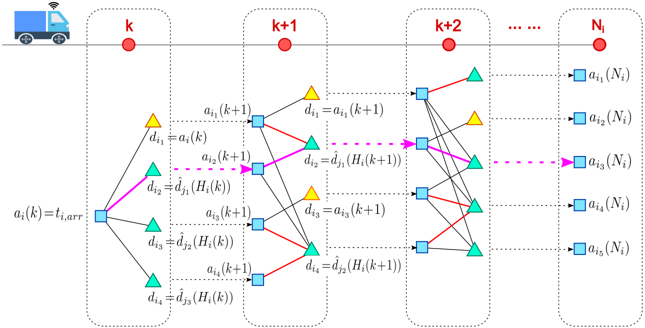
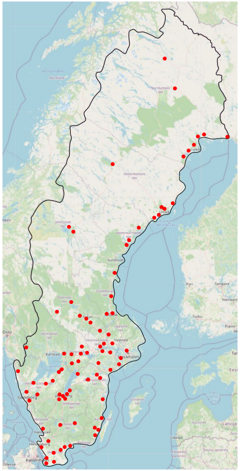
Delivery deadline $\rightarrow$ *Mixed Integer Nonlinear Programming Problem*

- Dynamic programming solution:



Simulation study

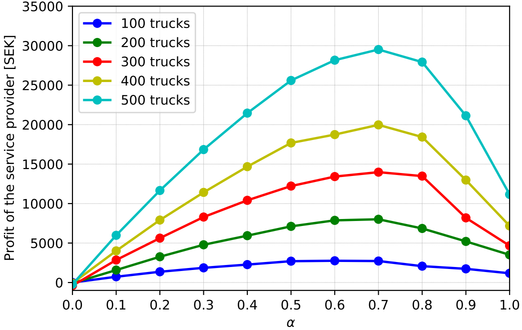


Parameter settings:

- Consider 84 major hubs in Swedish road network
- The routes are obtained from *OpenStreetMap*
- Each truck starts its trip at a random time during 8:00-12:00
- The total driving time of a truck per day is less than 9 hours
- The maximal waiting time is 10% of the total travel times
- The fuel consumption of follower trucks is reduced by 10%
- The platooning benefit is $\xi_i = 57.5$ SEK per follower per hour
- The cost of waiting is $\epsilon_i = 260$ SEK per hour.

Evaluation of the pricing rule

$R_{s,f} = \alpha P_f$



The profit of the third-party service provider

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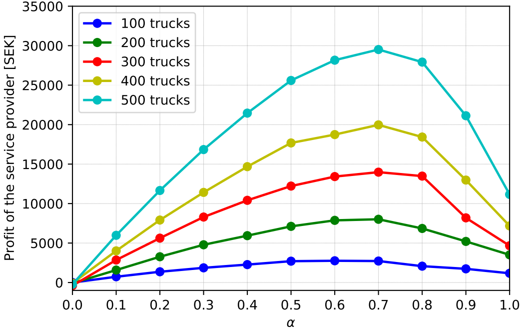

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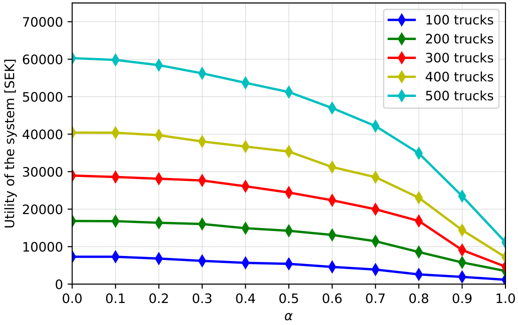

The utility of the platooning system

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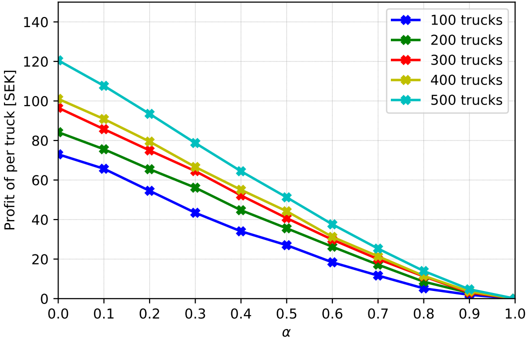

The average profit per truck

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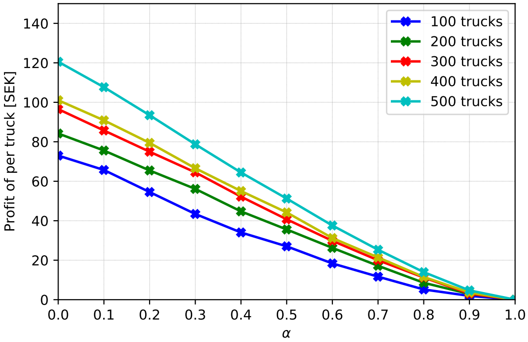

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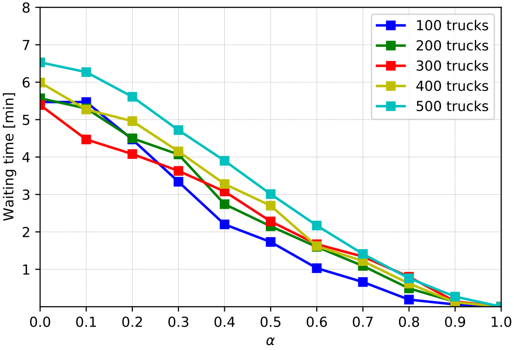

The average waiting time per truck

Conclusions

- We model a transportation system with a third-party service provider and propose a pricing rule for charging trucks that use the platoon coordination service.

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  - If the third-party service provider is in a monopoly position, it can get a considerable platooning profit by setting a high service fee.

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Email address: tingbai@kth.se