Optimal Sensor Placement for Traffic Data Collection: Case Studies and Challenges

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The Problem

Traffic Data Collection Techniques

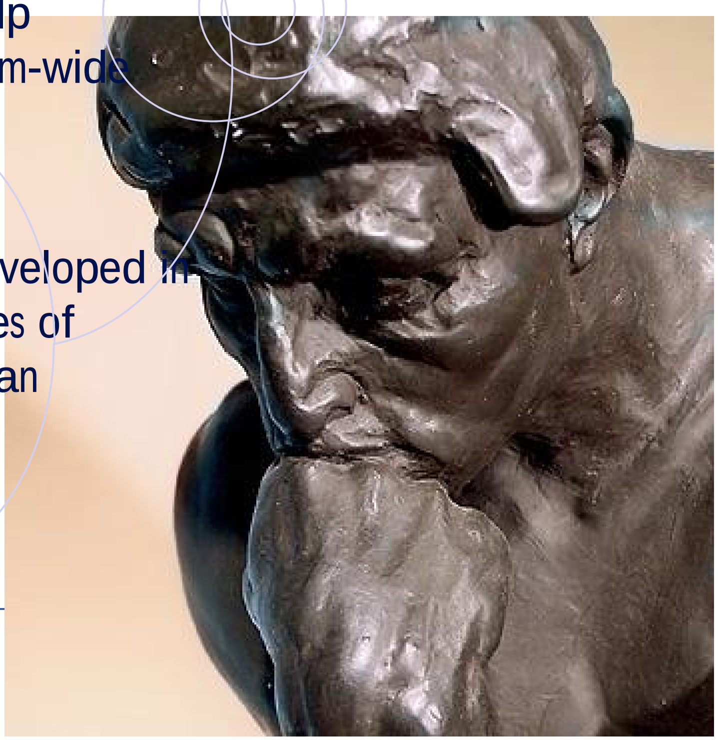
California Center for Innovative Transportation

Collected thoughts about traffic sensors

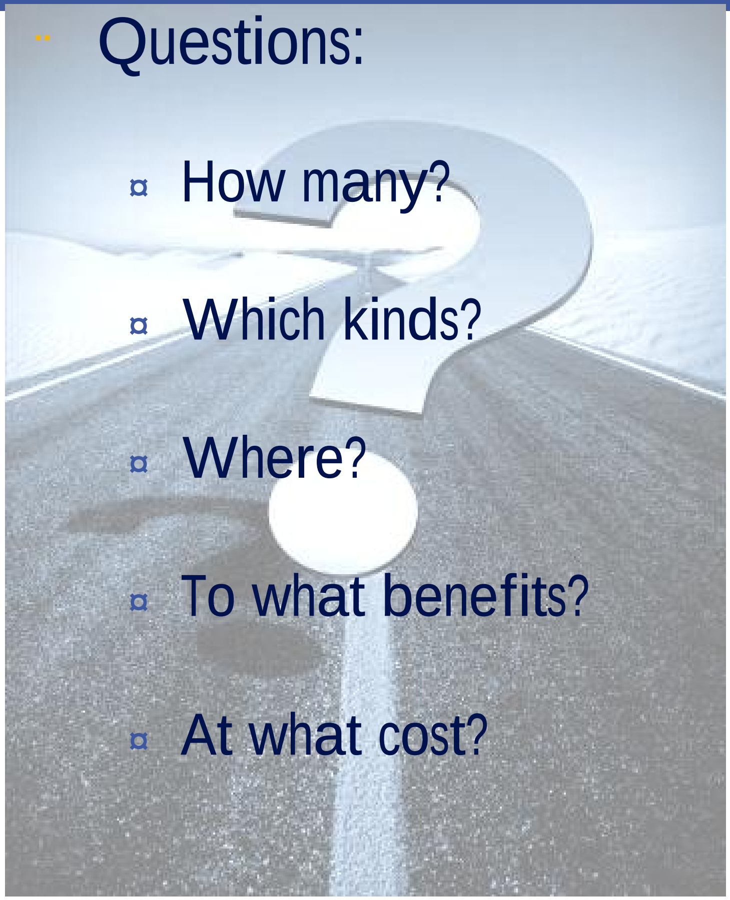
Most sensors and communication infrastructure are installed on a case-by-case basis without knowing whether the associated benefits are fully realized

Caltrans does not have a decision support tool to help evaluate and justify sensor deployment from a system-wide perspective

Optimal sensor deployment strategies should be developed in the context of specific applications for different types of corridors such as rural/mid-size/urban



Deploying traffic sensors



- Questions:
  - How many?
  - Which kinds?
  - Where?
  - To what benefits?
  - At what cost?

- Why they matter:
  - Attaining functional objectives
  - Making the right choices
  - Providing standard guidelines
  - Justifying budget changes

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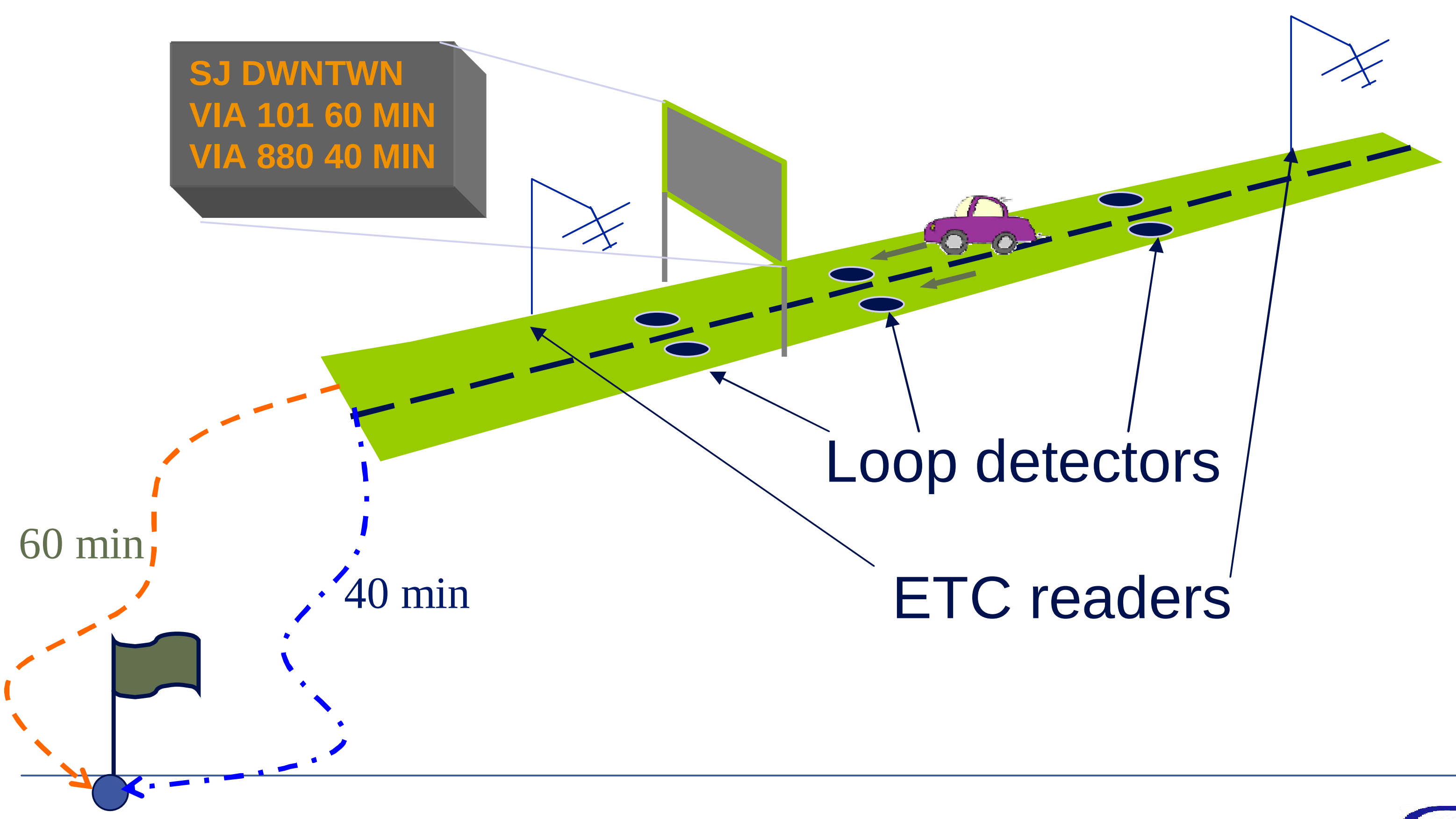
Case Study: Optimal Sensor Placement for Freeway Travel Time Estimation

Application: Displaying Travel Times on CMS



A Dynamic Programming Model

- Empirical Studies
  - Thomas (1999), Eisenman et al. (2006), Liu et al. (2006), Fujito et al. (2006), Kown et al. (2006), Ban et al. (2007)
  - Based on existing sensor deployment, investigate how changes of sensor locations impact the performance of travel time estimation.
- Optimal Sensor Placement Study Sponsored by Caltrans
  - Investigate the requirements for numbers and locations of sensors to collect traffic data for 1) travel time estimation, 2) ramp metering control, and 3) freeway performance monitoring.
- Current Findings
  - We formulate the problem using Dynamic Programming, which can be solved optimally in polynomial time
  - Test the model and solution algorithm using both simulation and real world data from GPS-Enabled Cell Phones.

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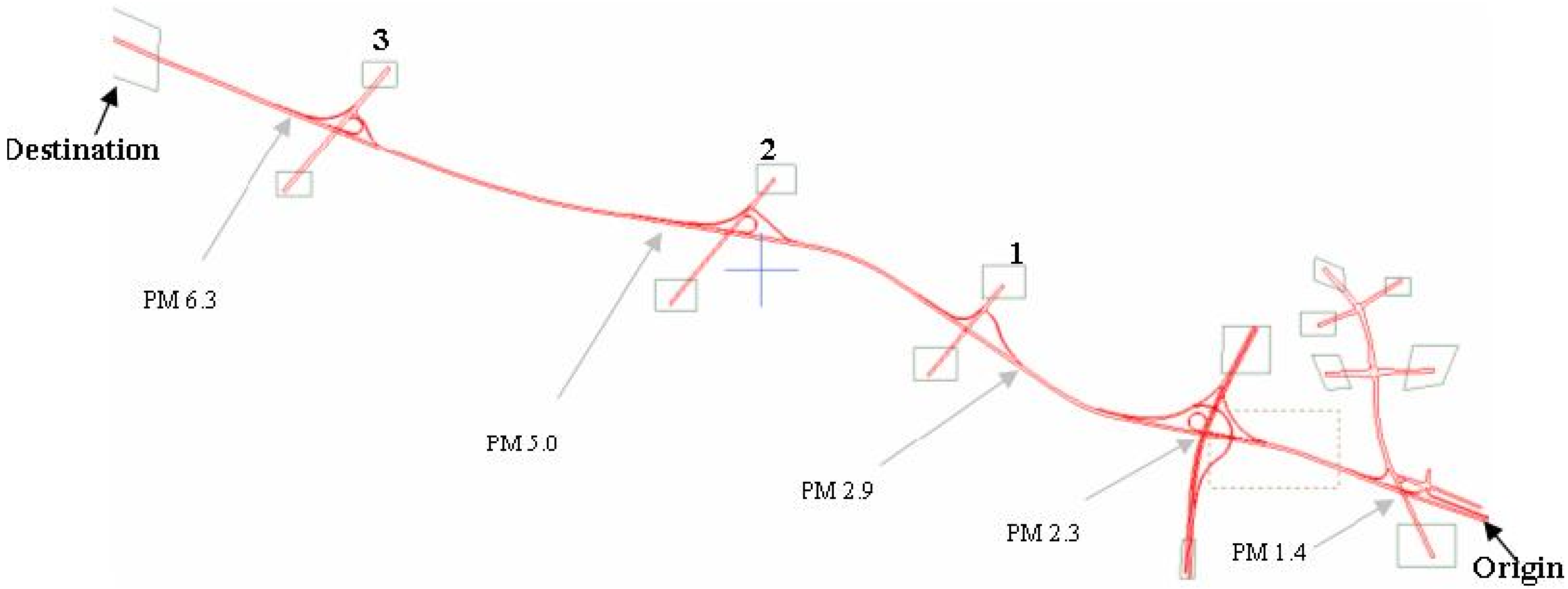
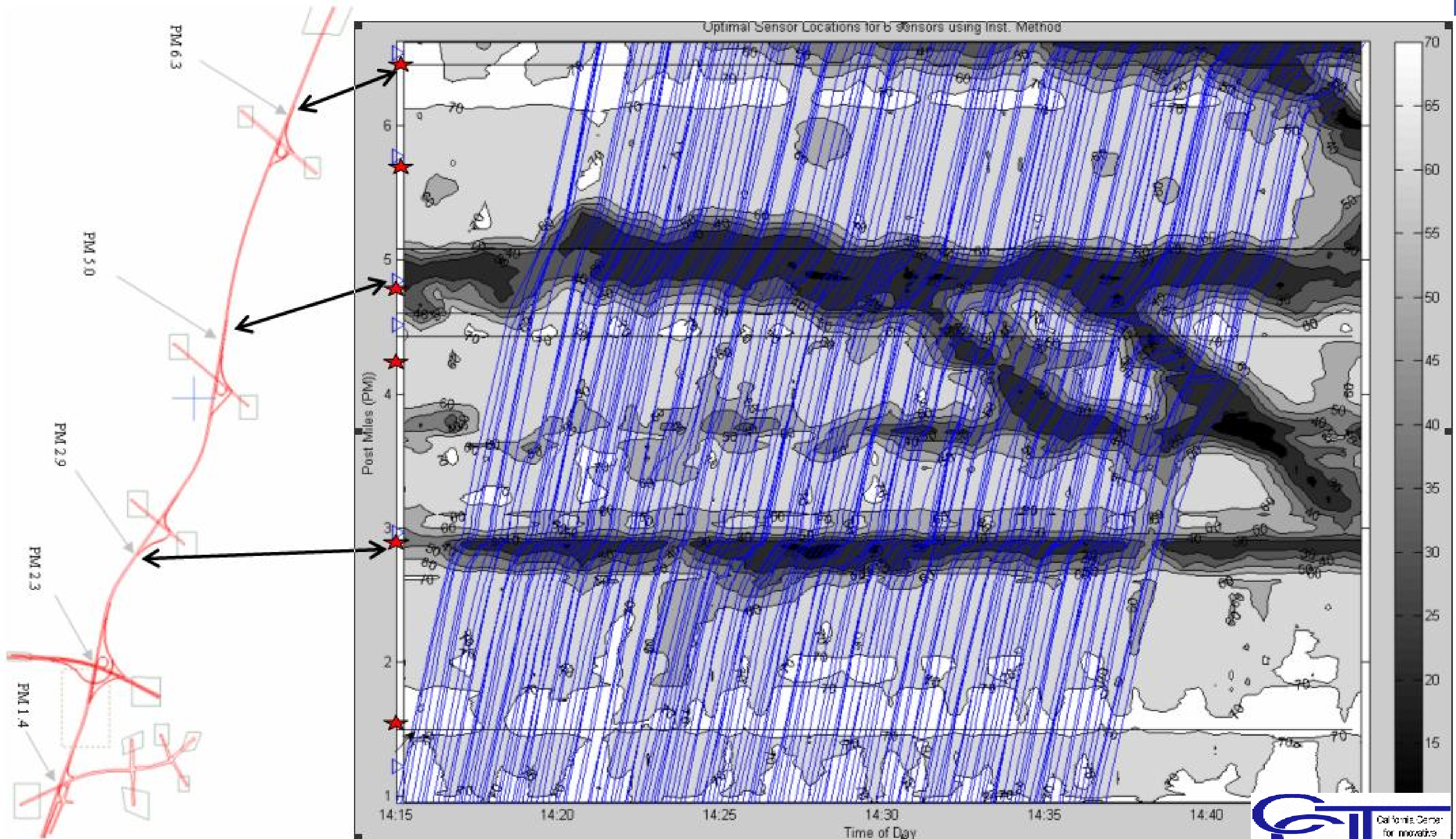
Numerical Results Using Micro-Simulation Data

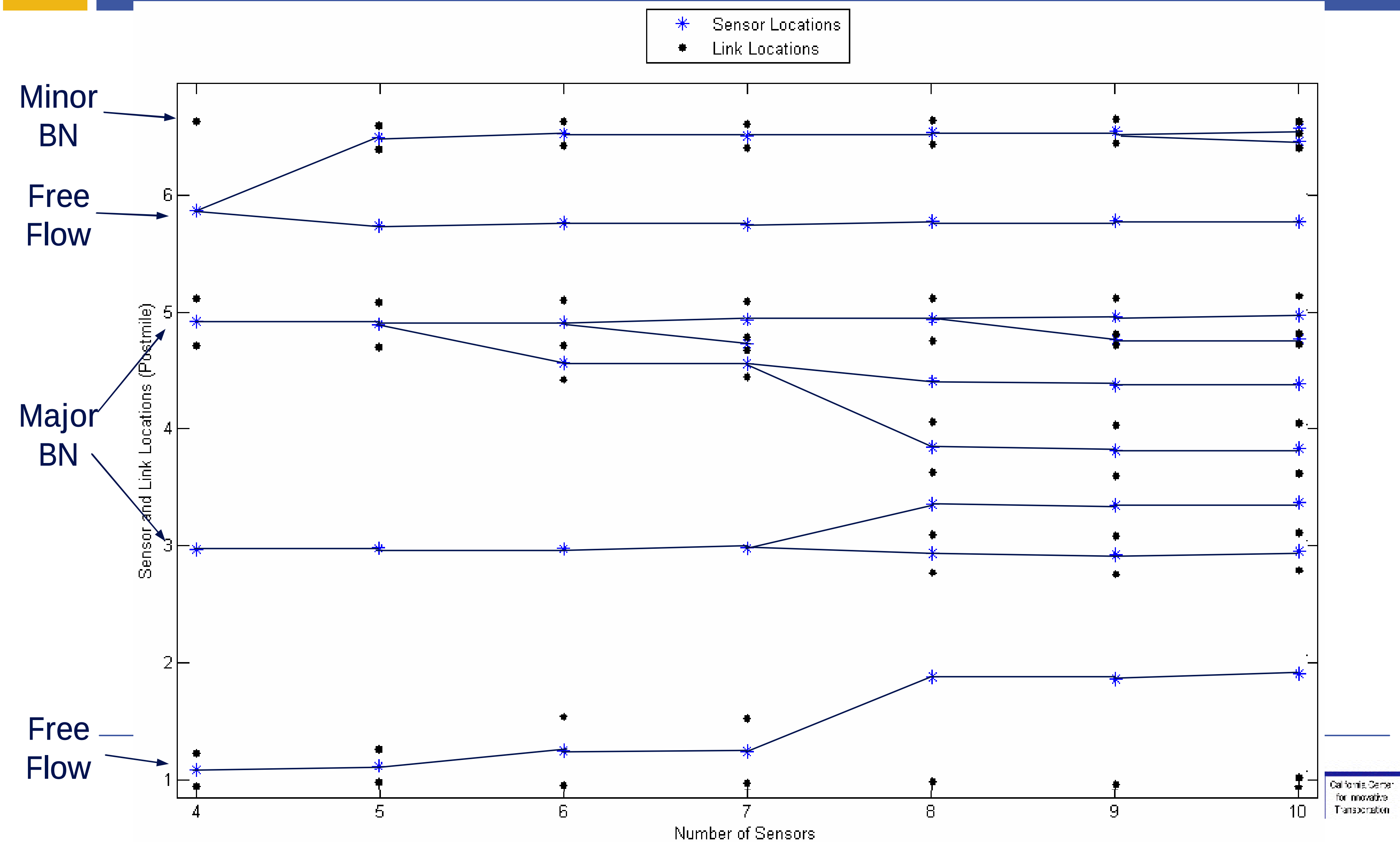
Simulation Network (I-405 in LA)



Optimal Locations for 6 Sensors

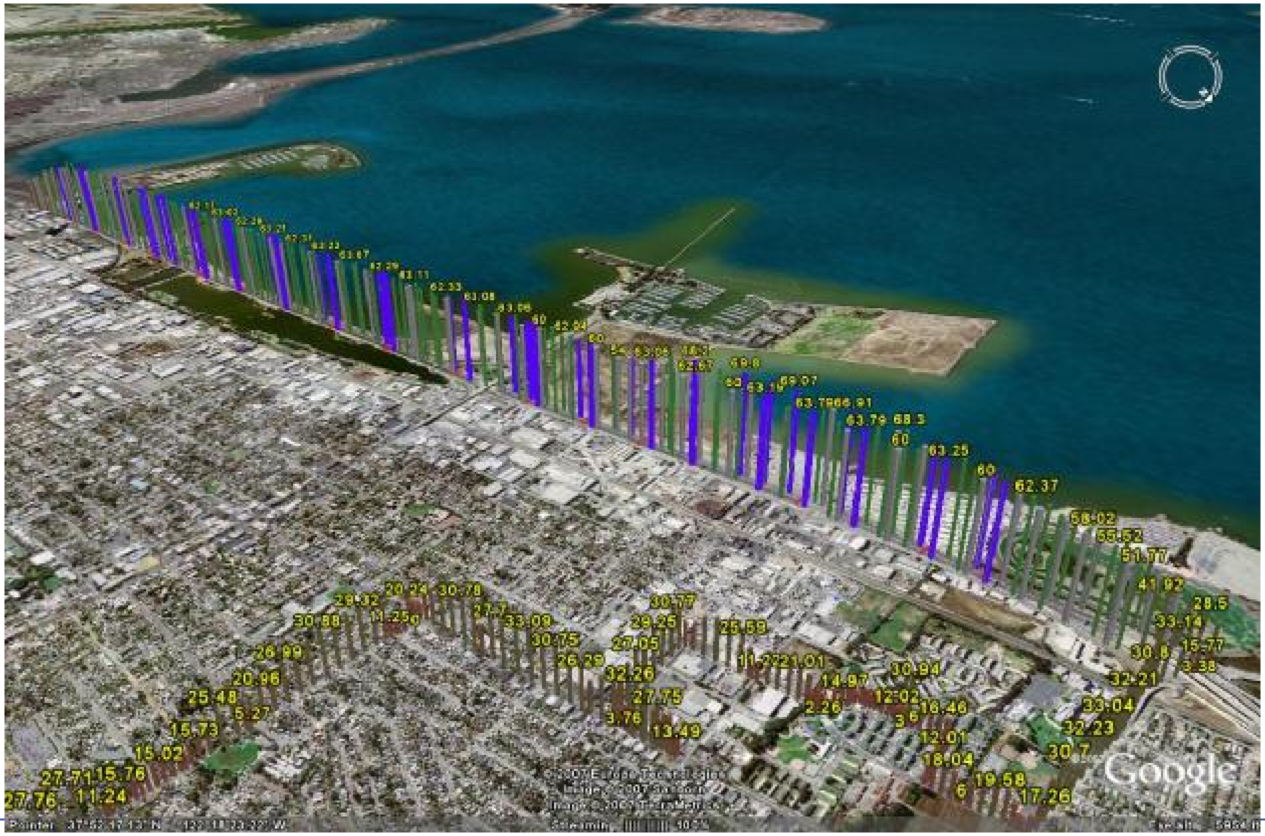


Evolution of Optimal Sensor Locations



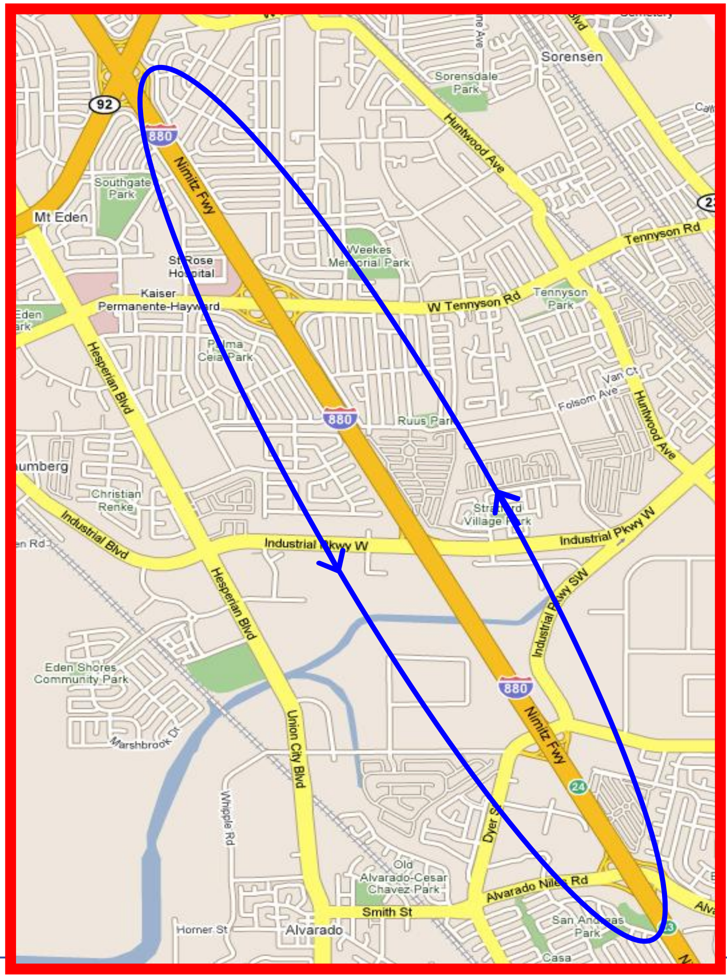
Numerical Results Using GPS-Equipped Cellular Phone Data

Cell Phone Data



Data Collection

- 20 Cars Equipped with Nokia GPS N-95 Cell Phone, looping between Alvarado Niles Rd and CA-92 (about 3 miles) from 1:00 pm to 5:00 pm on Nov. 02, 2007.
- Average loop travel time is about 20 minutes, equivalently 60 veh/hour, which is about 1% of the total freeway volume on that day (6000 veh/hour).
- Collect trajectories of looping vehicles
- Estimated speed fields of the study route for 2:00 pm – 4:00 pm.



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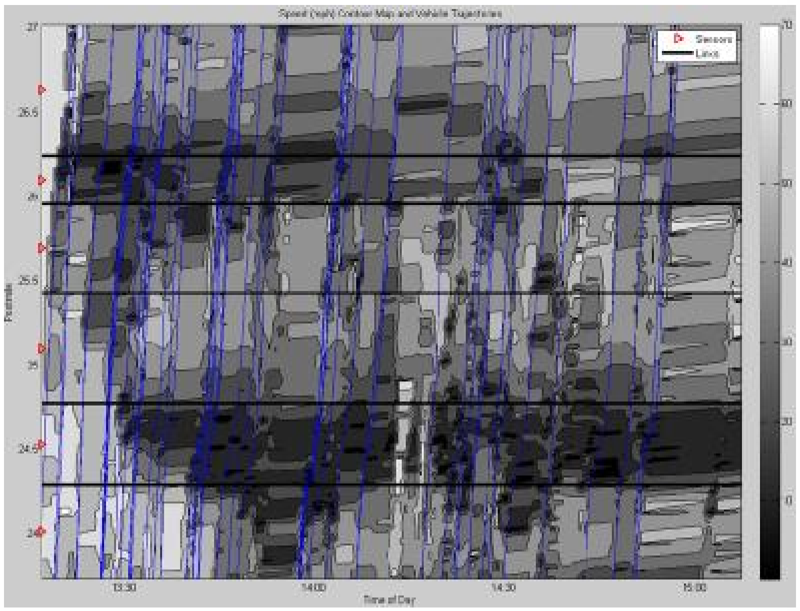
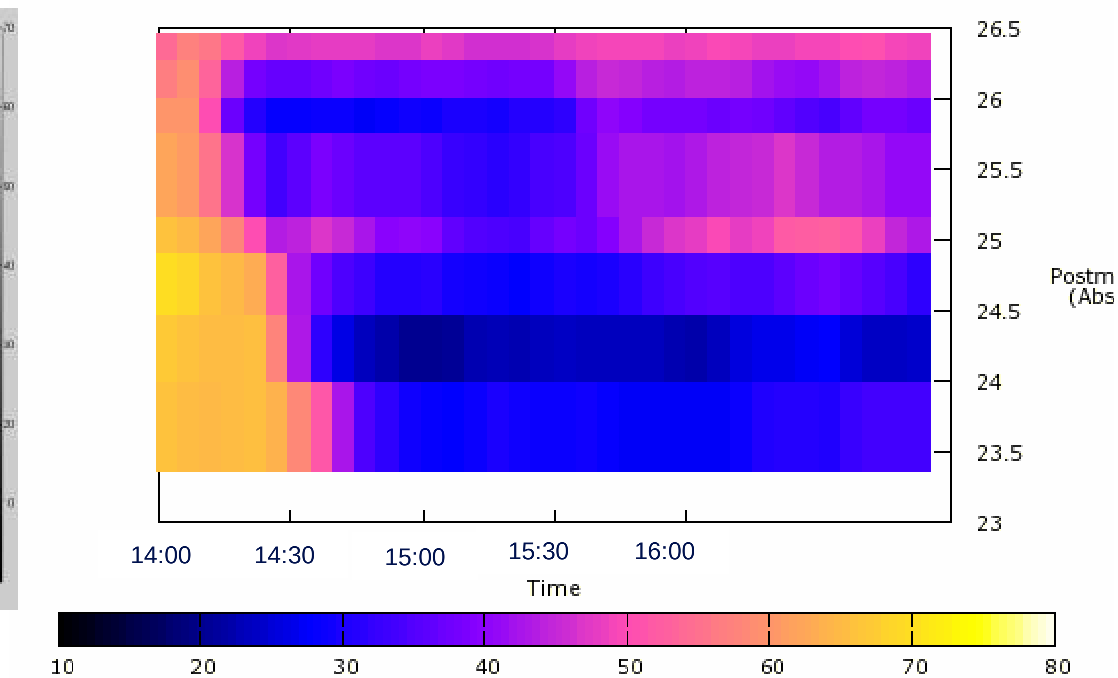
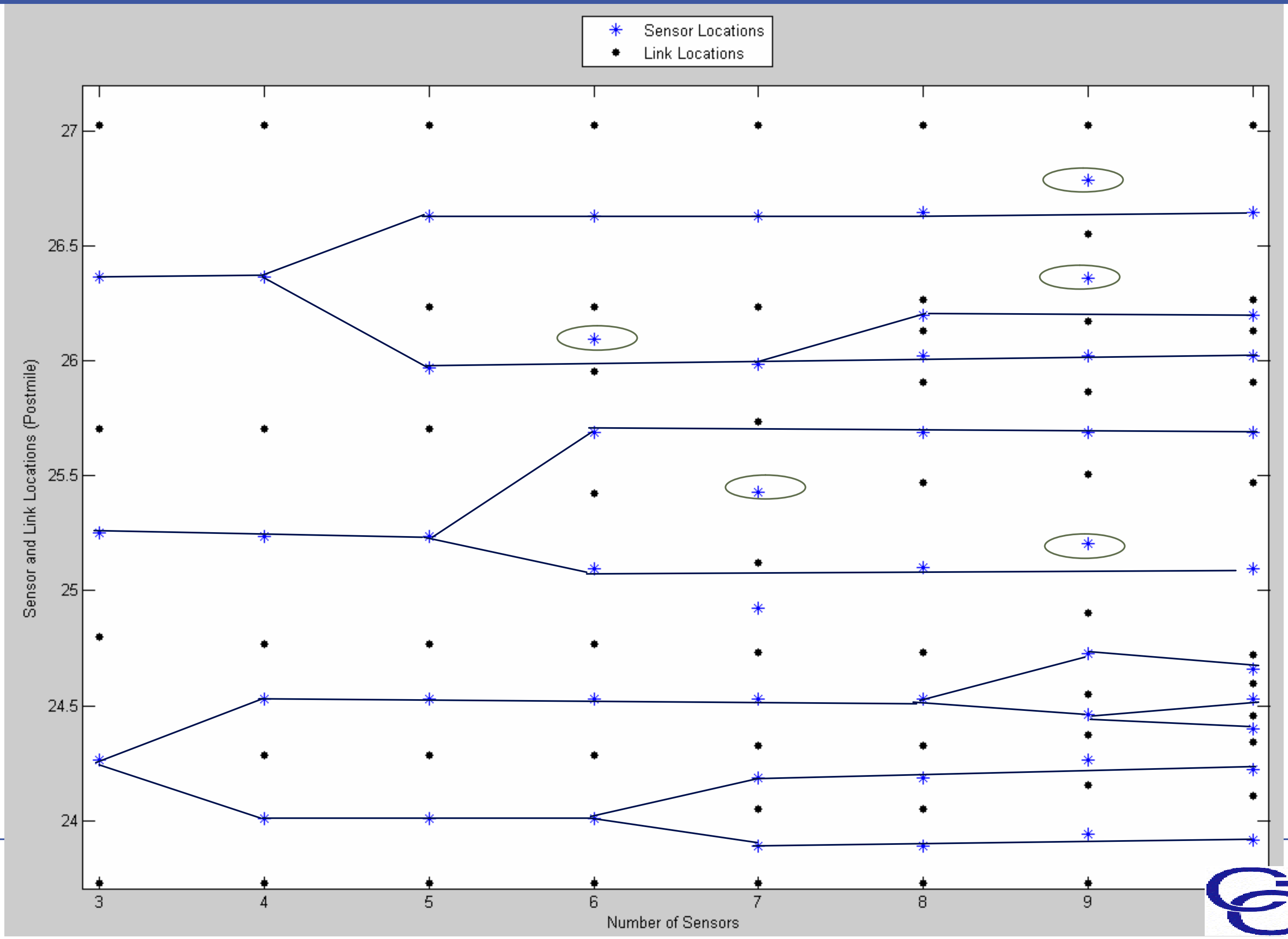


20-Car Experiment

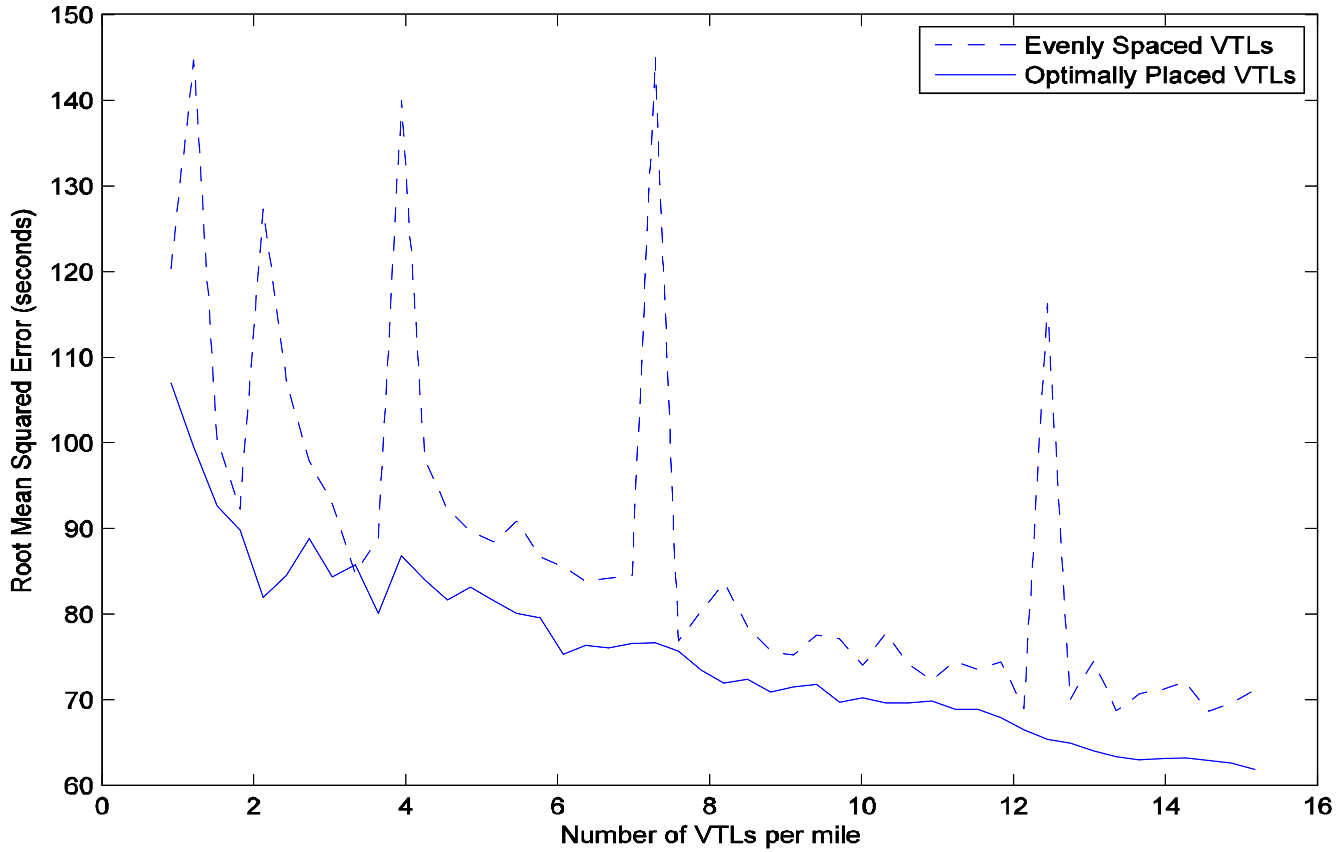


PeMS Data

Evolution of Optimal Locations

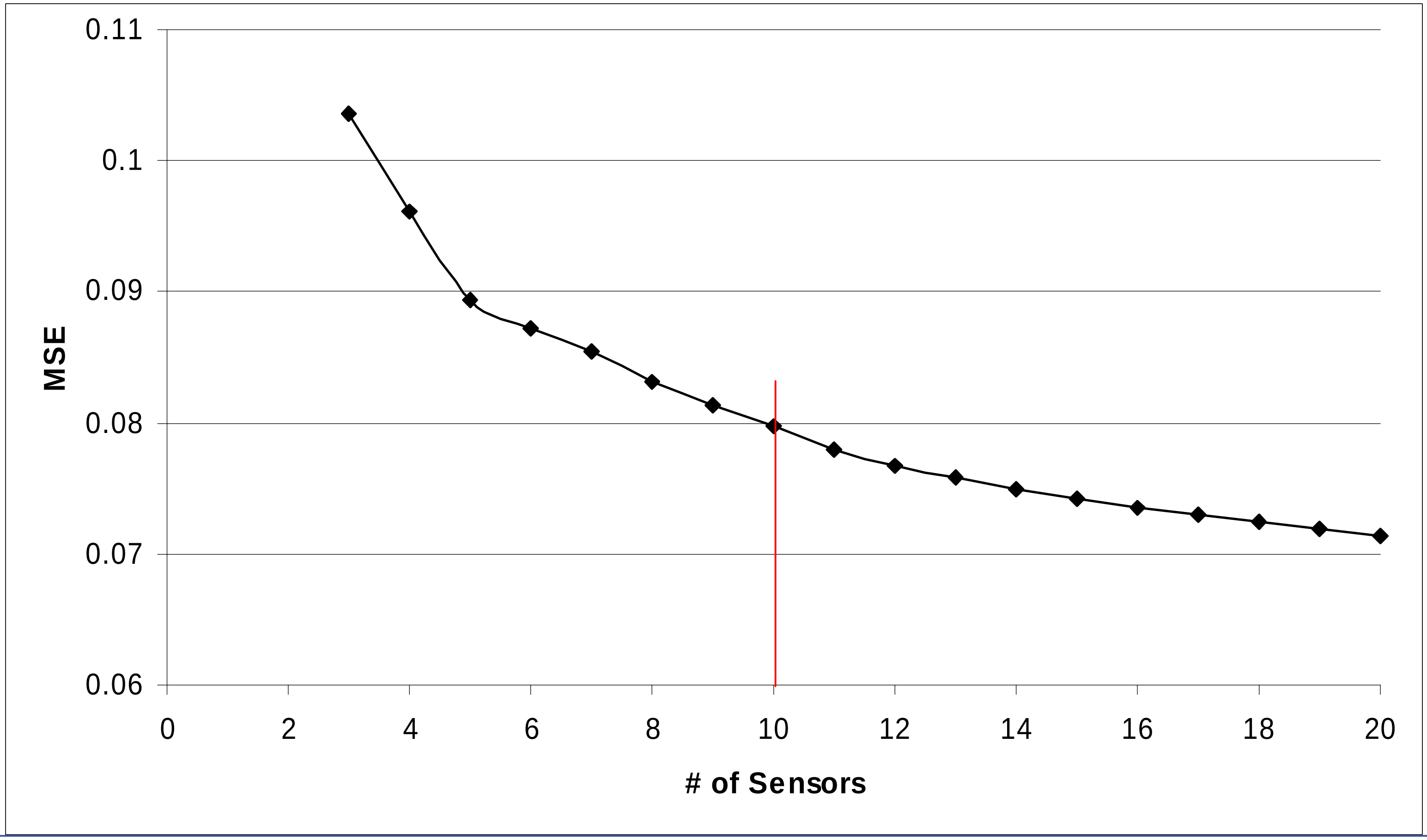


Performance Comparison of Optimally Deployed Sensors with Evenly Spaced Sensors



Challenges: How to Value Information Quality (Accuracy, Reliability, etc.)?

Travel Time Estimation Error vs. # of Sensors (via Simulation Data)



Potential Directions

- System Perspective: information coverage (geographical and demographic), system performance improvement (delay reduction, accident/incident reduction)
- User Perspective: travel time reduction, willingness to pay

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