Towards Cooperative Vehicle and Intersection Control: An Energy Efficient Approach

Presented by: Yunfei Hou

State University of New York at Buffalo, USA

Future Intersection in Action

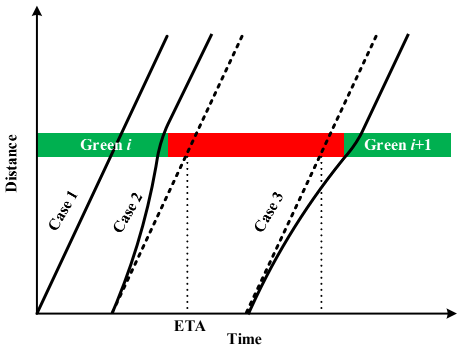
University at Buffalo
The State University of New York

Credits: Black Sheep Productions

Related works

University at Buffalo
The State University of New York

- Control on ***either*** Infrastructure or Vehicle side
  - Signal Control: Adaptive Traffic Signal
    - Actuated Signal
    - SCATS, SCOOT, RHODES
    - Detecting vehicles through V2I communications
  - Vehicle Speed Control: Eco-Signal & Eco-Driving



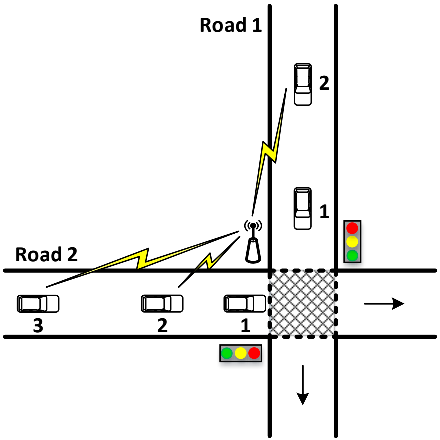
Distance-Time Diagram of Eco-Driving

Cooperative Vehicle and Intersection Control (CVIC)

University at Buffalo
The State University of New York

- Our idea: ***Jointly*** control both the traffic signal and vehicles

- Our Model
  - An isolated intersection
  - Vehicles can communicate with the intersection controller (V2I)
  - Vehicles do not overtake others near the intersection
  - Traffic consists of trucks and passenger vehicles



A simple intersection

A two-level approach

University at Buffalo
The State University of New York

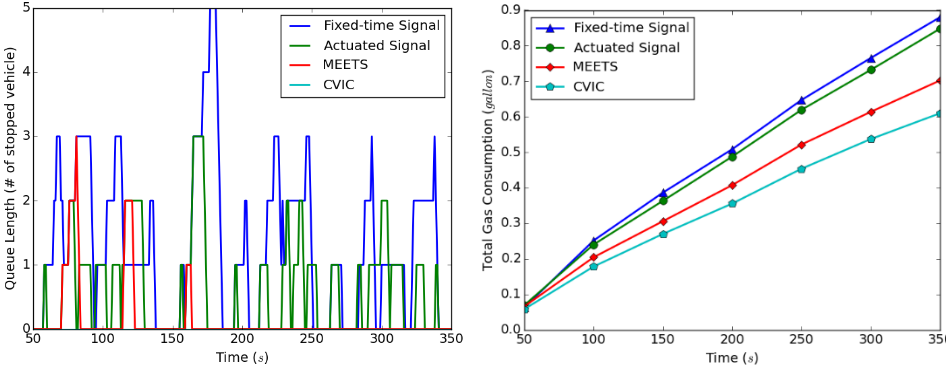
1. Intersection control:
   - Given:
     - Expected arrival time of each vehicle, vehicle type
   - Find:
     - Traffic signal timing (explicitly schedule each vehicle)
   - Objective:
     - Minimize energy consumption for all vehicles (global level)
2. Vehicle speed control:
   - Given:
     - Scheduled time to pass the intersection, the leading vehicle's positions
   - Find:
     - Speed plan
   - Objective:
     - Minimize energy consumption for a vehicle (local level)

Solution

- CVIC = MEETS + ECC
- Multi-modal Energy Efficient Traffic Signal (MEETS) Control Strategy
  - Energy loss for a vehicle comes from:
    - 1) the loss of kinetic energy if the vehicle has to stop at the intersection
    - 2) engine idling during the time of waiting
  - A dynamic programming approach to minimize total energy loss for all vehicles
- Eco-Cruise Control (ECC) for Speed Planning
  - Keep track of the reference speed, and avoid colliding with the leading vehicle by Model Predictive Control
  - Minimize the mechanical work that has been used for braking

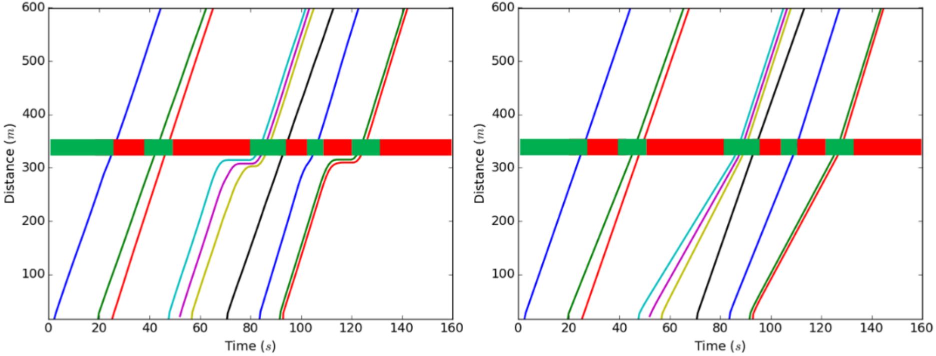
Results

University at Buffalo
The State University of New York



Results in the low traffic flow scenario (300/400 veh/ln/hr)
with all passenger vehicles
Left: Queue length of different strategies over time
Right: Total gas consumptions of different strategies over time

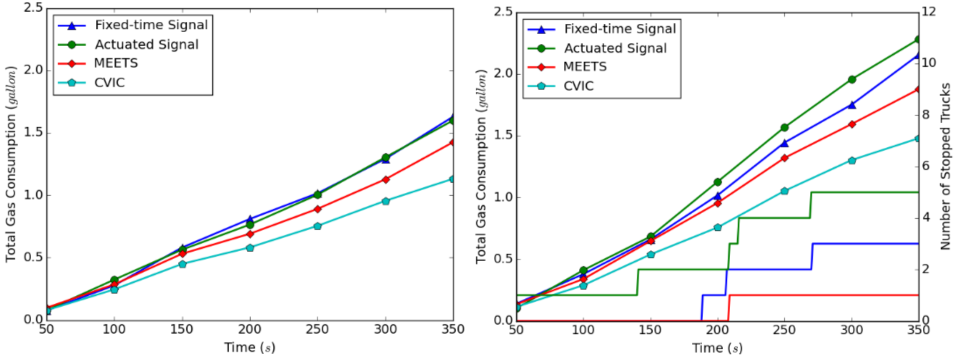
Results



Comparison of the driving behavior of 10 vehicles
Left: Vehicle traces without ECC controller
Right: Vehicle traces with ECC

Results

University at Buffalo
The State University of New York



Results in the high traffic flow scenario (600/800 veh/ln/hr)
Left: Total energy consumptions of different strategies with all passenger vehicles
Right: Total energy consumptions of different strategies with 5% heavy-duty trucks

Future Energy Projections

University at Buffalo
The State University of New York

- Parameter settings:

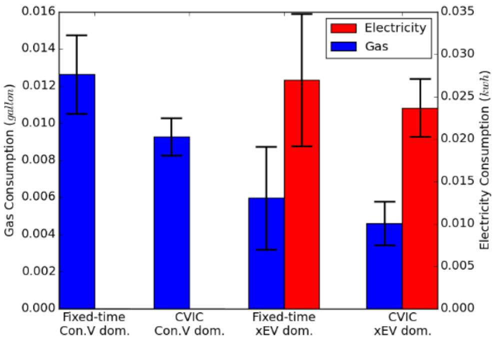
	HEV	EV	Con.V
Con.V dominant	0	0	100%
xEV dominant	37.3 %	39.6%	23.1%

Projected Vehicle Composition[1,2]

[1] Ref: "Vehicle Technologies Program Government Performance and Results Act (GPRA) Report for Fiscal Year 2015" Argonne National Laboratory

[2] Assumption on PHEV: 2/3 time works as EV, 1/3 time as HEV

- Result:

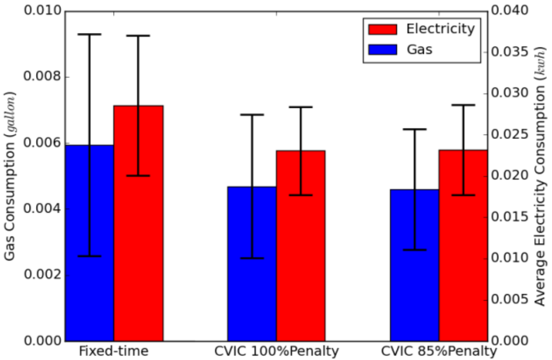


Average and standard deviation of energy consumption per vehicle in the low traffic flow scenario (300/400 veh/ln/hr)

Sensitivity tests

University at Buffalo
The State University of New York

- How would different penalty factors on stopping xEVs vs. Con.Vs affect the result?
- The difference is negligible in our test, because:
  - With CVIC, not many vehicles need to be stopped
  - The projected traffic consists mainly of advanced vehicles (77% are EV or HEV)



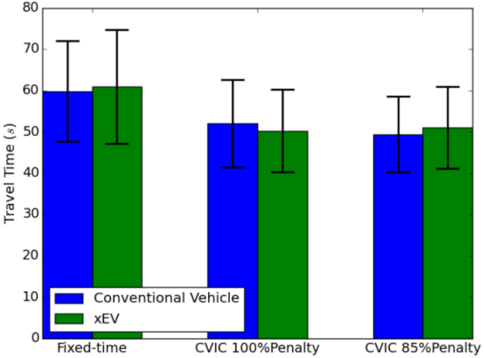
Average and standard deviation of energy consumption in the high traffic flow scenario (600/800 veh/ln/hr)

Sensitivity tests

University at Buffalo
The State University of New York

- Will the CVIC system with reduced penalty for stopping xEVs cause a longer delay for those vehicles?

- For similar reasons, the average travel time is very close
  - Under the scenarios investigated, CVIC will not increase the travel time for advanced vehicles



Average and standard deviation of travel time in the high traffic flow scenario (600/800 veh/ln/hr)

Limitations

University at Buffalo
The State University of New York

- Current CVIC design will not suggest a vehicle to speed up
  - For eco-driving applications, it is possible for a vehicle to avoid stopping by speed-up before signal turns red
- Speed plan can be more energy efficient
  - Design the speed plan is to solve an optimal control problem (not MPC), but it requires an analytic model on fuel consumption

Acknowledgement

University at Buffalo
The State University of New York

- University at Buffalo
  - Slaheldeen M. S. Seliman
  - Enshu Wang
  - Chunming Qiao
  - Qing He
- National Renewable Energy Laboratory
  - Jeffrey Gonder
  - Eric Wood
  - Yuche Chen
  - Stanley Young
- Funding Source
  - National Renewable Energy Laboratory

University at Buffalo
The State University of New York

Thank you!

Q&A