



Research Brief: Connected Vehicle-Based Traffic Signal Optimization

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Introduction

Connected vehicles in smart cities, including vehicle to vehicle (V2V), vehicle to infrastructure (V2I), and vehicle to anything (V2X) communications, can provide more opportunities and impose new challenges for urban traffic signal control. Instead of relying on infrastructure sensors, urban traffic signal control can be transformed by connected vehicle (CV) technology, which enables vehicle-to-everything (V2X) communications and leads to an intelligent transportation system where all vehicles, road users, and infrastructure systems can communicate with each other.

This project aims to explore the basic research on developing signal control and coordination methods under the CV environment, develop a framework for urban traffic signal optimization with CVs, and test the developed methods. The research team developed a framework, including modeling techniques, algorithms, and testing strategies, for urban traffic signal optimization with CVs. This framework is able to optimize traffic signal timing for a single intersection or along a corridor.

Methodology

Researchers developed CV-based traffic signal timing optimization methods using individual vehicles' trajectories. Their method evaluates the weighted sum of travel times and fuel consumption of all vehicles in the study area to determine optimal green times and offsets. For intersection level (phase duration) optimization, they propose a dynamic programming with two-step method. For corridor-level (offset) optimization, they employ a prediction-based solution method for the two-level problem.

The researchers evaluated their proposed optimization methods at both the single intersection and corridor levels using data generated from traffic simulations in VISSIM. First, they estimated the optimal cycle length using SYNCHRO for different traffic demand cases, then they applied different methods to a certain scenario to optimize the signal timing plans. Third, they applied and evaluated the performance of each signal timing plan using test cases with different combinations of traffic demand levels and vehicle types.

For a single intersection, the algorithm utilized arrival information (speeds, locations, etc.) from CVs as the input to optimize the green times by considering vehicles' fuel consumption and travel time. The problem was first formulated as a mixed integer non-linear programming (MINLP) problem by applying the Intelligent Driver Model to predict vehicle trajectories. A dynamic programming formulation was then developed to approximate the MINLP.

Overview

- This project developed and tested a framework for urban traffic signal optimization with CVs for a single intersection and a five-intersection corridor
- The researchers tested their proposed optimization methods using traffic simulation data, comparing the results of different methods in optimizing the signal timing plans
- The proposed method performed better than alternative optimization strategies and showed the most significant improvements under medium traffic demand levels

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For a corridor with multiple intersections, the problem was also formulated as a MINLP considering the fixed cycle length constraint to optimize the phase durations and offsets. IDM was again applied. To reduce the complexity of the model, the problem was split into two levels: an intersection level for generating optimal phase durations using the DP method, and a corridor level to update the optimal offsets for all intersections. To solve this model, a prediction-based solution technique was developed that can solve the problem iteratively.

Results & Conclusion

The performance of the algorithm was evaluated using data generated from traffic simulation. For a single intersection, the results of the proposed DP model were compared with two other models. The first one is the traditional actuated signal timing plan generated by SYNCHRO. The second is to solve the MINLP formulation directly using the NOMAD solver in MATLAB. The results showed that the proposed DP method is always superior to SYNCHRO under all cases and can generate similar (slightly worse) solutions compared with NOMAD. However, NOMAD has difficulties finding optimal solutions when the number of variables is relatively large. This makes the proposed DP method more favorable when dealing with large problems (e.g., for multiple cycles). For a corridor, the results from MINLP and the two-level model both outperformed the signal optimization and coordination plan generated by SYNCHRO. This was tested for six cases that consider various combinations of traffic volumes and vehicle types.

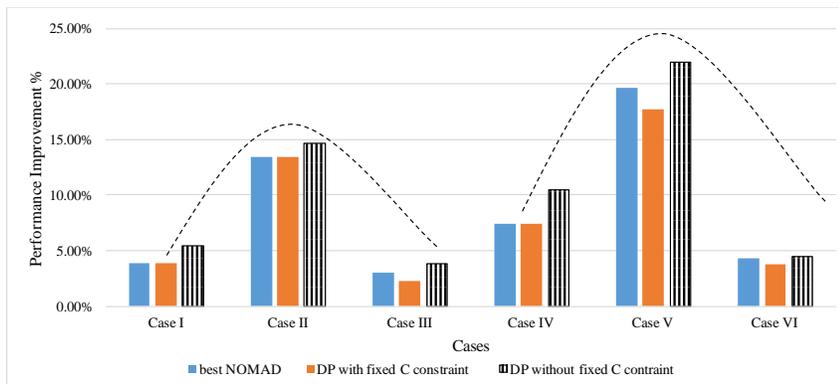


Figure 1: Improvement of model performance over SYNCHRO results

Figure 1 shows performance improvements resulting from different optimization methods for a single intersection under different combinations of demand levels and vehicle types. The model improvements are more significant at the middle demand levels (Case II and V). This may be because under unsaturated but relatively heavy traffic conditions, there are more opportunities to optimize the splits and reduce the total cost of fuel consumption and travel time. Furthermore, the performance improvements are more obvious if considering different vehicle types, as shown in Case IV – VI. The results also suggested that signal coordination may bring limited benefits to intersections with low traffic volumes or to the vehicles on the minor street.

For more information and to read the project's full report, visit the C2SMART website.

→ [Project Webpage](#)

→ [Final Report](#)

About C2SMART

C2SMART is a USDOT Tier 1 University Transportation Center taking on some of today's most pressing urban mobility challenges. Using cities as living laboratories, the center examines transportation problems and field tests novel solutions that draw on recent advances in communication and smart technologies. Our consortium includes New York University, Rutgers University, University of Texas at El Paso, University of Washington, and City College of New York.

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