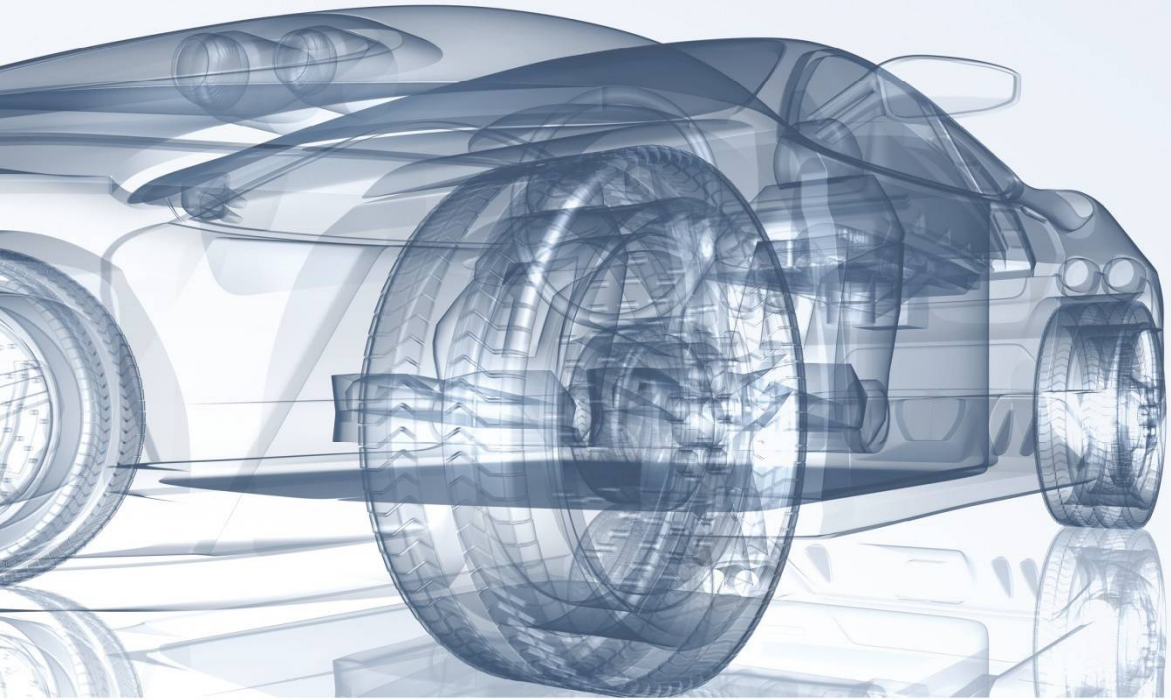
evs 30



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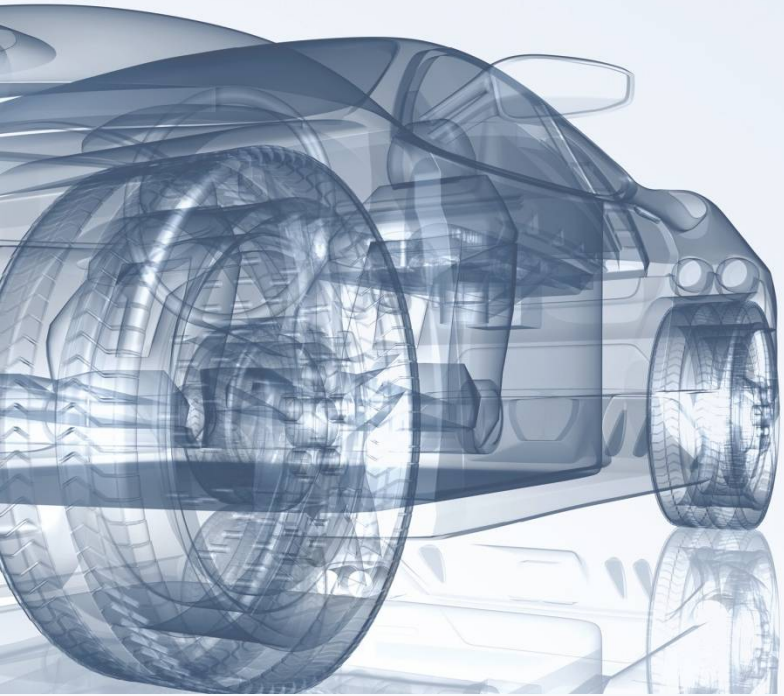


Route based energy management for plug in hybrid electric vehicles

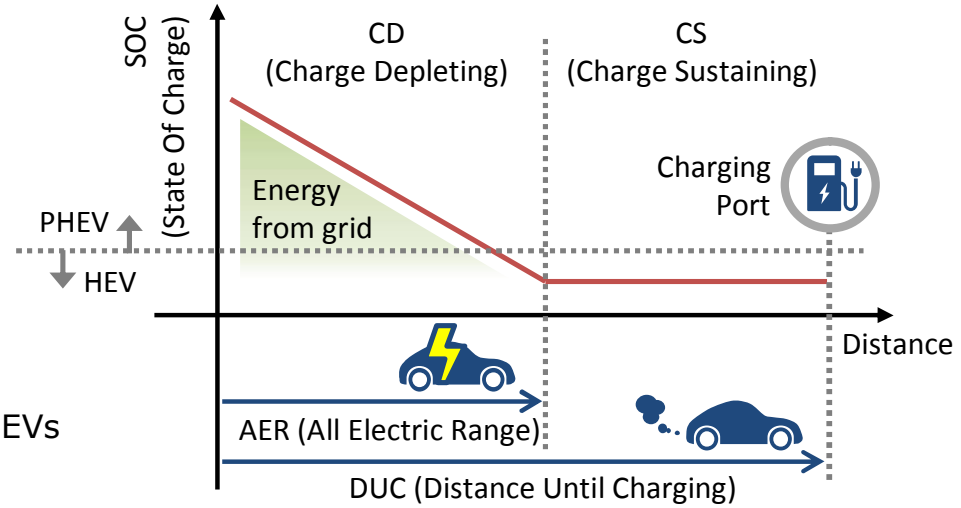
Joonyoung Park & Sungdeok Kim

Contents

- Conventional mode shifting strategy
- Route based mode shifting strategy
  - Acquiring route information
  - Mode shifting criterion
  - Geo-fencing technology
- Experiment
- Summary

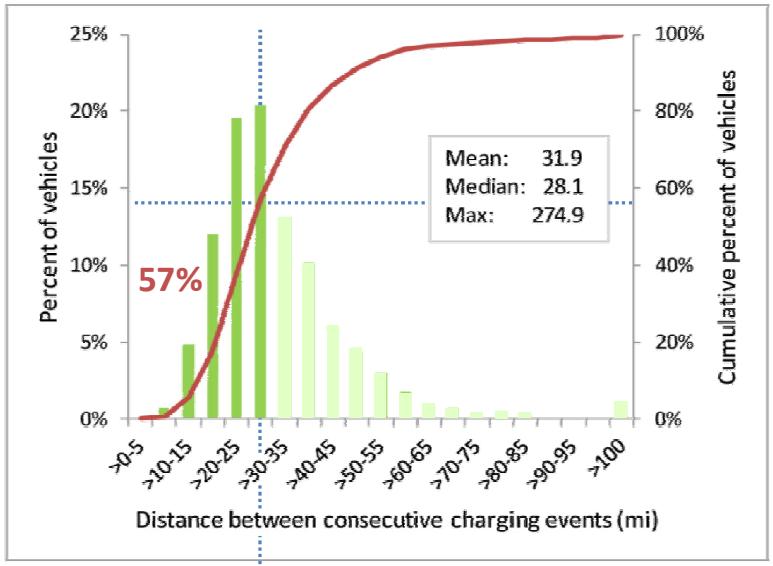
Conventional mode shifting strategy for PHEVs

- Perform static mode transition over AER mostly relying on SOC without consideration of energy efficiency
- Remain CD within AER without any fuel consumption like EVs (The electric components need to be designed to cover road load)



Conventional mode shifting of PHEVs

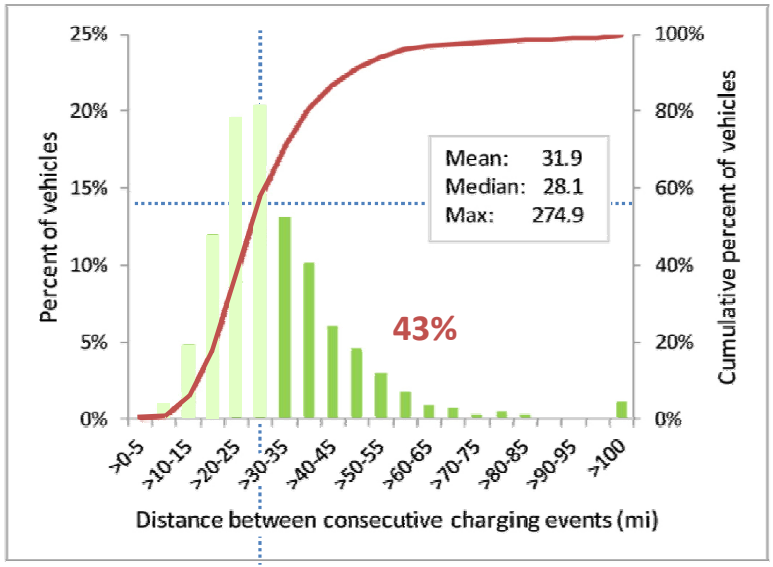
Driving pattern of PHEV users



Average DUC of PHEVs

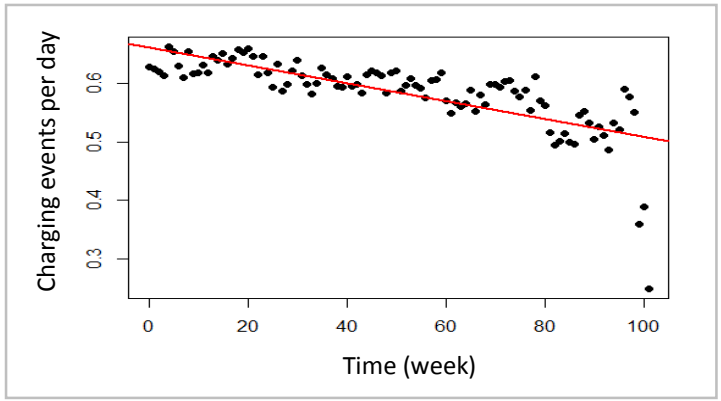
J. Smart, W. Powell, and S. Schey, Extended Range Electric Vehicle Driving and Charging Behavior Observed Early in the EV Project, SAE2013-01-1441, Jan. 2013

Driving pattern of PHEV users



Average AER of popular PHEVs

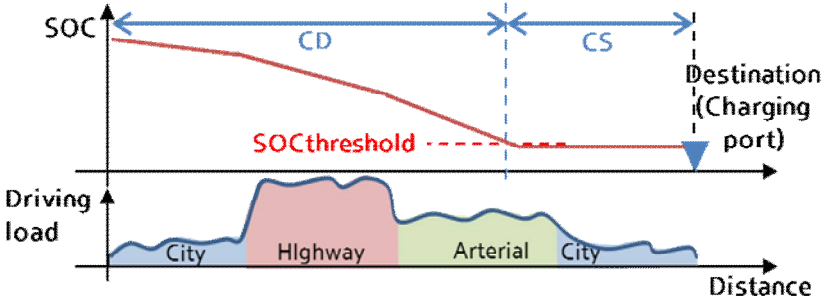
Average DUC of PHEVs



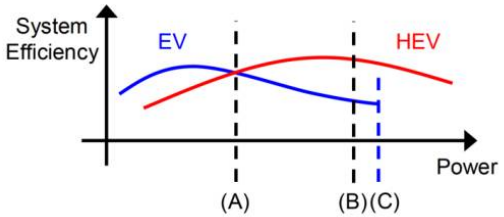
Changing of charging frequency

Limitations of the conventional strategy

- Energy efficiency
- User experience
- Pedestrian exposure to air pollution



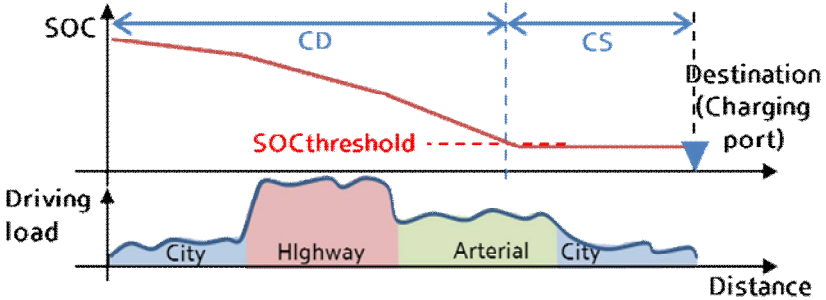
Conventional CD/CS shifting



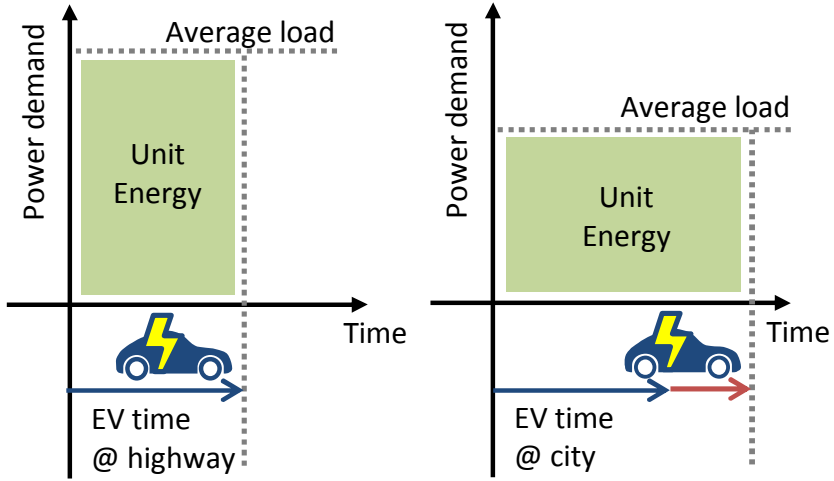
Energy efficiency of EV and HEV modes
engine on threshold for CS(A), CD(B)
and max. power of the motor(C)

Limitations of the conventional strategy

- Energy efficiency
- User experience : short EV time with wind & road noise
- Pedestrian exposure to air pollution



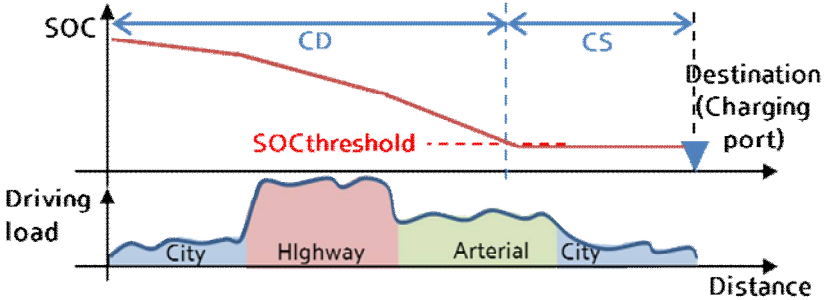
Conventional CD/CS shifting



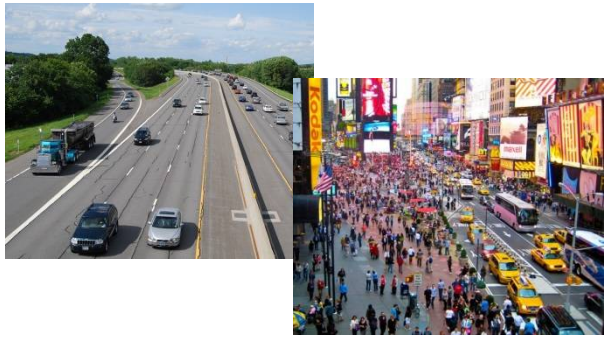
EV driving time comparison

Limitations of the conventional strategy

- Energy efficiency
- User experience
- Pedestrian exposure to air pollution



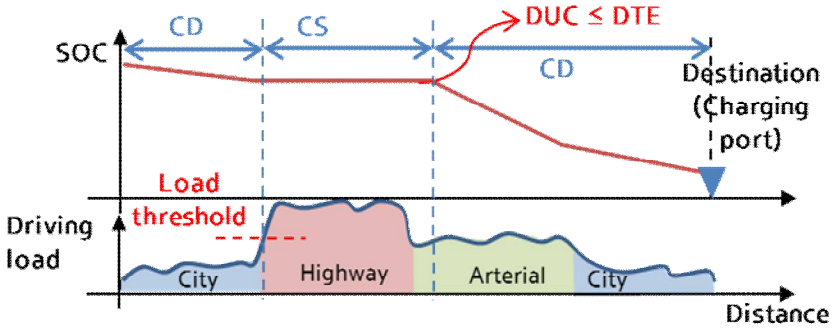
Conventional CD/CS shifting



Appropriate EV driving circumstance?

Route based mode shifting strategy

- Allocates CD and CS mode based on road load
- Shift from CD to CS considering energy efficiency when terminal destination is expected over AER (CS makes powertrain system more efficient under high load conditions)
- Improve fuel efficiency(FE) on real-world driving conditions, gain off-cycle credit, and provide appealing points for sales

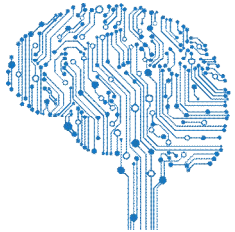


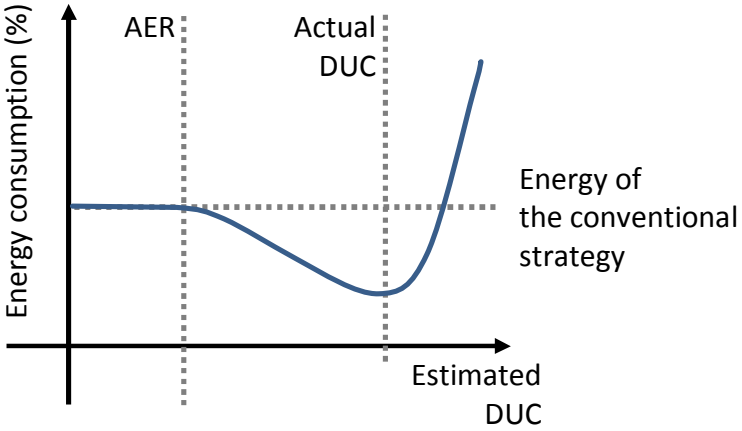
Route based CD/CS shifting

Acquiring route information

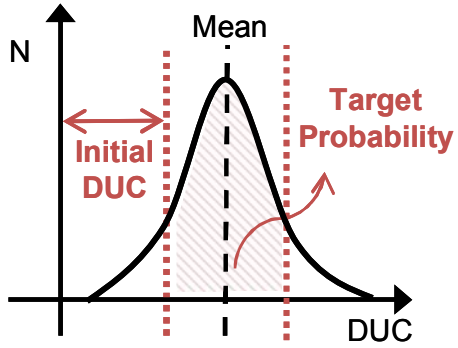
- Navigation systems
- Apps for charging plan
- Agorithm to learn driving behavior

→ However, the estimation error is inevitable





Impact of DUC error

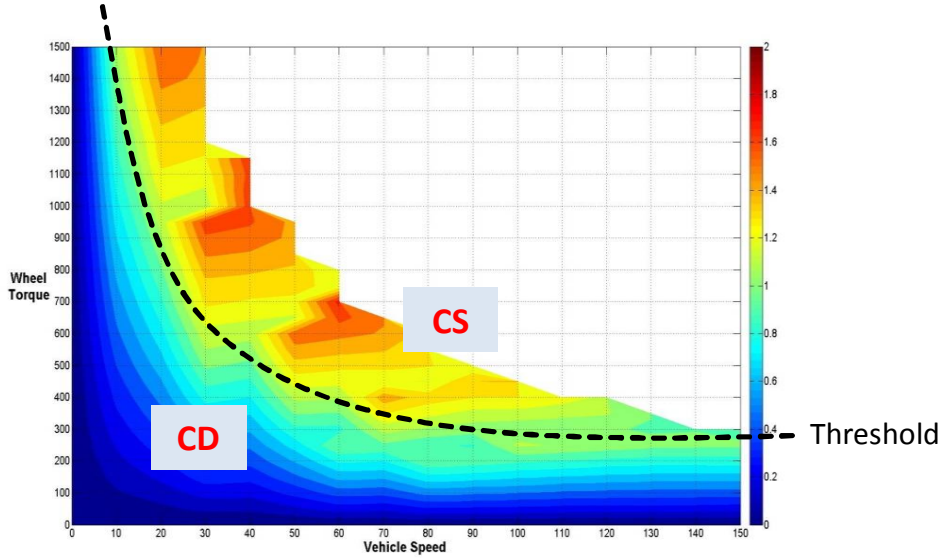


Drawing DUC from target probability

Mode shifting criterion

- Static threshold

  : can be set up by taking into account efficiency



Relative energy consumption ratio
for all possible driving condition

$$\text{Relative Energy Consumption Ratio} = \frac{\text{Energy consumption in CD}}{\text{Energy consumtion in CS}}$$

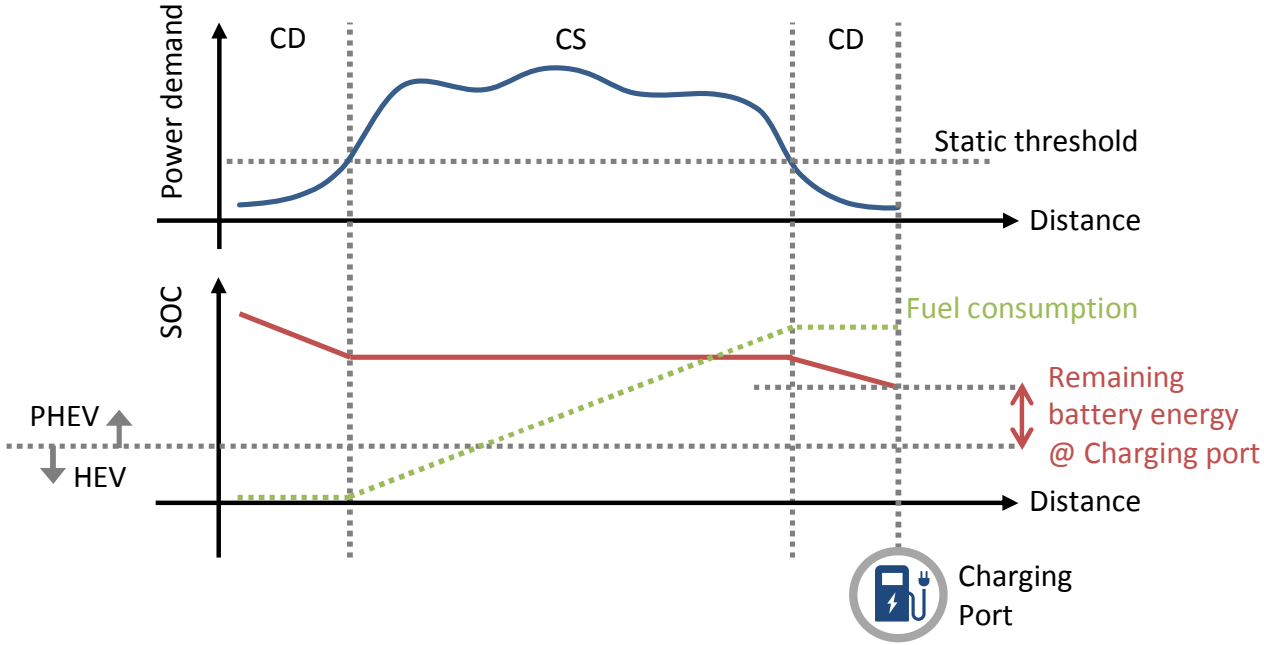
$$= \frac{\text{Battery Energy}}{(\text{Battery Energy} + \lambda \times \text{Fuel Energy})}$$

where, λ : Equivalent factor

Mode shifting criterion

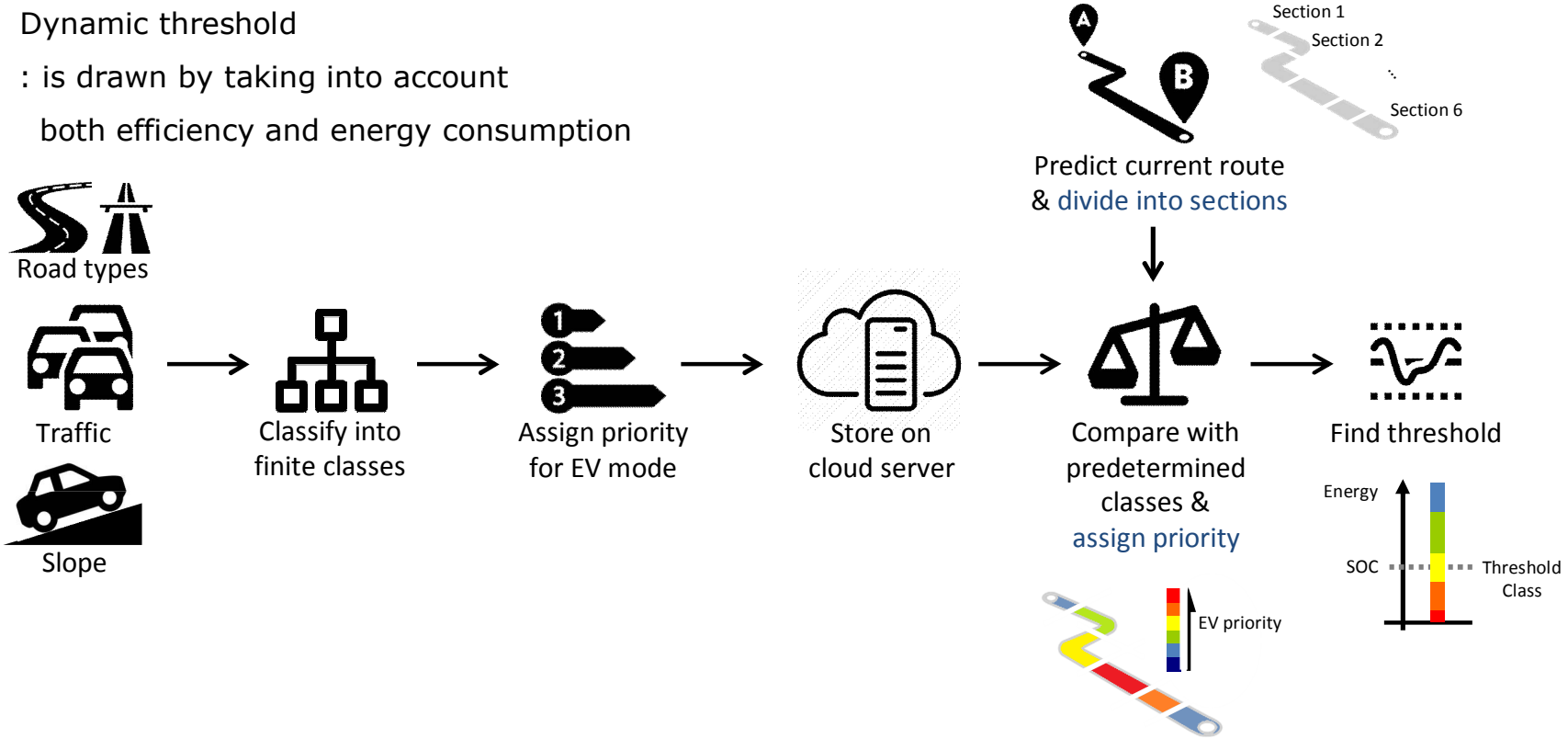
- Static threshold

  : does not ensure the minmum energy consumption for the given route



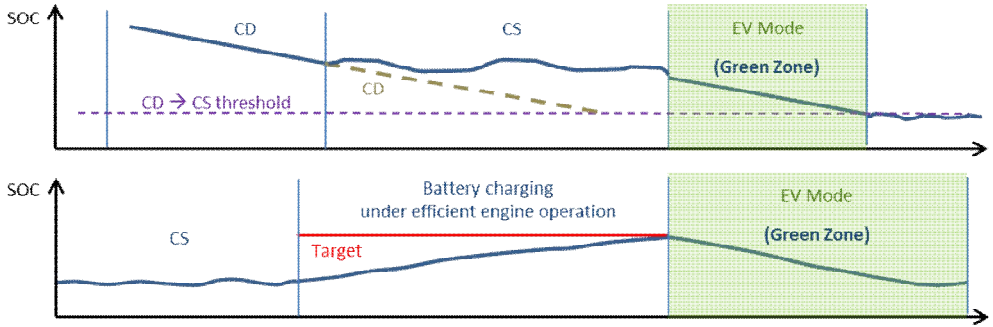
Mode shifting criterion

- Dynamic threshold
  : is drawn by taking into account
  both efficiency and energy consumption



Utilizing geo-fencing technology, Green-zone drive

- Allocates CD mode on the Green zones along the given route to protect pedestrians from pollution
- The Green zone can be indentified by
  - Government enforcement
  - Geographical characteristics
  - Bid data (level of emission and pedestrian activity)
- Charging phase may need to be conducted in advance to ensure EV drive on the Green zone

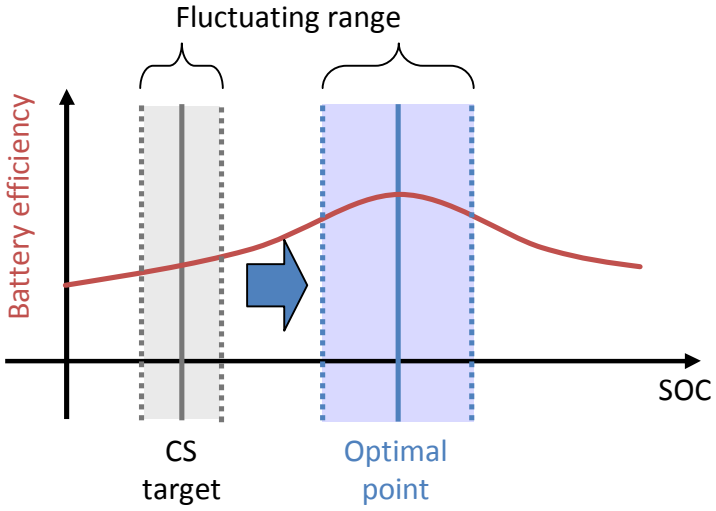


Allocating CD & CS mode for GZ

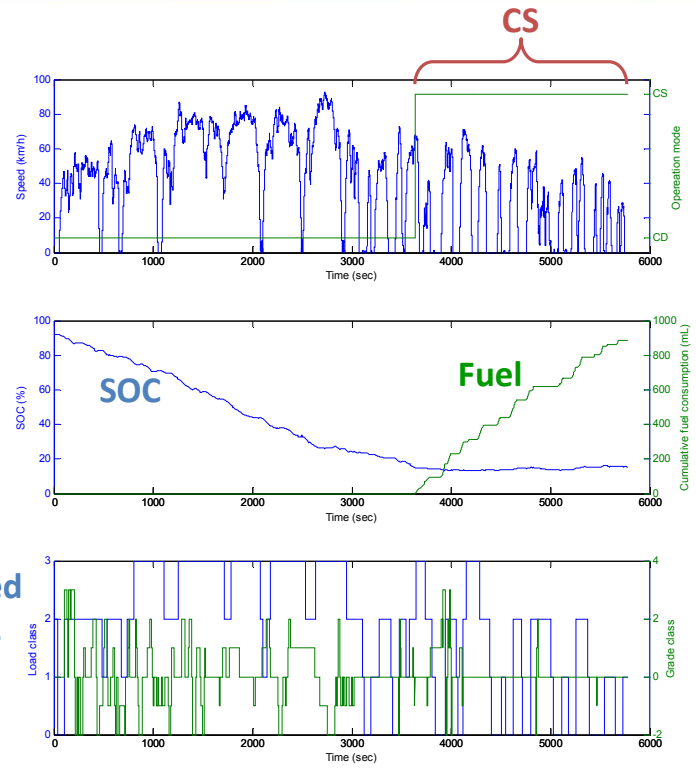
Conducting charge control for GZ

Battery energy management for extended trip

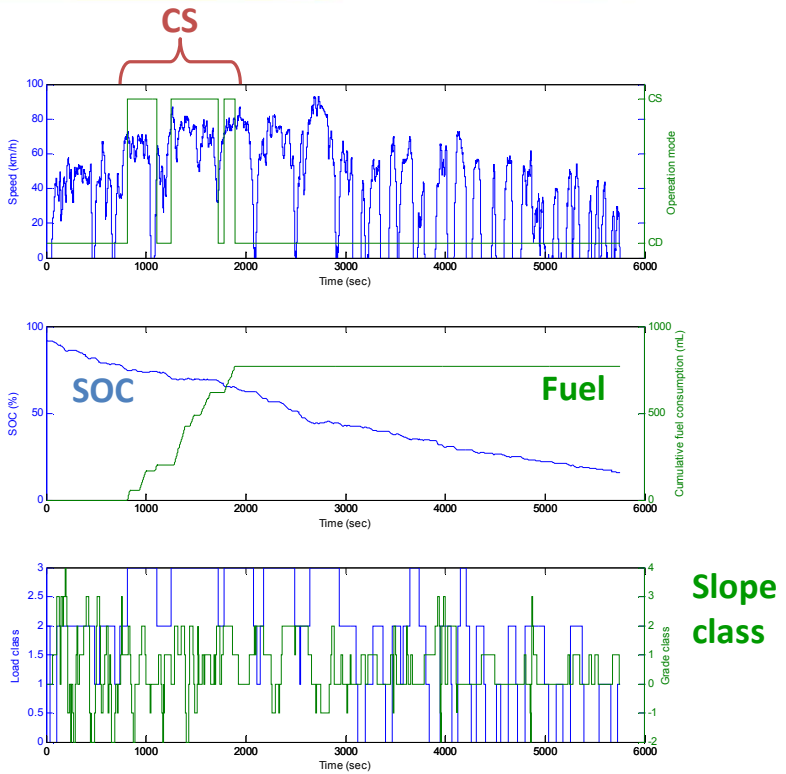
- Battery SOC remains near depleted range in the CS mode
- If the CS trip is long, the SOC range is inappropriate in terms of efficiency and SOH
- Increasing the target and extending fluctuating range can improve battery operating efficiency and load leveling capability



Experiment



Conventional SOC based strategy



Route based strategy

Summary

- The route based energy management for PHEVs has advantages in improving energy efficiency, enhancing user experience and protecting pedestrians from pollution

- The shifting criterion between CD and CS mode needs to be set up with careful consideration of uncertainty of route information

- The strategy can enhance its potential by implementing advanced functionalities such as the geo-fencing technology