Velocity Optimization of Pure Electric Vehicles with Traffic Dynamics Consideration

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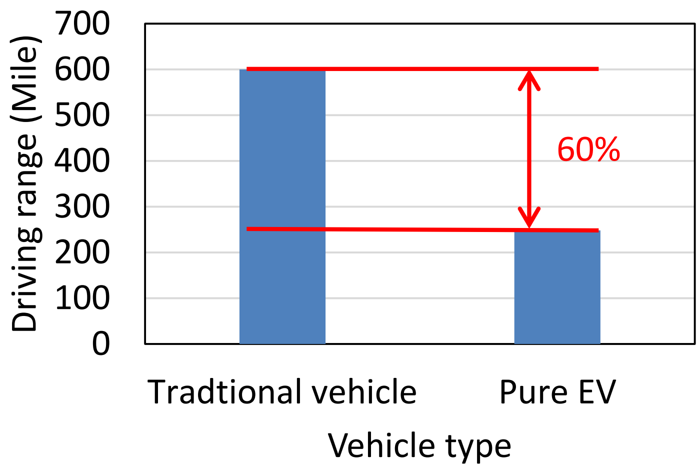
Outline

- Introduction
- System Design
- Performance Evaluation
- Conclusion

Introduction

Factors impeding wide electric vehicle application

- ❑ Short driving range

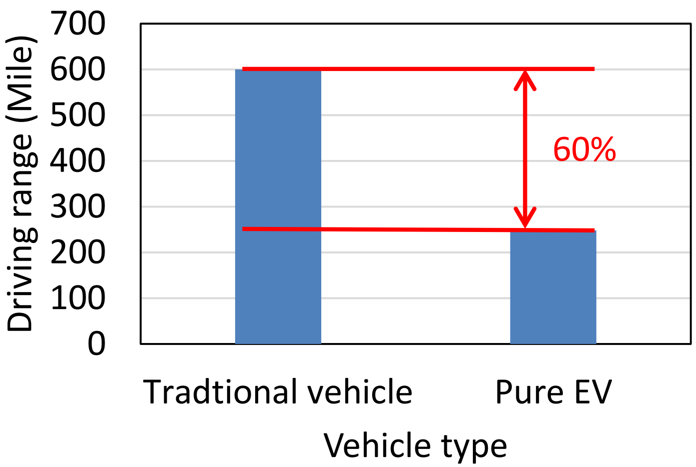


Driving range per battery charge or full fuel fill

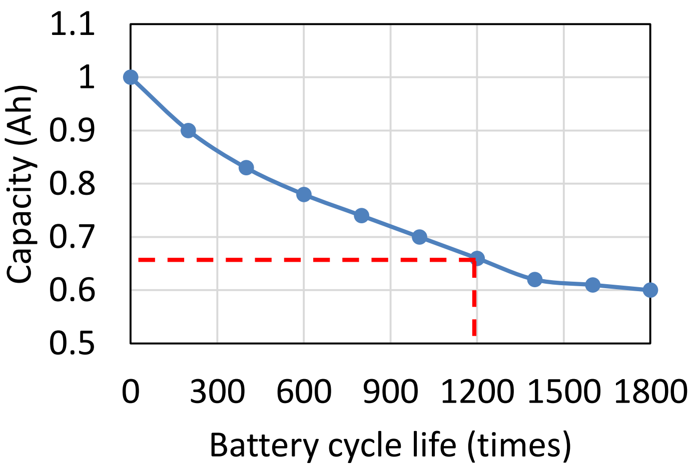
Introduction

Factors impeding wide electric vehicle application

- ❑ Short driving range
- ❑ Limited battery cycle life



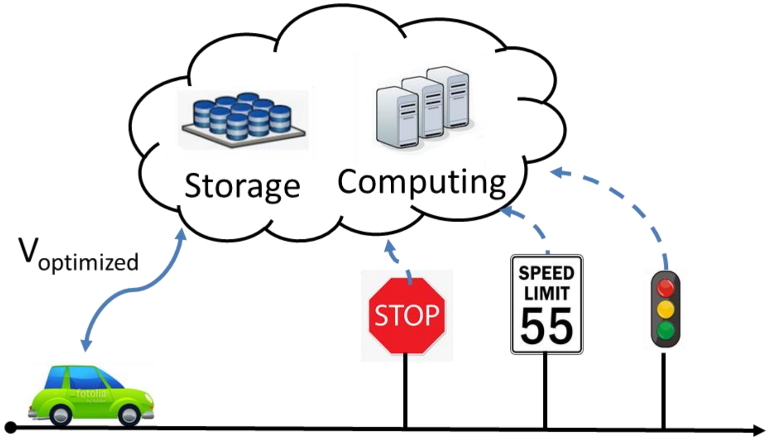
Driving range per battery charge or full fuel fill



Battery cycle life of lithium-ion battery

Introduction
Solution: Velocity optimization

- ❑ Consider constraints such as vehicle acceleration, speed limit, stop sign and traffic light on the road



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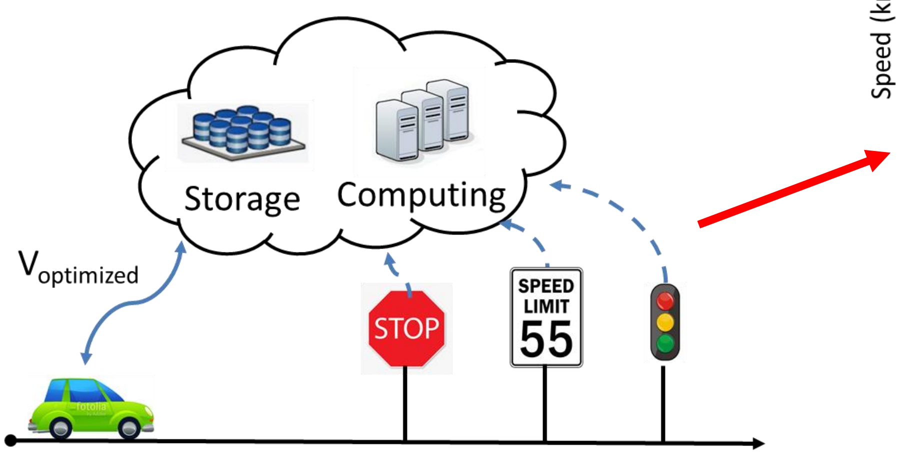
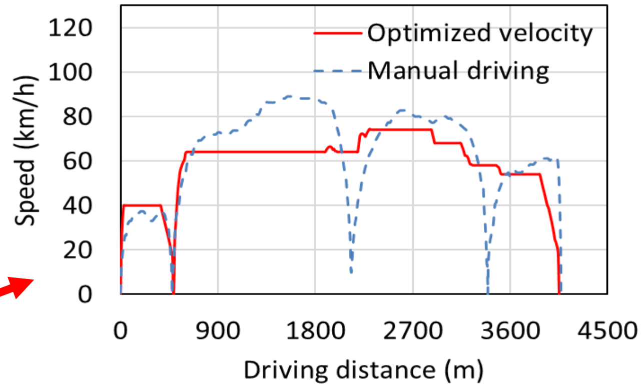
Introduction

Solution: Velocity optimization

- ❑ Consider constraints such as vehicle acceleration, speed limit, stop sign and traffic light on the road
- ❑ Optimize the velocity profile to reduce total energy consumption





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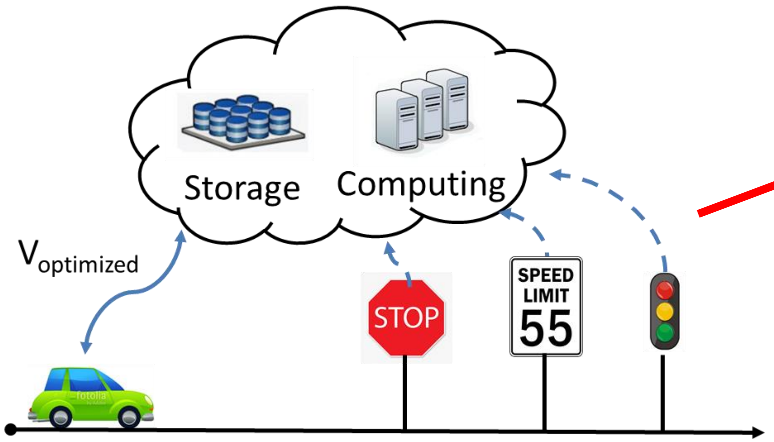

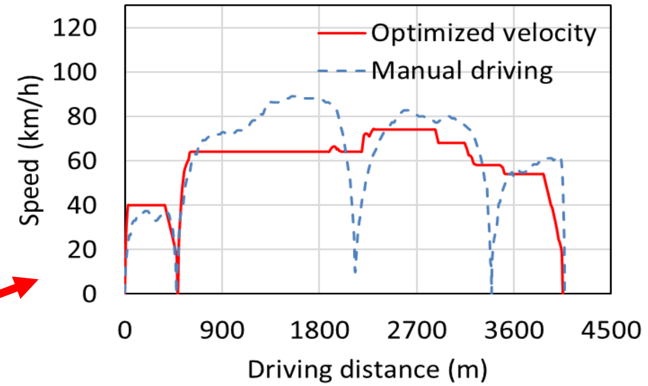

Energy consumption reduced by 20%

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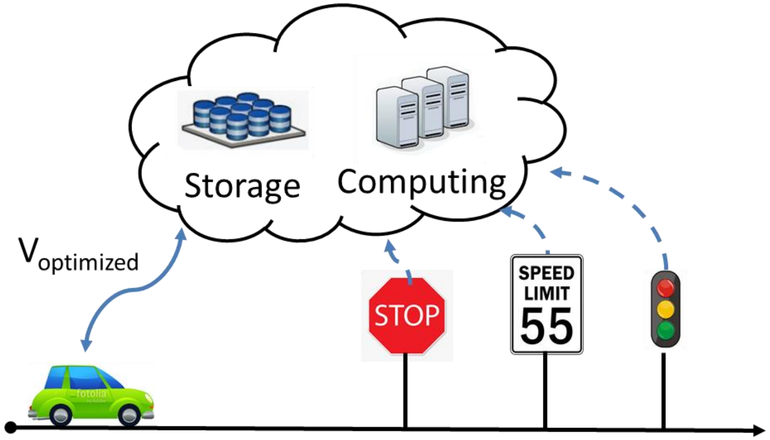
Introduction

Challenges of current velocity optimization methods

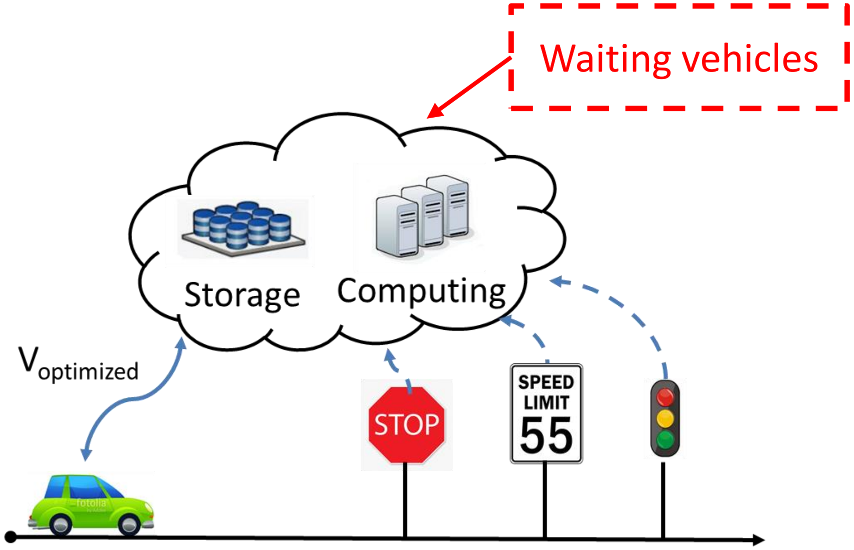
- How to estimate waiting vehicles in the traffic signal areas



Introduction

Challenges of current velocity optimization methods

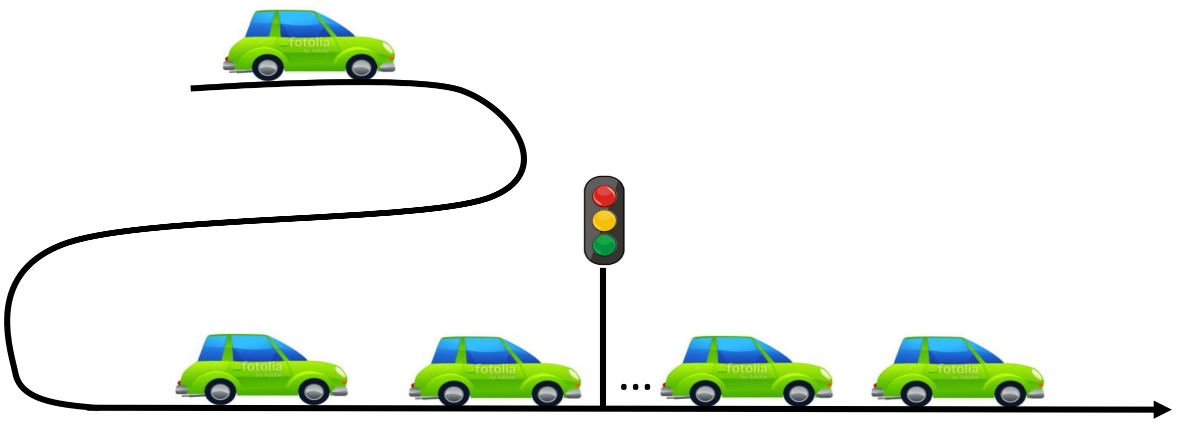
- ❑ How to estimate waiting vehicles in the traffic signal areas
- ❑ How to apply waiting vehicle information into velocity optimization



Introduction

Our method: DP-based velocity optimization system

- Propose vehicle movement (VM) model



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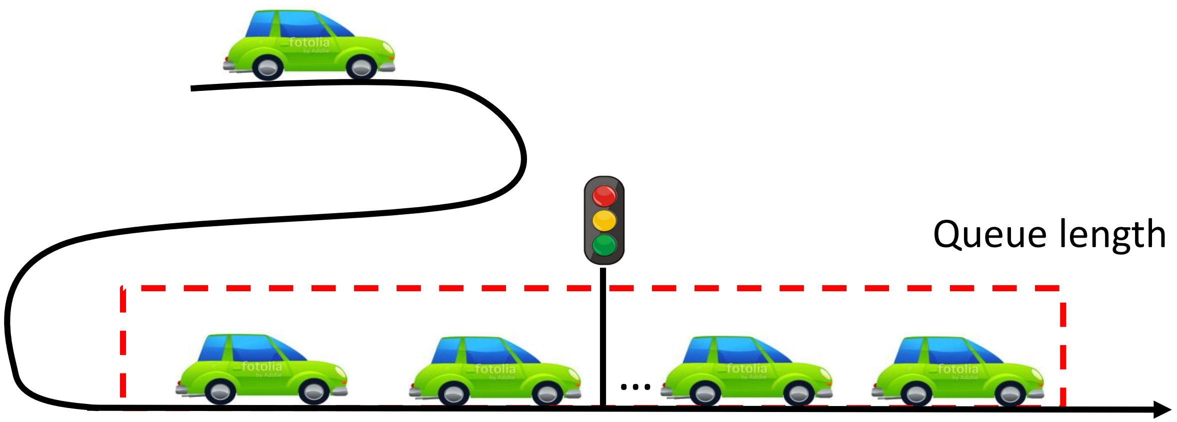
Our method: DP-based velocity optimization system

- ❑ Propose vehicle movement (VM) model
- ❑ Build queue length model



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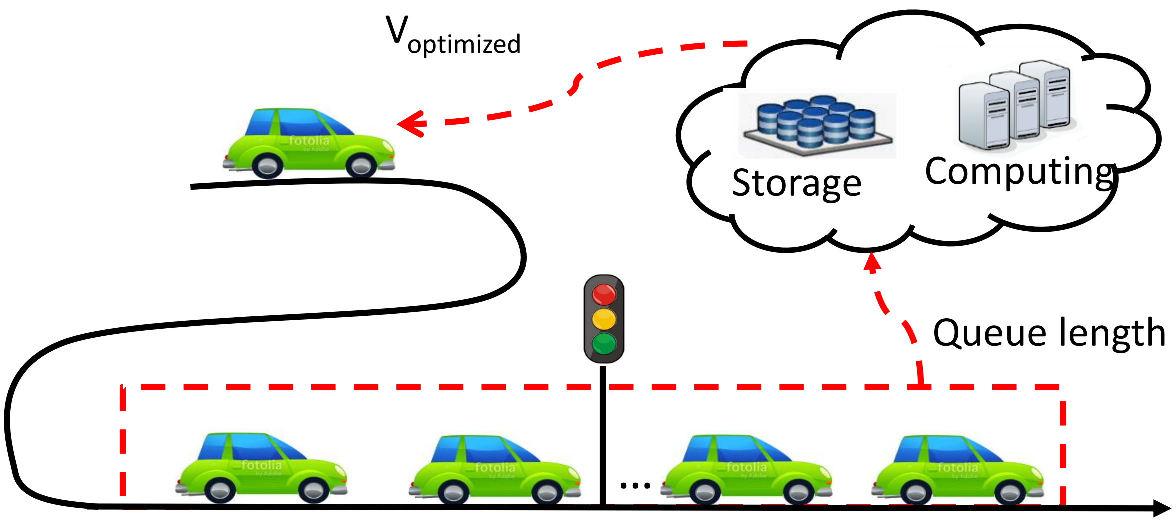
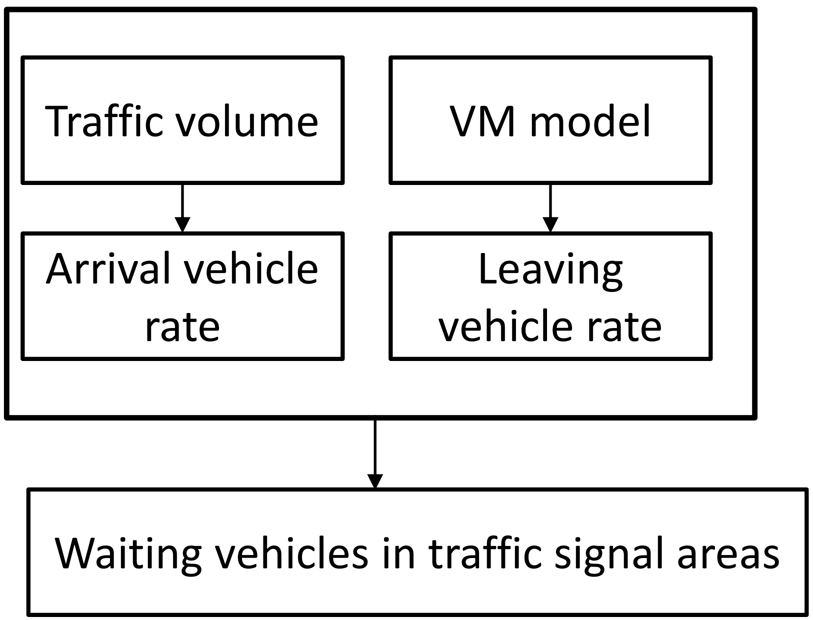
Our method: DP-based velocity optimization system

- Propose vehicle movement (VM) model
- Build queue length model
- Apply vehicle queue length into DP (Dynamic Programming) algorithm



System Design
Overview

Queue length model



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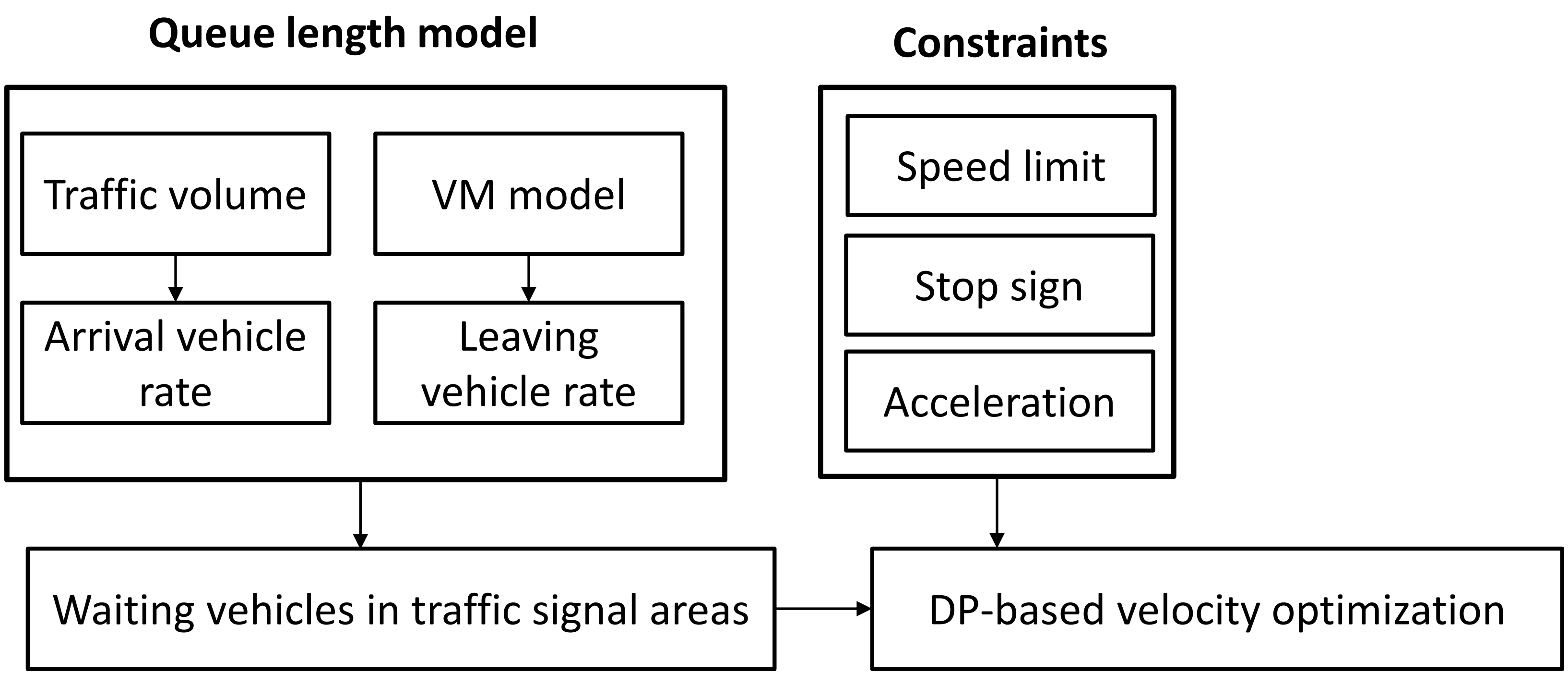

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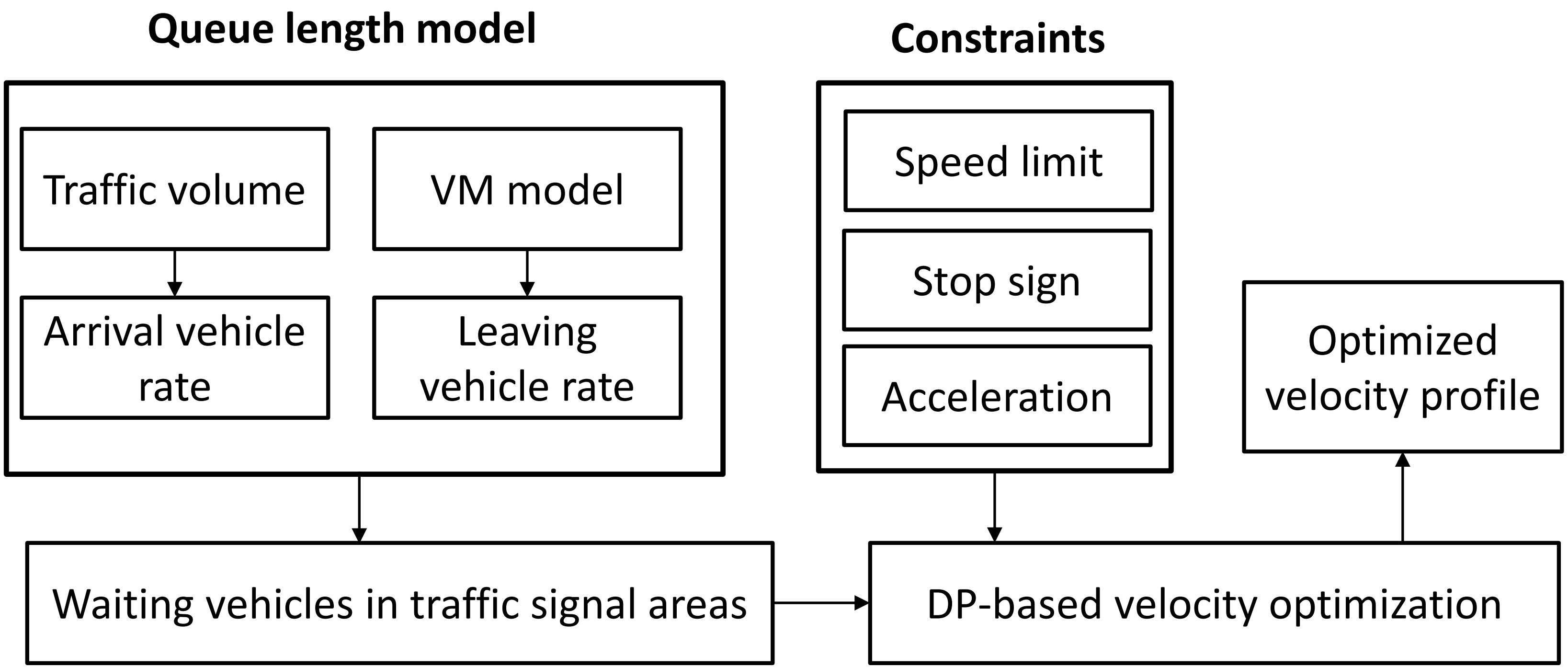
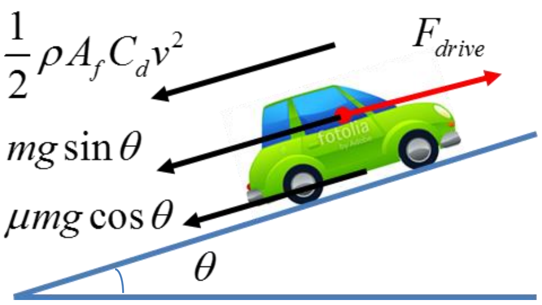


System Design
Energy consumption model of pure EVs

- Driving force:

$$F_{drive} = m\frac{dv}{dt} + \frac{1}{2}\rho A_f C_d v^2 + mg\sin\theta + \mu mg\cos\theta$$



Driving force of pure EV

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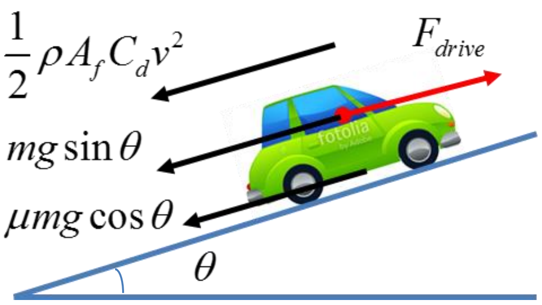
- Energy generated by the battery pack:

$$E = UQ\eta_1\eta_2$$



Driving force of pure EV

U - Battery pack voltage;
Q - Charge consumption;
η_1 - Battery transforming efficiency;
η_2 - Powertrain working efficiency;

System Design

Energy consumption model of pure EVs

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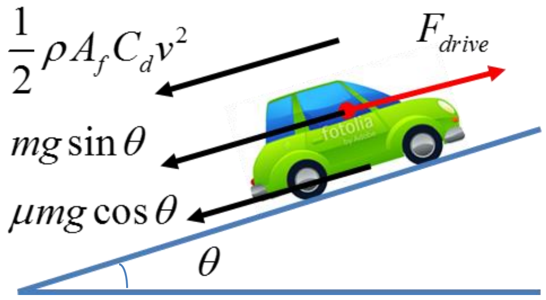

Driving force of pure EV

- Energy generated by the battery pack:

$$E = UQ\eta_1\eta_2$$

- Energy consumption per time:

$$\xi = \frac{F_{drive}v}{U\eta_1\eta_2}$$

U - Battery pack voltage;
Q - Charge consumption;
η_1 - Battery transforming efficiency;
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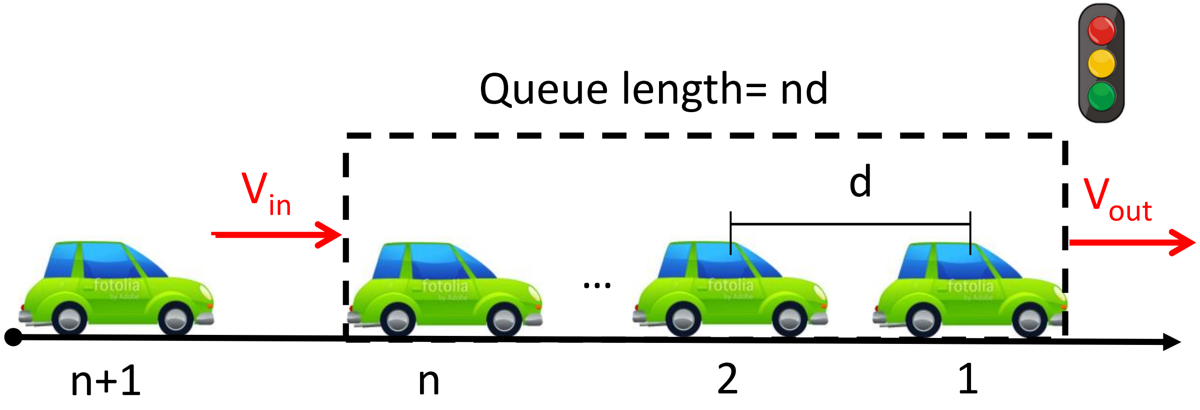
System Design

Traffic dynamics in traffic signal areas

Queue length model is built to estimate waiting vehicle numbers in traffic signal areas:

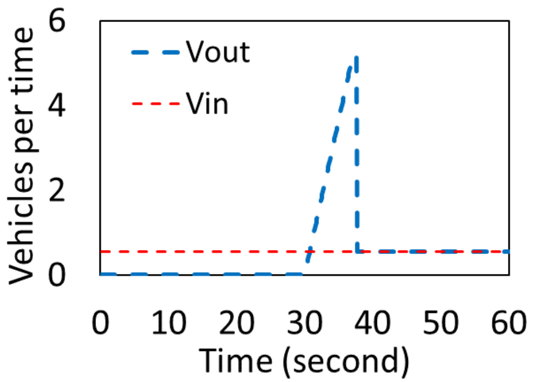
- Vehicle arrival rate V_{in}
- Vehicle leaving rate V_{out}



System Design

Traffic dynamics in traffic signal areas

- Arrival vehicle rate V_{in} : estimated based on real-time traffic volume

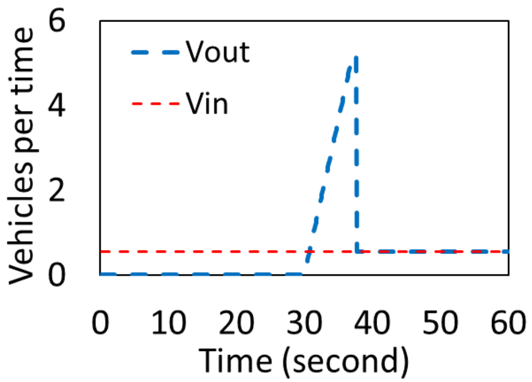


Arrival and leaving vehicle rates

System Design

Traffic dynamics in traffic signal areas

- Arrival vehicle rate V_{in} : estimated based on real-time traffic volume
- Vehicle leaving rate V_{out} : estimated with vehicle movement model

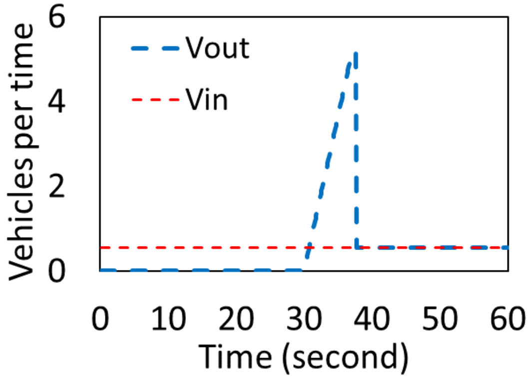


Arrival and leaving vehicle rates

System Design

Traffic dynamics in traffic signal areas

- Arrival vehicle rate V_{in} : estimated based on real-time traffic volume
- Vehicle leaving rate V_{out} : estimated with vehicle movement model
- Queue length L_q: calculated with V_{in} and V_{out}



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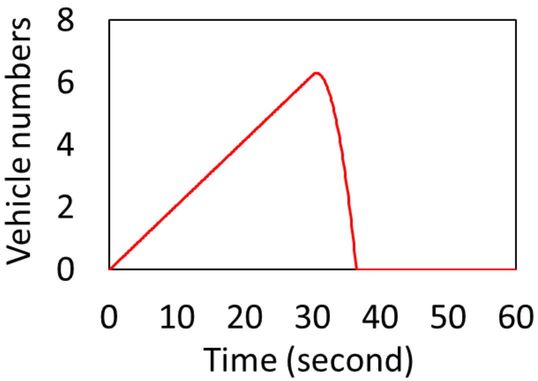

Waiting vehicle numbers in one traffic light period of US-25 highway

System Design

Traffic dynamics in traffic signal areas

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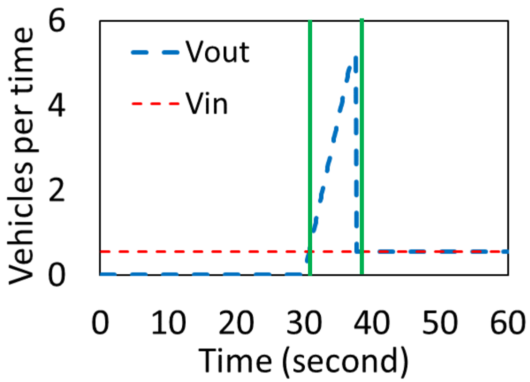

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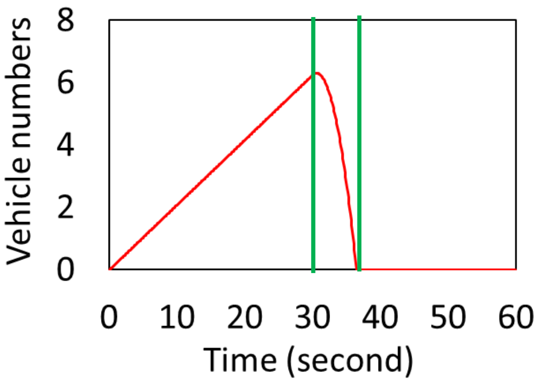

Waiting vehicle numbers in one traffic light period of US-25 highway

Experiment
Simulation settings

1. Vehicle parameters in energy consumption model

Parameters	m	A_f	C_d	μ	η_1	η_2
Values	1300 kg	1.97 m^2	0.33	0.018	0.9	0.97

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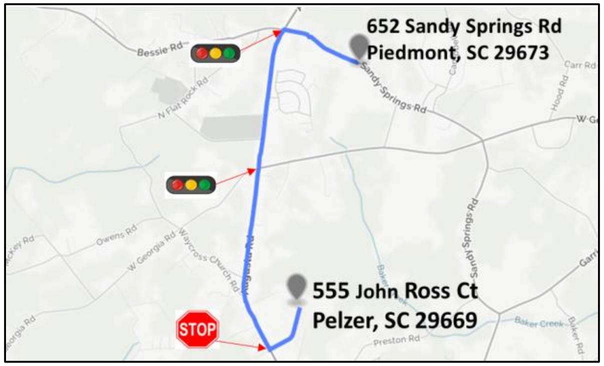
2. Experiment road segment on US-25 highway

- ❑ Total 4050 m long
- ❑ One stop sign
- ❑ Two traffic signals
- ❑ speed limit - 65 mile/hour



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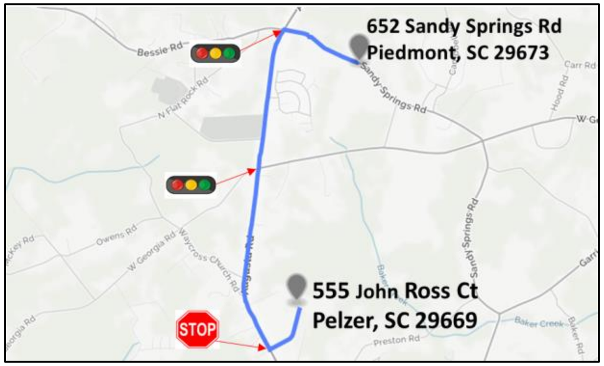


3. Velocity optimization results are verified in SUMO environment

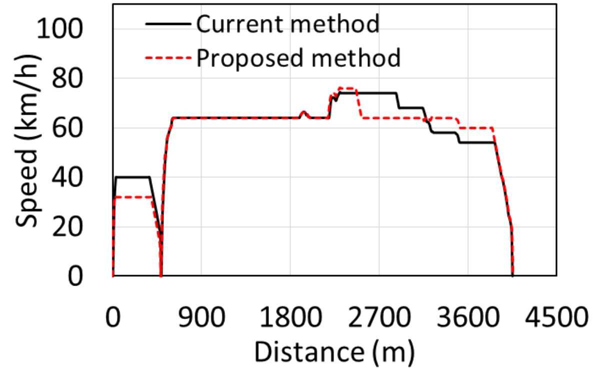
Experiment

Velocity optimization

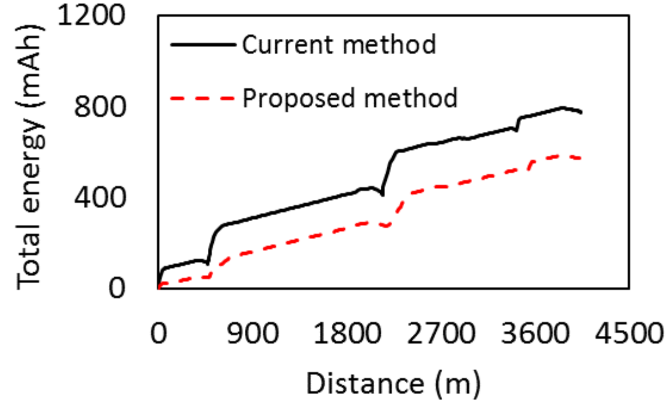
Metric: Total energy consumption during the trip

Observation: Reduces by **8.4%** energy compared with current method in the experiment

Reason: Enables EVs to immediately pass through traffic lights without meeting waiting vehicles



Velocity optimization comparisons



Consumed energy comparisons

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Conclusion

1. We proposed a velocity optimization system for EVs with considering queue length in traffic signal areas
2. We conducted velocity optimization simulation study with SUMO to verify our method

University of Virginia

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Future work

1. Consider the effect of road gradient on the proposed system
2. More practical experiments in different traffic conditions

Thank you!
Questions & Comments?

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