Con-Ops for ramp metering on I-15

Freeway Control team

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1 Introduction

This document gives an overview for how ramp metering will be tested on the I-15 freeway. Key topics discussed are the site selection, a complete understanding of the instrumentation along the chosen sub-site, the algorithm for coordinated ramp metering, and the data requirements to power the ramp metering algorithm.

2 Sub-site selection

The current network proposed is represented in Figure 2 running from San Marcos to Mira Mesa, for a length of roughly 20 miles. The current network construction only considers the southbound direction, but expansion to both directions is possible. Reviewing the Aimsun model with Dmitris, it appears most onramps have metering controls currently implemented. Additionally, based on the Beats model, loop detectors are well-spaced, and exist on most onramps.

Next steps

1. Review current congestion patterns to understand how effective ramp metering can be.
2. Construct two separate networks: southbound and northbound to allow for control in both directions.

3 Algorithm

The algorithm being implemented will be adjoint ramp metering method currently being developed in the group. It is a predictive algorithm, which is powered by estimates of data in the future. The algorithm runs in open loop, but would be embedded inside of an MPC-type framework which only takes the first N time-steps of the policy at each request. The algorithm is best summarized by the following set of requirements.

Input

- Network
  - Topological properties
  - Link lengths
  - Calibrated fundamental diagrams
    - Should be a separate module
    - Could be intelligent enough to adapt to weather, but we require first-order model with accurate bottleneck information and free-flow speeds
  - **Optional**

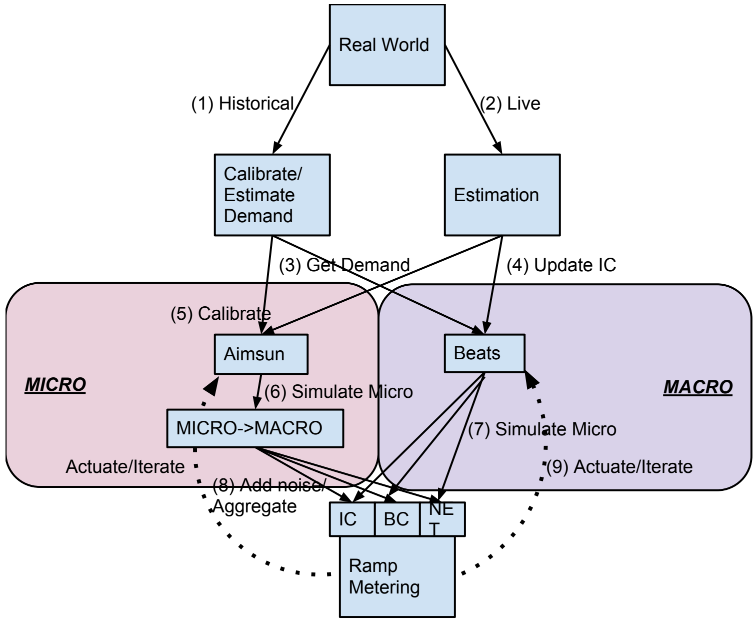

Figure 1: Block diagram for ramp metering

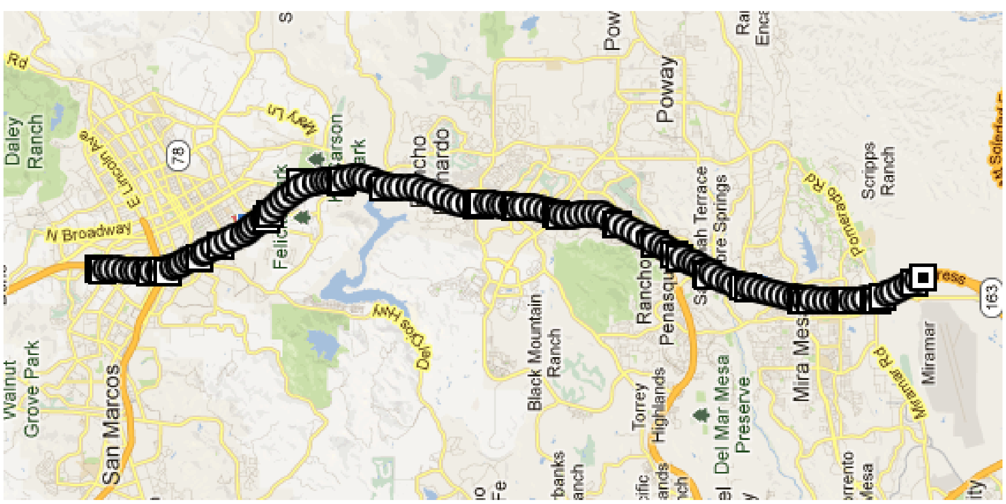

Figure 2: Current sub-site selection based on network built with Beats.

    * Offramp capacities: right now we assume infinite
    * Max queue lengths: assumed to be unlimited
    * Minimum metering rates: assumed to be 0 right now.

- Initial state of the network
  - Should be received from the estimation module.
  - Queue lengths and mainline densities required.
- Time horizon T over which predicted boundary data is available.
- Granularity Δt for updating the metering rate
- Desired running time T_{run}
- Boundary flow on the mainline over T time.
- Boundary flows for the onramps over T time.
- Estimated split ratios for offramps over T time.
  - These will most likely be determined from historical data.
  - Recommended that a separate module be tasked with determining this data

Output

- Ramp metering rates on every onramp over the period T at granularity Δt.
  - Algorithm will intelligently finish before T_{run}, potentially sacrificing optimal performance in order to finish in time
  - Value returned could be given as a ratio of on-time to off-time for the signal, or an onramp flux rate.

4 Con-Ops

- The mainline begins just north of HW78 at West El Norte and ends just south of HW56 at Poway Road.
- The time period for the entire simulation will take place of a full weekday with typical congestion patterns learned from historical PEMS or one of the Aimsun datasets.
- The time horizon of the algorithm will be between 1-2 hours. The actual time-horizon will largely depend on the uncertainty of the initial conditions and boundary conditions. **Continued collaboration with these teams will help determine an optimal time horizon.**
- We will run the ramp metering algorithm as a slave inside of the a larger "runner". The algorithm will consider all ramps with lights as controllable with a specified update rate.
- Currently, any "smoothing" of the output will not take place inside the algorithm, and will be done at a higher level. The runner is responsible for converting Aimsun sensor data into macroscopic input that is amenable to the ramp metering module.
- All guarantees of the system will be validated against
  - During light loads, the metering algorithm will return no control.

- When ramps exceed the maximum queue length, the algorithm will return no control.
- Minimum metering rates will be validated.

- Performance estimate metrics will be returned to the runner, including estimated improvement in total travel time and fairness.

5 Inventory

5.1 Field data

PEMS data is well covered in at least the southbound direction, with regular spacing on the mainline, and a loop detector on nearly every onramp. Such data will be necessary to power a boundary data module, an estimation module, and a split-ratio/demand behavior module. Such modules are critical to the performance of the prediction-based adjoint algorithm.

Next steps

- Understand the health statistics of the loop detectors, and their ability to give accurate demand information
- Understand probe data penetration and other data sources necessary for initial condition estimation.
- Understand the current efforts in the group on the creation of the respective modules that will drive our model **and what their data needs are:**
  - Estimation
  - Demand
  - Split ratios
  - Calibration

5.2 Aimsun data

Aimsun model seems to be very mature, with complete information on the freeway, onramps and offramps. Such data should be satisfactory to construct all network-related parameters. Furthermore, there is ramp metering implemented on the Aimsun model, but Dmitris says that there is no access to the underlying metering scheme. This metering scheme can be over-ridden with a custom metering scheme, such as Alinea.

Next steps

- Understand how demand is implemented in Aimsun, and how to interpret the output of simulations