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Traffic Signal Plans to Decongest Street Grids

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POLICY BRIEF

BACKGROUND AND OBJECTIVES

Methods for synchronizing traffic signals on four-directional street grids abound in the literature. Virtually all methods suffer from two flaws that undermine their ability to decongest cities. First, the methods assign distinct green times to each signal on a grid based upon local measurements of traffic flows. Adaptive strategies go so far as to change each signal's green times over the course of a rush, in response to time-varying changes in local flows. Second, all methods seek to synchronize signals to the forward motion of vehicle platoons, as if network traffic was always lightly congested and in steady state. Yet, rush periods in many real-world cities are characterized by residual queues that form at some intersections, grow long, and impede forward-moving platoons.

Rather than trying to synchronize traffic signals by optimizing green times to local conditions, we formulate a strategy that is better for the entire system. This is achieved by using a single set of green times for all signals on a grid. In the absence of residual queues, a uniform timing plan enables near-perfect synchronization for all inbound traffic heading toward downtown areas in the morning rush, and for all outbound traffic in the evenings. Inbound morning commuters, and outbound evening commuters, might see no more than a single red phase over their entire trips, even though each trip can entail two directions of travel. Rather than assume that all intersections are always undersaturated, the proposed strategy adapts to long queues within designated zones as needed, by toggling between the scheme described above and a second synchronization mode suitable for congestion.

METHODOLOGY

We suggest allocating common green durations at each intersection on a grid to achieve equal capacities in orthogonal travel directions. One might therefore assign directional green times in inverse proportion to the average number of lanes on orthogonal streets (e.g., green durations might be split equally across N-S and E-W movements if the average number of lanes on the grid's N-S and E-W streets are roughly equal).

The common green durations are synchronized to maximize vehicle trip-completion rates on the grid, and thus minimize congestion and delays network-wide. This is achieved by providing favorable synchronization to traffic flows in the dominant travel directions (inbound in the morning, outbound in the evening) at the cost of giving poor progression to lower demands in opposing directions. Common green times for a favored direction are synchronized relative to a reference intersection elsewhere on the grid. A reference intersection is chosen to be the one residing closest to the center of gravity of clustered workplace destinations. A grid can have as many reference intersections as there are downtown neighborhoods with these workplace clusters.

Once established, a synchronization plan (and green durations) is maintained over time by operating all the grid's signals on a common cycle length, as is common practice. To operate in rush-period traffic, we recommend maximizing intersection capacity by using the largest cycle length practicable. Synchronization plans are thereafter established as described below.

In undersaturated traffic sans residual queues, green phases are synchronized to the forward-motion of vehicle platoons in the favored, dominant-flow directions. The elapsed time between a green invitation at an intersection *j* and its nearest reference intersection is set (for a favored direction) in a simple way: it is the remainder obtained by dividing the free-flow vehicle trip time between *j* and the reference intersection by the common cycle length. This plan provides near-perfect (maximum one-stop) synchronization along all direct travel paths between *j* and the reference intersection.

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The strategy retains excellent synchronization on these paths when adapting to residual queues. The synchronization is altered in these cases simply by replacing vehicle trip times with the trip times of backward waves that propagate through queues, as per kinematic wave theory. This has the desirable effect of preventing favored movements from being impeded by queues. (Green phases are initiated for a favored movement only after queues immediately downstream begin moving forward.)

The strategy toggles between these forward and backward synchronization modes in zones that are subject to long queues during a rush. A simple algorithm ensures that transitions between these modes occur safely and promptly.

RESEARCH FINDINGS

Simulation tests using the AIMSUN microscopic traffic platform show that the proposed strategy mitigates network-wide congestion and delays far more effectively than even the gold standard for network synchronization. Tests also indicate that our strategy can be readily adapted to real-world conditions, including those on networks that are not laid out as rectangular grids.

Baseline tests featured two sets of 20 N-S and 20 E-W parallel and signalized streets with workplace destinations tightly clustered in the grid's center and travel demands that produced substantial congestion (13 minutes of delay, on average, during the morning rush when signals were coordinated using zero offsets.) Compared against the SYNCHRO computer program, a gold standard in the literature, our strategy reduced network-wide travel delay by more than 25% and dissipated network congestion about 20-25 minutes earlier in the rush. The proposed method continued to shine in this way (i) in the evening rush; (ii) when workplace destinations were spatially dispersed as in sprawling cities and when clustered in multiple locations as in multi-centric cities; and (iii) even when the network was distorted to form an irregular, non-rectangular grid.

POLICY AND PRACTICE RECOMMENDATIONS

Present findings underscore the value of eschewing efforts to time network traffic signals to accommodate local (intersection-specific) traffic conditions and focusing instead on prioritizing traffic movements in dominant directions of travel: inbound flows in the morning rush and outbound flows in the evening. That said, simulation tests under additional real-world complexities seem warranted. It may be especially important to test the strategy on signalized networks that do not resemble grids, such as networks with diagonal streets and intersections with more than four approach links. The task might entail identifying an underlying grid by temporarily ignoring certain of the network's links and nodes; synchronizing signals on the underlying grid; and adapting and implementing the synchronization plan on the entire (non-grid) network. Most importantly, the proposed strategy ought to be tested in real settings. The present findings suggest that field tests would be well worth the efforts.