LAMAR UNIVERSITY

PROJECT SUMMARY

Texas Department of Transportation

0-6920: Proactive Traffic Signal Timing and Coordination for Congestion Mitigation on Arterial Roads

Background

Traffic streams on arterial roads are interrupted by traffic signals, which force vehicles to stop at signals on red, increasing travel time, fuel consumption, and emission levels due to acceleration/deceleration maneuvers and idling at traffic signals. To mitigate these effects and maximize intersection performance, this project developed a proactive signal control system to optimize signal phasing and timing plans. The research team developed a proactive signal control strategy based on communications among vehicles, loop detectors, and traffic signals. In addition, this project developed a framework and tool for evaluating the advances of communication technologies in signal design.

First, the proposed system modeled the vehicle queue generation and propagation ahead of traffic signals, and explored the relationship between road congestion and vehicular delays. Second, a communication platform was constructed to monitor real-time traffic conditions. Finally, a proactive signal control strategy was developed based on the collected traffic information. To ensure a robust and effective strategy, a predictive control model was introduced to predict short-term traffic conditions.

What the Researchers Did

Over the one-year project period, the research team completed the following tasks.

1. Project Preparation: Working with the TxDOT RTI project manager and two engineers from TxDOT Houston Office, the research team inspected the candidate testbeds, and compared their traffic levels, topology, and immediate environment.

2. Literature Review: conducted a comprehensive literature review about the development of proactive signal control systems.

3. Data Collection Plan: selected the testbed and determined the data required.

4. Network Performance Analysis via Simulation Verification: utilized two microscopic traffic simulators, INTEGRATION and VISSIM, to reproduce and analyze traffic conditions on the testbed, applying link volume and occupancy data collected by the TxDOT Houston Office to evaluate the testbed congestion levels.

5. Strategy Development: developed a proactive signal control system based on use of connected vehicles (CV) to minimize vehicle delay at multiple intersections.

6. Field Experiment: conducted a field experiment to verify the proactive signal control system and compared the link volumes, occupancies, vehicle queue lengths, and average wait times before and after applying the proactive system to verify the system's benefits.

What They Found

The research project yielded many findings with respect to the theoretical and field experiment of the proactive signal control system. Some key findings are as follows (see the final report for full details).

1. A proactive signal control system was developed to reduce vehicle delay at signalized intersections and mitigate traffic congestion. The system utilizes CV technologies to gather precise real-time traffic

Research Performed by:
Lamar University

Research Supervisor:
Xing Wu

Researchers:
Hao Yang
MM Haque

Project Completed:
12-31-2016

information, predict traffic entering intersections through different approaches, and establish an optimal signal control algorithm to adjust traffic condition intelligently. Plus, the system can be applied for signal control of multiple intersections effectively. A general simulation on a small virtual network, implementing the system at one isolated intersection and two consecutive intersections, illustrated the algorithm's effectiveness at reducing vehicle delays: compared with the fixed-time plan, the proactive control could reduce the travel delay by about 77% for one intersection, and by 62% for two consecutive intersections. The simulation verified that the proactive control performs better than the reactive control and the Nash-Bargaining control.

2. A comparison with the observed traffic conditions revealed that both traffic simulators, INTEGRATION and VISSIM, were able to model the existing actuated signal control systems and accurately reproduce testbed traffic conditions. The simulation evaluation of the proactive system indicated that the system significantly mitigated road congestion on the testbeds.

- On the first testbed (FM 1960), using CVs, the simulations showed that the proactive system could reduce the vehicle delay up to 80%, i.e., 160-second reduction in one 1.7-km trip. Each vehicle's average number of stops could drop from 2.8 to 2, decreasing the stop delay by up to 89%. With fewer stops, vehicles experience greater energy efficiency. The simulated fuel consumption dropped by about 21% on weekdays, and 25% on weekends—saving about $2,400/day on weekdays, and $3,270/day on weekends.
- On the second testbed (NASA Road 1), CV technologies were not used, and the proactive system was limited by the functionality available on the ASC/3 controller (which is TxDOT's existing signal controller), so the system was less efficient. However, the simulations showed that the proactive system still reduced the average delay about 11%, the average number of stops about 10%, and the stop delay about 29%.

3. Finally, due to the sensor problems on the first testbed, the field experiments were conducted on the second testbed only. The results indicated that the proactive signal control system allowed more vehicles to traverse the intersection at the same time, implying that the proactive system is more efficient at releasing traffic and increasing intersection capacities. Meanwhile, the December 2016 field observation during peak hours found that the average queue length could be reduced up to 60%, and the average waiting time was reduced by as much as 50%. TxDOT's Houston Office did not receive any driver complaints when the system was activated, indicating the system met drivers' expectations at this intersection.

What This Means

Based on the findings from this project, the research team has two recommendations for future implementations:

1. TxDOT can extend the proactive signal control system to more intersections in a larger network, mitigating road congestion levels and reducing vehicle emissions and fuel consumption.

2. The proactive system requires more accurate detection of link volumes and occupancies. To improve the performance of intersections, more traffic volume detectors should be installed on roads, and the information acquired should be shared by multiple surrounding intersections.

For More Information

Project Manager:
Darrin Jensen, RTI (512) 416-4728

Research Supervisor:
Xing Wu, Lamar University (409) 880-8757

Technical reports when published are available at **http://library.ctr.utexas.edu.**

Research and Technology Implementation Office
Texas Department of Transportation
125 E. 11th Street
Austin, TX 78701-2483

www.txdot.gov
Keyword: Research