TECHNICAL *Summary*

INDOT Research

Technology Transfer and Project Implementation Information

TRB Subject Code: 54-5 Traffic Control Devices *November 2001*
Publication No.: FHWA/IN/JTRP-2001/5, SPR-2391 *Final Report*

A REAL-TIME OFFSET TRANSITIONING ALGORITHM FOR COORDINATING TRAFFIC SIGNALS

Introduction

Over the last few decades, extensive efforts have been made in the development of adaptive and responsive traffic control systems. The United States Department of Transportation (US DOT) has sponsored a great amount of research and field deployment of new traffic adaptive algorithms, such as OPAC and RHODES. Internationally, systems like SCOOT and SCATS, developed in the United Kingdom and Australia respectively, have seen increasing deployments. These adaptive control systems are based on applying specific proprietary software to a signal control system. It is estimated that travel time savings from these adaptive systems could range between 8% and 25%.

Adaptive control systems typically require an extensive input of system parameters and weighting factors for favoring individual movements plus a large number of vehicle detectors to collect movement-specific traffic data. A major drawback of these systems is the extensive effort required for training personnel on the new proprietary architecture. Operation and maintenance of these systems can also be very costly and time consuming.

In a parallel track, the private sector has developed closed loop systems that are operated by coordinated-actuated controllers. These systems provide actuated control capabilities through their ability to respond to cycle-by-cycle variation in traffic demand while still being able to provide progression for the arterial movement. Unfortunately though, the quality of vehicle progression depends on both the initial setting of offsets and the stochastic nature of traffic on individual intersections, causing waiting queues and what is known as the early-return-to-green phenomenon.

Expanding the control logic for modern coordinated- actuated systems to account for problems such as early-return-to-green, waiting queues, and improperly designed offsets would address many of the day to day problems associated with closed loop systems. Additional training would be minimized, in comparison to fully adaptive systems, since traffic engineers and technicians managing traffic signal operating systems are already familiar with coordinated-actuated logic. Fundamental concepts and communication systems for coordinated-actuated systems would also remain the same. Additionally, extra cost would be kept to a minimum since no extra detectors or infrastructure would be required.

The objective of this research is to introduce an adaptive real-time offset transitioning expansion to actuated controllers to improve coordination of traffic signals. This algorithm, the Purdue Real-time Offset Transitioning Algorithm for Coordinating Traffic Signals (PRO-TRACTS) is designed to mitigate the effect of early-return-to-green problems experienced with coordinated-actuated controllers and accounts for downstream vehicle queues that may impede vehicle progression. PRO-TRACTS fine-tunes the offsets at signalized intersections continuously to improve progression regardless of the offsets' initial values. The algorithm presented in this report works with both the internal model of the CORSIM simulation package and actual NTCIP controllers.

Findings

The report introduced a new metric by which offset performance can be evaluated. The new metric, namely the F' model, makes use of the fact that bad offsets at downstream intersections generate backward shockwaves that can extend to the upstream detector location. The metric developed in this research tests for the significance of the presence of shockwaves by calculating a proxy to the variance of the reciprocal of the speed at the upstream detector. The philosophy behind this procedure is that a large variance in speed suggests that a shockwave has a significant effect on the traffic flow. This procedure is modeled after the analysis of variance F distribution testing. Discriminant analysis is used to develop thresholds to which the F' value is compared to determine the amount of offset adjustment needed.

A new NTCIP object for capturing a cycle-based detector actuation profile at the controller level was defined in this report. The defined object will enable the implementation of PRO-TRACTS in the field by allowing real-time exchange of the data required to fine-tune the offsets.

It was found that in some situations, PRO-TRACTS caused an increase in total network delay compared to system-optimum timings when activated with optimum timing plans. These results were not surprising since favoring a directional movement is an additional constraint in the system optimization function. When enforcing a constraint such as favoring a certain traffic movement, the best that can be achieved in the overall system objective function is to keep it constant. However, if the current timing plans were not the system optimum plans, PRO-TRACTS can result in a reduction in total system delay as well.

Adjusting offsets in real-time caused some stability problems when PRO-TRACTS was run with CORSIM's internal control model. A hardware-in-the-loop simulations of the US 31 traffic network in Kokomo, Indiana revealed that field traffic controllers are more stable than CORSIM's internal model in responding to real-time offset adjustment.

The platooning phenomenon has an effect on all coordination schemes since platoon dispersion can make it impossible to fit the whole platoon within a downstream green window. The platooning phenomenon was found to have significant impacts on the performance of PRO-TRACTS. When the traffic turning from the side streets is a low percentage compared to the arterial's through-movement, a good coordination scheme would align the arterial through-movement with the green window, leaving the turning traffic from the side streets to face the red window. This situation causes only a weak shockwave resulting from the turning traffic compared to the strong shockwave that results from a bad offset that align the platoon with the red window. However, if the side street traffic volume approaches that of the arterial's through, even the turning traffic from the side streets will generate a strong shockwave that could cause PRO-TRACTS activation.

The ideal location for a PRO-TRACTS detector is between the termination of the shockwave generated by the side street turning traffic and the shockwave generated by the arterial's traffic. The algorithm is best suited for arterials with primarily through-traffic since a wider separation is provided between the two shockwaves.

Another factor that affected the stability of PRO-TRACTS was the frequency of phase skips and oscillatory traffic patterns caused by certain situations, such as spillbacks or lane blockages. Since PRO-TRACTS is a reactive algorithm, it assumes that the next cycle's arrivals are comparable to the current cycle's arrivals. With phase skips, the discrepancy in arrival patterns of succeeding cycles causes PRO-TRACTS offsets to fluctuate, reducing its efficiency. Future research should address this issue.

Implementation

Two simulation case studies were conducted on two traffic networks: SR 26 in Lafayette, Indiana and US31 in Kokomo, Indiana. The studies showed that for a network with poor or sub-optimal offsets, PRO-TRACTS consistently resulted in an improvement in both the travel time and the number of stops in the arterial direction to which it was applied, with a greater impact in reducing the number of stops. In the SR26 case study, PRO-TRACTS achieved a performance level close to that of Synchro's timing plans, while it achieved a better performance than Synchro's plans in the US 31 case study. The magnitude of such an improvement depends on the existing performance of the network offsets. Obviously, if there is only minor room for improvement, one can only expect that much. On the other hand, when starting with a system with poor offsets, computer simulations revealed up to 16% savings in the total travel time and up to 43% savings in the total number of stops for the coordinated movement.

The case studies investigated in this research found that PRO-TRACTS has always caused an improvement in the direction to which it was applied. However, the impact on the other direction was typically an increase in the travel time. Although coordination usually takes place during the peak period when traffic is typically at its highest in one direction, there might be situations when the two direction of traffic are almost equal, in which a case, it is difficult to decide which direction to coordinate. Future research should also consider this situation by expanding the algorithm to work in two directions.

Contacts

For more information:

Prof. Andrzej Tarko
Principal Investigator
Purdue University
1284 Civil Engineering Building
West Lafayette, IN 47907-1284
Phone: 765-494-5027
Fax: 765-496-1105

Prof. Darcy Bullock
Principal Investigator
Purdue University
1284 Civil Engineering Building
West Lafayette, IN 47907-1284
Phone: 765-494-2226
Fax: 765-496-1105

Indiana Department of Transportation
Division of Research
1205 Montgomery Street
P.O. Box 2279
West Lafayette, IN 47906
Phone: 765-463-1521
Fax: 765-497-1665

Purdue University
Joint Transportation Research Program
School of Civil Engineering
West Lafayette, IN 47907-1284
Phone: 765-494-9310
Fax: 765-496-1105