High-Performance Computing (HPC) Enabled Computation of Demand Models at Scale to Predict the Energy Impacts of Emerging Mobility Solutions

Project ID # eems042

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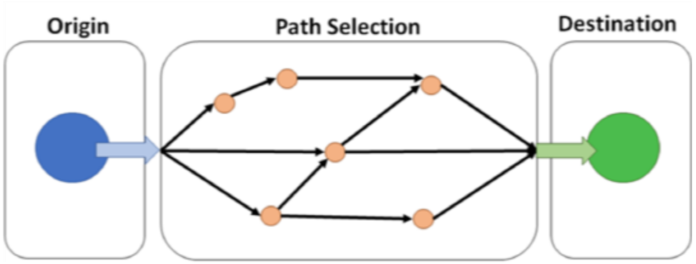
OVERVIEW

Timeline

- Project Start: April 2018
- Project End: October 2019
- 5% complete

Budget

- Total project funding
- $250K/ 1 year



Barriers

- Complexity of urban-scale integrated transportation networks are too large to model in reasonable compute time. With traffic assignment approach, routing accounts for 95% of compute.
- Traffic assignment has traditionally focused only on travel time, not energy use.
- The impact of information aware routing is unknown, yet is a key part of current urban scale mobility dynamics.

Partners

- Connected Corridor, UCB
- CalTrans, DOT
- LA Metro

RELEVANCE

- **Supporting the EEMS strategic goal to develop new tools, techniques, and core capabilities to understand and identify the most important levers to improve the energy productivity of future integrated mobility systems**
  - Improve urban-scale energy modeling of integrated transportation network behavior and associated impact of new vehicle technologies using traffic assignment methodologies
    - Automation of vehicles: How should they share information?
    - Use of navigation apps: How to address problems created by full-information user equilibrium?
    - Efficient response to network disturbances: What is the best mechanism for routing traffic efficiently? E.g. emergency management, accidents, events
  - Use high performance computing to address the compute load in the traffic assignment methodologies and model energy use in large-scale networks
    - Distribute computational load of routing algorithm across multiple nodes
    - Provide an energy cost function to evaluate energy impacts

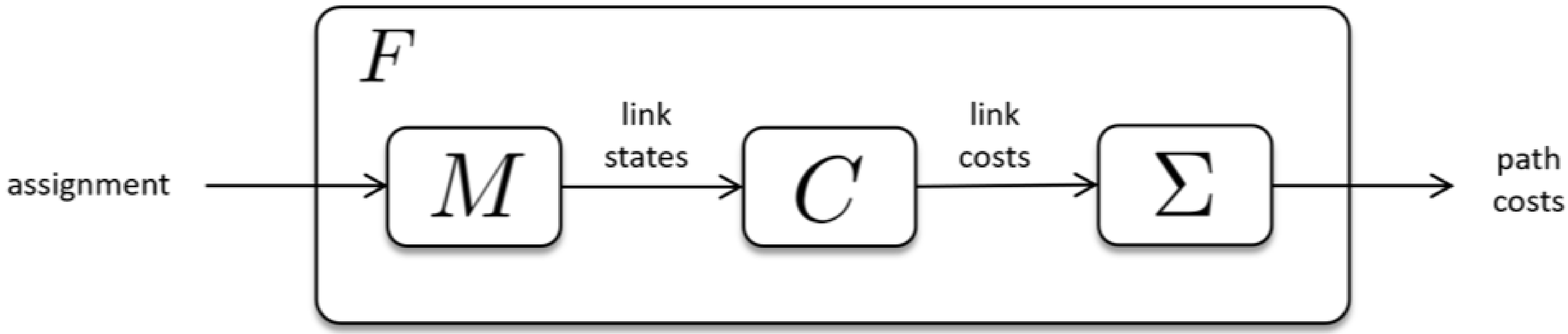
APPROACH: Traffic Assignment

General formulation:

An assignment h* is an equilibrium assignment if it satisfies:

$$(h - h^*) \cdot F(h^*) \geq 0, \quad \text{for all possible assignment } h$$

F is a mapping from assignment h to travel times on each path.



Note: Variational inequality formulation above can also handle dynamic traffic assignment (logical next step after project demonstrates on UE).

APPROACH: PROJECT GOALS

- Create standard process for ingesting map data at scale on distributed platforms and running different models and different demand data on th map with a unified format
- Implement at least two models at scale
  - one static (i.e. user equilibrium or game theoretic extension), and
  - one dynamic (i.e. dynamic traffic assignment capable of handling information aware routing)
- Implement a distributed solution algorithm for both the static user equilibrium formulation and the dynamic traffic assignment solution
- Benchmark data scenarios

COMPUTATIONAL APPROACH

Traffic Model

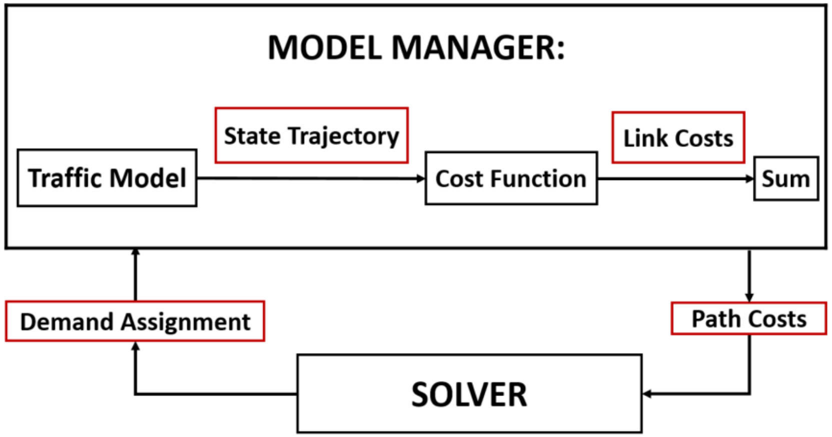
- OSM network with defined OD demand profile

Cost Function

- Travel Time
- Energy

Parallel Variational Inequality Solvers

- Frank-Wolfe
- Method of Successive Averages
- Extra Projection Method



Implementation: Python + MPI

ACCOMPLISHMENTS: Latency Function for Energy

Formulation of UE for energy

General latency function for time is BPR

$$t(\mathcal{Q}_a) = t_a^0 \left(1 + \alpha \cdot \left(\frac{\mathcal{Q}_a}{c_a}\right)^\beta\right)$$

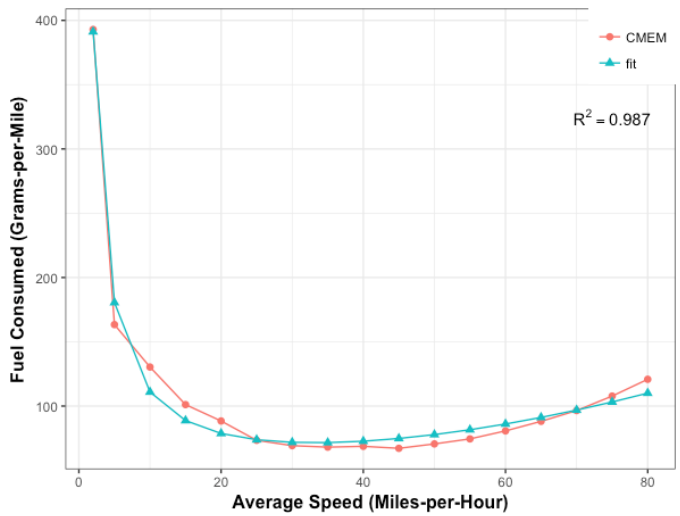
Empirical model of energy consumption*

$$\mathrm{EF}_{\mathrm{fuel}}(v_a) = A + \frac{B}{v_a} + C \cdot v_a^2$$

Latency function for energy/fuel

$$\mathcal{F}(\mathcal{Q}_a) = \mathcal{Q}_a \cdot L_a \cdot \left(A + \frac{C \cdot {v_a}^2}{\left(\alpha \cdot \left(\frac{\mathcal{Q}_a}{c_a}\right)^\beta + 1\right)^2} + \frac{B \cdot \left(\alpha \cdot \left(\frac{\mathcal{Q}_a}{c_a}\right)^\beta + 1\right)}{v_a} \right)$$

Comprehensive Modal Emission Model (CMEM)



$\mathcal{Q}_a$ flow on link a

c_a capacity of link a

L_a length of link a

t_a^0 free flow travel time of link a

v_a free flow speed of link a

$$v_a = \frac{L_a}{t_a^0}$$

$$\alpha = 0.15$$

$$\beta = 4$$

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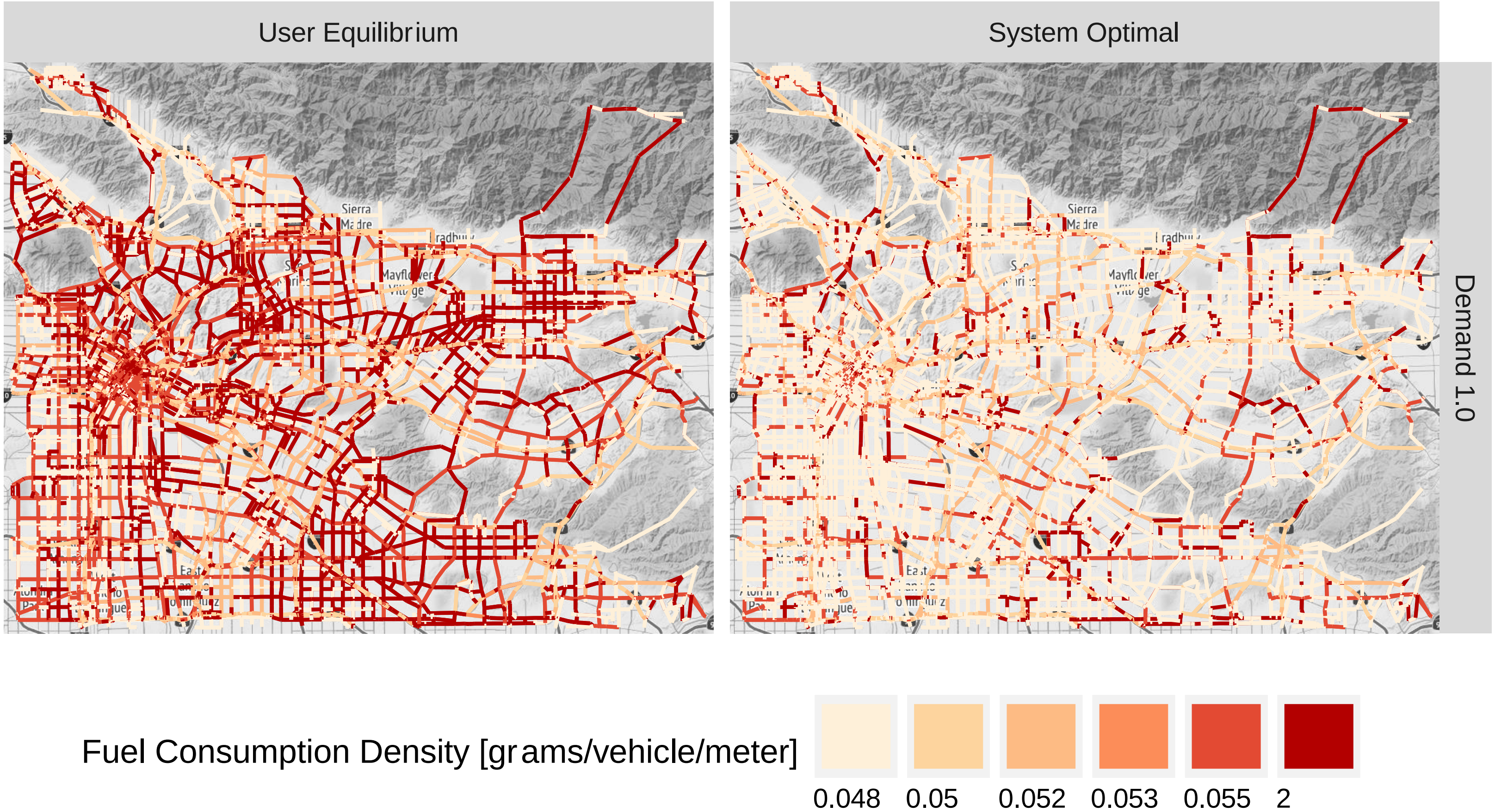
ACCOMPLISHMENTS

Fuel Consumption Density



COLLABORATION

Government and Academia : Infrastructure Data

Connected Corridor, University of California Berkeley
CalTrans, LA Metro

Industry : Mobility Data

GPS Data for Connected Corridor Region

PROPOSED FUTURE RESEARCH

- Extend models to represent multiple driver classes at large-scale: app-routed vs. non-routed drivers
  - Evaluate the energy impact of different driver routing profiles (September 2018)

- Parallel algorithms to solve dynamic traffic assignment problems
  - Extend current solvers to the dynamic traffic assignment problem where the assignment accounts for real-time congestion patterns (April 2019)

- Dynamic traffic assignment under various information patterns
  - Instantaneous travel time (with/without delays)
  - Historical travel time forecast
  - Partial or flawed information.

Any proposed future work is subject to change based on funding levels.

SUMMARY

- UE problems are used as a demonstration benchmark for the framework provided by the project, i.e. the ability to solve convex programs at scale by decentralization.
- The framework built is generic and applies to time varying problems (dynamic traffic assignment in particular).
- The framework has been applied to energy formulations of routing.
- In the future, it will also include the ability to model various information patterns in routing (for both travel time and energy).

Technical Back-Up Slides

SPEED FUEL RELATIONS

Empirical models have been developed to relate emissions with average speeds for different vehicle types/stocks.

A formula is then fit to the model data to estimate the fuel consumption as a function of the average vehicle speed.