Title: A Dynamical Framework for Integrated Corridor Management

PI: Ketan Savla
Sonny Astani Department of Civil and Environmental Engineering
University of Southern California
Los Angeles, CA 90089-2531
Email: ksavla@usc.edu

Project Objective

Rapid advancements in traffic sensing and control technology, from loop detectors, traffic cameras and mobile phones, to electronic road signs, dynamic congestion pricing and personalized navigation devices, are facilitating dynamic traffic control. Moreover, Integrated Corridor Management aims to integrate various transportation subsystems, such as freeways, arterial roads and public transit, and use the sensing and control technology embedded in the integrated transportation infrastructure to improve efficiency and resiliency of our congested corridors. It is therefore imperative to design rigorous control methodologies for traffic flow over networks in the context of these emerging technologies. Our research seeks to develop computationally efficient traffic control strategies for arterial and freeway networks with provable performance guarantees on throughput, travel time, and resilience to traffic incidents.

Problem Statement

While traditionally used for planning purposes, the framework of dynamic traffic assignment is being increasingly used for determination of optimal ramp metering, speed limit, and routing control for freeway networks. However, the underlying optimization problem is non-convex, thereby lending this approach computationally infeasible for real-time applications, especially for large-scale networks, and over long time horizons. Alternately, one can get a convex formulation at the expense of relaxing certain features of traffic dynamics, thereby questioning the optimality of the obtained control policies. Existing dynamic (or adaptive, as is commonly referred to as in the literature) traffic signal control policies are either centralized, and hence computationally intensive, or require information about key network parameters, such as turning ratios, that may deviate significantly from their historical values during traffic incidents.

Motivated by these shortcomings, our research furthers the state of the art in traffic control by (i) exact convex relaxations and distributed implementations for optimal control of freeway networks for well-known models of traffic flow dynamics; (ii) decentralized traffic signal control algorithms requiring minimal information about network parameters; and (iii) evaluation via case studies in a microscopic traffic simulator for a Los Angeles area sub-network.

Research Methodology

For freeway networks, we model traffic flow dynamics by the well-known Cell Transmission Model (CTM). We obtain a convex formulation by relaxing the supply and demand constraints of CTM, and then designing optimal loop controllers to make the solution of the relaxed problem feasible with respect to actual CTM dynamics. We adapt standard first order (Alternating Direction Method of Multipliers) and second order (Newton) methods to the setup of traffic flow control, and utilize properties of traffic dynamics to establish convergence properties. For arterial control networks, our model is reminiscent of stochastic queuing networks, where the departure rate from a link is governed by its saturated flow capacity, and green time allocations as determined by the traffic signal control algorithms in place. The arrival rate into a link is governed by the departure rates from the upstream links, turn ratios and phase architecture at upstream intersections. Assuming fixed cycle times and offsets (these values are obtained from the signal timing sheets), we adapt proportionally fair algorithms to the setup of traffic signal control. A salient advantage of these algorithms is that they are decentralized, and do not require information about turning ratios, travel demand or saturated flow capacities.

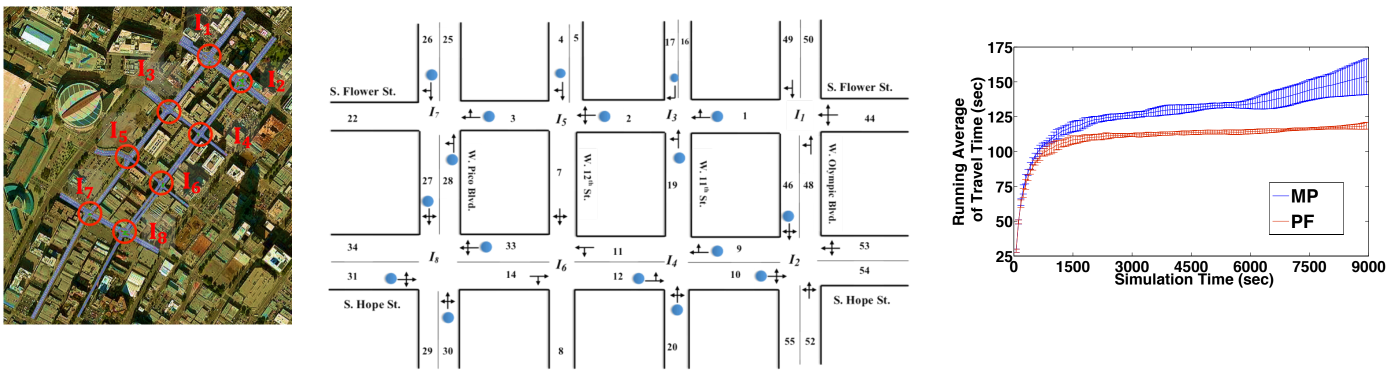

Figure 1

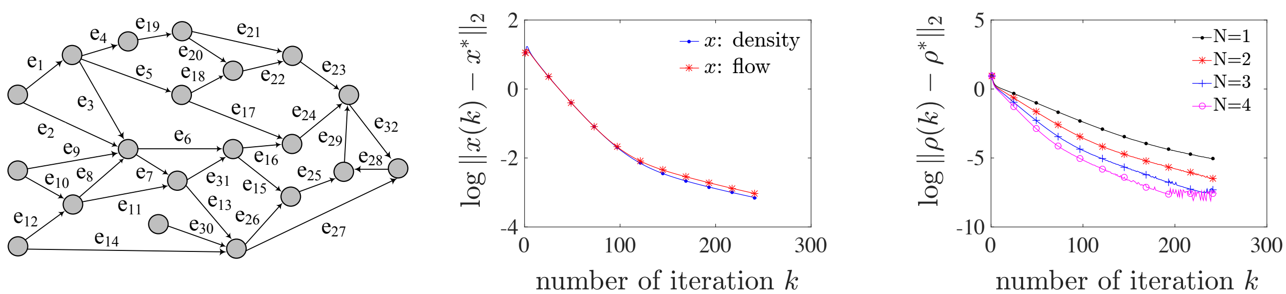

Figure 2

Results

Theoretical properties of the proposed traffic signal control policies (throughput maximization) and of the freeway network control policies (convexity, distributed algorithms with convergence guarantees to the optimal solution) can be found in our publications. Figure 1 compares the average travel time under a max pressure (MP) algorithm from the literature and our proposed proportionally fair (PF) traffic signal control algorithms for the network shown in Figure 1 (left and middle). Traffic incident occurs at t=5400, which shuts down links 14 and 19. Figure 1 (right) shows better performance of the PF controller before and after traffic incident.

Figure 2 compares computational times under first (middle) and second (right) order algorithms for computing optimal control policies via distributed implementations for the network shown in left panel. Figure 2 illustrates superior faster convergence rate for the second order algorithm.