Self-Organizing Control Logic for Oversaturated Arterials

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Abstract

Decentralized, actuated traffic signal control has many advantages, but lacks mechanisms for coordinating with other signals along an arterial. When an intersection along an arterial is near or over saturation, coordination can play an important role in preserving and utilizing capacity by preventing spillback and starvation. In this paper, rules that can be added to a base of decentralized, clock-free actuated control are proposed for managing queues during periods of oversaturation. They are part of a larger framework for developing logic that will make arterial traffic signals self-organizing, rather than organized around a common signal cycle. Features of the proposed logic include green truncation in case of intersection spillback, early green and double realization for left turn phases prone to pocket spillback due to a limited turn bay length, and dynamic coordination for groups of signals spaced too closely together to hold a normal cycle's queue. With dynamic coordination, green waves are scheduled each cycle following the critical intersection's critical arterial through phase, with non-critical intersections adjusting offsets based on queue counts and a logic that allows temporary spillback at upstream intersections in order to prevent starvation at the critical intersection, and temporary starvation at downstream intersections in order to prevent spillback at the critical intersection. Simulation tests using a benchmark network shows 45% less delay than standard coordinated control, and 4% less than an optimizing control method designed for oversaturated arterials. Simulation tests on two realistic networks also show delay reductions of 8% and 35% compared to coordinated control.

On unsaturated arterials, coordination between traffic signals is mainly concerned with providing good progression (green waves) between successive intersections, because that helps reduce delay to through traffic. Traditional signal control for arterials achieves coordination using a common, fixed cycle length, fixed offsets, and phase splits that are mostly fixed, with some ability to reallocate phase splits from a minor phase to the arterial through phases in the case of coordinated-actuated control. Many adaptive traffic control systems (e.g., ACS Lite, SCOOT, SCATS) use the same coordination logic (i.e., sharing a common cycle length and having fixed offsets), while they periodically and incrementally update timing parameters based on detector data [1].

However, when an arterial has an intersection that is oversaturated (i.e., demand exceeds capacity) for more than a few signal cycles, long queues can grow, creating queue interactions that reduce capacity through phenomena known as spillback (when a standing queue downstream of an intersection restricts discharge from that intersection), starvation (when green at a critical intersection is wasted because of an upstream red signal), and turn bay overflow (when turning vehicles cannot all fit into a turn bay, and block a through lane). Queue interaction becomes more pronounced at closely-spaced signals due to limited storage capacity on the segments between signals, and can occur even when an arterial is undersaturated. Capacity reductions due to queue interactions exacerbate oversaturation and can lead to very large delays. Because many control algorithms designed for under-saturated conditions do not account for these queue interactions, they often perform poorly when an arterial approaches capacity.

A standard way to deal with oversaturation in traffic signal control is to have longer cycle lengths in order to lower the proportion of the signal cycle that is lost for clearance and start-up associated with phase changes (typically 4 seconds per phase change). However, the gains from longer cycle lengths are small and diminishing. Moreover, in practice longer cycles often fail to yield greater capacity, because formation of longer queues during the longer red period increases the extent of capacity-reducing queue interactions. Denney et al. [2] showed that when longer cycle lengths lead to queues extending beyond turning bays (even when there is no turning bay overflow), cars destined for a turn bay will be trapped in through lanes upstream of the start of the turn bay. Once traffic starts flowing, these cars will turn out of a through lane into a turn bay, creating “holes” in the traffic flow. This is a form of starvation that results in a drop in saturation flow rate once the green time exceeds the value needed to discharge the front part of the queue (the part reaching back to the start of the turn bay).

Numerous researchers have examined the question of arterial control during periods of oversaturation. Many of them employ global optimization techniques. Lieberman et al. [3] developed a model called RT/IMPOST that uses mixed integer linear programming, with the objective of maximizing system throughput by avoiding spillback and starvation. The control policy adjusts the arterial green phase durations every cycle to control and stabilize queue lengths and to provide equitable service to competing traffic streams. Simulation tests showed a large reduction in delay compared to standard arterial control.

Hu et al. [4] developed a forward-backward procedure that adjusts green times along an arterial in order to mitigate oversaturation. The forward process aims to increase green times by searching for available green time which can be taken from side streets or conflicting phases to limit the extent of oversaturation along the arterial. The backward procedure gates traffic at intersections to prevent residual queue and spillback when available green time increase by forward process is not sufficient. Green duration changes are performed considering the impacts on upstream and downstream intersections. Cycle length is kept fixed and unchanged, but offsets are dynamic in response to changes in green time allocation. The developed control strategies were tested using simulation and showed a 12% reduction in average vehicle delay compared to standard arterial control.

Lämmer and Helbing [5] explore the idea of using decentralized control with acyclic operation (i.e., variable phase sequences and no fixed cycle length). They state that during oversaturation, control strategies should be governed by the availability of downstream storage space more than by pressure from an upstream queue. They proposed a bi-layer control strategy, with a supervisory layer designed to account for queue interactions. Simulation tests for an arterial near saturation gave good results.

Gershenson and Rosenblueth [6] propose the notion that traffic signals can be self-organizing, meaning that a global pattern or a structure suited to solving a global level problem is developed only by following local rules. Their model includes a rule to truncate green phases when spillback from a downstream intersection interferes with queue discharge, and demonstrates self-organizing behavior in simulation that outperforms fixed cycle coordination in both under- and oversaturated conditions. However, it is not clear how much of the success of their model is an artifact of the simple network used: one-way streets in a regular grid with no turning traffic and no lost time for phase changes.

This paper reports on a research effort to develop algorithms for self-organizing traffic signals using decentralized, rule-based control, for real urban traffic conditions. Self-organizing signals hold the promise of being more flexible than fixed cycle coordination in responding to real-time changes in traffic demand or capacity, better accommodating transit priority, and providing better service for pedestrians by shortening most signal cycles. A companion paper [7] describes the overall framework for arterial control with methods for adding coordination mechanisms during periods of operating under capacity. This paper focuses on control algorithms for oversaturated conditions.

Control Principles and Algorithms for Oversaturated Arterials

When an arterial is oversaturated, efficient signal control should focus on maintaining and utilizing capacity at bottlenecks in order to limit the rate at which queues grow and hasten recovery after the period of oversaturation ends. This section describes the basic principles and specific algorithms proposed for self-organizing signal control during periods of oversaturation.

Efficient Actuated Control

Standard actuated control forms the basis of self-organizing control logic. The principle of actuated control is to hold a signal green only while its queue discharges, and pass control to a conflicting phase when flow drops below the saturation flow rate. This scheme generally helps minimize delay at isolated signals by keeping signal cycles as short as possible while preventing overflow (vehicles being left in the queue when the green ends). Shorter cycles in turn mean shorter queues, creating less potential for queue interactions that reduce capacity and therefore help delay the onset of overcapacity. Actuated control is also ideal for recovering from oversaturation, as it helps ensure that queue dissipation is detected so that time can be used by phases that still have standing queues.

Control settings and detector configuration can make a difference in whether actuated signals achieve their desired switching behavior. Furth et al. [8] show the importance of using upstream extension detectors, short unit extensions, and non-simultaneous gap-out for phases ending at a barrier in order to ensure that phases switch as soon as a queue is discharged. Failing to use these features results in wasted green time which lengthens the signal cycle and therefore lengthens queues. In addition, Cesme and Furth [9] show the inefficiency of standard gap-out logic on multilane approaches, and propose a method based on multi-headways (e.g., the time for a fixed number of vehicles to pass a detector). To illustrate, for a 3-lane approach, the controller uses the time needed for 6 vehicles to pass as a criterion for terminating an active green phase. Our proposed algorithms include all of these features.

Green Truncation in Response to Spillback

When a discharging queue is blocked by a downstream queue that has spilled back to or near an upstream intersection, simple actuation logic will continue to extend the green, resulting in capacity loss, longer cycles, and greater delay [10]. For this reason, signal control sometimes includes spillback detectors located just downstream of an intersection, as shown in Figure 1a; when occupied for longer than normal for a passing car, they trigger an end to the green extension.

Several aspects of our proposed queue management logic aim to prevent spillback. However, if it occurs, the proposed logic uses spillback detectors that, if occupied while a through phase is green, will truncate the green while respecting minimum green and clearance time needs. If a phase is due to turn green, its green start will be delayed (and therefore the preceding phase held in green) until the spillback detector occupancy falls below a threshold.

Inhibiting Secondary Extensions

When an arterial is below saturation, some capacity can be wasted in order to improve progression by holding a signal green even though it has gapped out in anticipation of an arriving platoon; this is called a secondary extension. This tradeoff is part of the self-organizing logic proposed for under-saturated conditions [7], using a scheme in which the amount of green time that can be wasted per vehicle declines as the volume / capacity ratio (v/c) approaches 1.0. When v/c reaches 1.0 at any given intersection, the need to preserve capacity dominates, and secondary extensions at that intersection are inhibited. However, at intersections that are not themselves at capacity, secondary extensions can still be allowed.

Turn Pocket Spillback Prevention

Pocket spillback occurs when the queue length for turning vehicles extends beyond the length of a turn bay. During oversaturation, pocket spillback can block an adjacent through lane, drastically reducing the capacity of the through movement once the elapsed green time reaches the time needed to discharge the queue stored between the pocket spillback point and the stopline. This capacity reduction is of greatest concern when spillback affects a critical direction through phase. It is most likely to occur when traffic volumes approach or exceed capacity and cycle lengths, in response, become longer.

Two strategies are proposed for avoiding pocket spillback into a critical through lane, depending on whether the left turn movement is leading or lagging. These tactics are only applied when an intersection has been determined to be near or over capacity (intersection v/c exceeds 0.90) in order to avoid unnecessarily interfering with the signal cycle. Note that a left turn movement that could spill back into a critical through lane will not in itself be a critical movement, since it runs in parallel (not in conflict) with the critical through movement. Pocket spillback is identified when a spillback detector, placed at the entrance of a turn bay, reaches a threshold occupancy that can vary depending on the detector length, speed limit, and target speed, as illustrated in Figure 1b.

If the left turn movement prone to spillback is lagging (Figure 2a), detection of pocket spillback will trigger green truncation for its opposing through movement, subject to minimum green constraints, in order to begin the left turn movement immediately. To illustrate using Figure 2a, if the EBL queue starts overflowing into the adjacent EBT through lane, control logic terminates the green for WBT (subject to minimum green time), and starts EBL early. Note that the opposing through movement (WBT in the example) is not a critical movement. Also note that identification of what phases are critical is done adaptively, updated every five cycles, so that if repeated truncation begins to cause long queues on the opposing through movement, it can become critical and if so, will then be protected from truncation.

(a) Intersection Spillback Detector **(b) Pocket Spillback Detector**

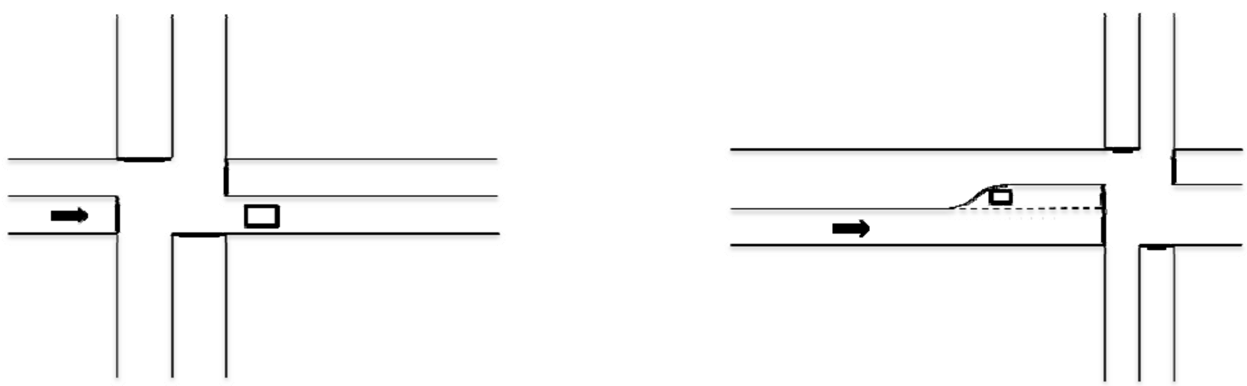

Figure 1: Spillback Detectors for Intersection Spillback and Pocket Spillback.

(a) Lagging Left and Leading Through Phase **(b) Leading Left and Lagging Through Phase**

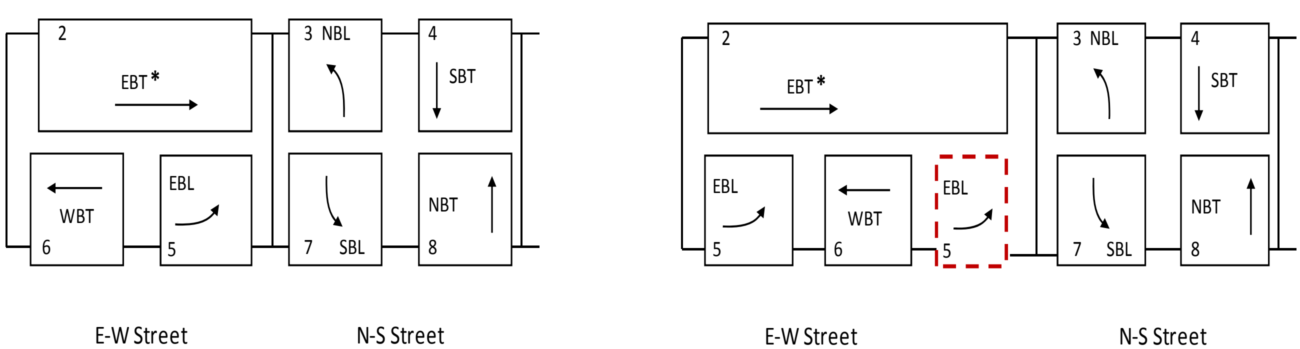

Figure 2: Dual Ring with Protected Left Turn Phasing.

Notes:

* Indicates critical arterial through movement

Dashed line indicates the dynamic second realization of the left turn phase in case of pocket spillback

If the left turn prone to spillback is leading, we propose adding a dynamic second realization of the left turn phase, shown as dashed line. That is, if pocket spillback is detected after the leading left turn phase but while the same direction's through movement is still running, the opposing through phase will be truncated and the left turn given a second realization as a lagging phase, as illustrated in Figure 2b. The lagging second realization will only be employed in cycles in which pocket spillback is detected, and only when intersection v/c exceeds 0.90.

The proposed logic for protecting against pocket spillback was tested in simulation at the junction of George Mason Drive and Columbia Pike in Arlington, Virginia. During the a.m. peak, when eastbound through is critical, the short left turn pocket on Columbia Pike eastbound often spills back into the adjacent though lane. Eastbound left turns are normally leading. Results from eight simulation replications in VISSIM showed that the proposed self-organizing logic resulted in an increase in intersection throughput of 316 vphpl (vehicles per hour per lane) for all critical movements combined compared to standard coordinated-actuated control optimized using Synchro. By turning on and off different aspects of the proposed self-organizing logic, it was determined that dynamic second left turn realizations increased critical movement throughput by 183 vphpl (the remainder of the gain was due to using efficient actuated control in place of fixed-cycle coordination.) This is a substantial capacity gain, comparable to adding a second left turn lane, which in turn can be expected to lead to a large reduction in delay. In this test, second left-turn realizations occurred in approximately seventy percent of the cycles.

Dynamic Coordination for Closely-Spaced Intersections ("Coupled Zones")

Where intersection spacing is too short to hold the normal queues that can develop during a signal cycle, allowing intersections to cycle independently can lead to spillback and starvation. To provide the necessary coordination, we propose using dynamic coordination for groups of closely spaced intersections, also called coupled zones, in which the intersections cycle together with specified offsets for their start of green, but without cycle length being specified. Coupled zones typically consist of two or three pre-defined intersections, in which the first signal in both directions has sufficient queuing space, but signals within the zone have insufficient storage capacity. Dynamic coordination is also part the logic used for self-organizing signals during undersaturated conditions, and is described in [7]. In example networks we have modeled, intersections spaced 550 ft apart or less are coupled.

Within each coupled zone, the critical intersection is identified as the intersection requiring the greatest cycle length to achieve a degree of saturation of 1.0. This identification is updated regularly based on continuous volume measurements. When the critical intersection v/c ratio is below 0.90, the arterial phases in a coupled zone are scheduled to start simultaneously, adjusted for queue clearance time needs, in order to provide good progression in both directions. When the critical intersection v/c exceeds 0.90, offsets are calculated to provide ideal progression for the critical direction arterial phase ("mainline phase") based on travel time between intersections, adjusted for the time needed to discharge the queue waiting at each signal. Queue size is determined using trap logic, with a pulse detector at the entry and exit of each road segment.

A phase is said to be activated the moment the change interval preceding it begins. Target offset for an intersection *i* upstream of the critical intersection *j* should be given by

$$Offset_{ij} = -TT_{ij} + QueueLen_{ij}\, HSat_j + Y_j - Y_i \qquad (1)$$

where $Offset_{ij}$ = difference when *i*'s mainline phase is activated and when *j*'s mainline phase is activated, TT_{ij} = travel time from *i* to *j*, $QueueLen_{ij}$ = number of cars stored between *i* and *j*, and $HSat_j$ = saturation flow headway at *j*, and Y_i = length of the change interval (yellow plus all-red) at *i*. When $Offset_{ij}$ is positive – likely because distance between coupled intersections is small – mainline green at *i* should be activated after the critical intersection's mainline green, making it easy for *i* to follow *j* in time. If, at intersection *i*, the phase preceding the mainline gaps out before the scheduled mainline activation, the preceding phase is held in green ("holding extension") until the scheduled mainline start. If the preceding phase has not yet gapped out when the mainline phase is scheduled to be activated, the preceding phase is not truncated; however, this should happen rarely because non-critical intersections tend to cycle faster than the critical intersection.

If $Offset_{ij}$ is negative, scheduled activation at *i* is calculated as an offset from the earliest time *j*'s mainline green can be activated. This earliest activation time is calculated based on the existing signal state, queue counts for the intervening phases which are translated into a minimum green interval by multiplying by the saturation headway, and commitments such as pedestrian clearance. Because queue counts are used to update minimum green each cycle, earliest activation time is a relatively good predictor of the actual activation time, especially during periods of oversaturation, when long queues make it such that minimum green becomes equal to maximum green.

If, in any cycle, *j*'s mainline green starts later than anticipated, there may be spillback as the queue advances from *i* without an open path, but such spillback will be temporary and can be tolerated because it doesn't affect bottleneck capacity. In such an event, the rule for truncating green in case of spillback is suspended until the downstream intersection has ended its anticipated green interval.

Target offset for an intersection *k* downstream of the critical intersection *j* is given by

$$Offset_{kj} = TT_{jk} - QueueLen_{jk}\, HSat_k + Y_j - Y_k \qquad (2)$$

so that the queue at *k* will be cleared just in time for the arrival of the platoon released from *j*. If the offset is positive, *k*'s activation can easily follow *j*'s; if not, *k*'s activation time is scheduled as mainline *j*'s earliest possible activation time plus the (negative) offset. If *j* is activated later than expected, there will be some starvation at *k*, but it can be tolerated because it doesn't affect bottleneck capacity. Minor starvation at a downstream non-critical intersection is accepted to protect the critical intersection from spillback, just as minor spillback at an upstream non-critical intersection is accepted to protect the critical intersection from starvation.

Maximum Green Time

When an intersection is oversaturated, demand on the critical phases exceeds the intersection's capacity to process them, and so vehicles have to be stored on those critical approaches or on the segments feeding them. Maximum green times will determine the relative share of queuing on the critical approaches. They can be set for various strategic reasons, such as which approach has more storage capacity before causing secondary queuing, or to keep streets used by transit from being blocked. Average delay will be smaller if queues are kept smaller on approaches with more lanes; however, general attitudes toward equity limit the degree to which the public will tolerate one approach getting a long queue while another has a short one.

In principle, almost any rule for maximum green time can be used. In our tests, maximum green times (*MaxGreen*) were set as follows. First, a target maximum cycle length, *CTarget*, was established *a priori*. (In our tests, it had a fixed value of 105 s, which was arbitrarily selected). It is not enforced *per se*, but is only used to determine maximum green times (which make a maximum cycle length implicit). For single lane movements such as most left turns,

$$MaxGreen = CTarget * v/s \tag{3}$$

where v = volume and s = saturation flow rate. Both v and s are updated regularly (every five cycles) based on detector measurements. For multilane approaches,

$$MaxGreen = CTarget * v/s * max(1, X / XTarget) \tag{4}$$

where X is the movement's degree of saturation, given by $X = (v/s) / (g/C)$, where g is green time and C is cycle length, averaged over the last five cycles. *XTarget* equals 1.0 for the arterial mainline and 1.1 for other multilane approaches, giving a small degree of priority to the arterial mainline. If a movement's upstream detector normally used to measure v is blocked by a standing queue for more than five seconds, its *X* is assigned the value 1.2 (the rule of thumb was followed to select XTarget values and the value of 1.2 when an upstream detector is blocked by a standing queue).

Simulation Results

The logic for self-organizing signal control described in this paper and in [7] was tested using microscopic traffic simulation in three test-beds using VISSIM [11]. Control logic was coded in C++ and integrated with VISSIM using VISSIM's application programming interface, in which at the end of every time-step the simulation program informs the control program of detector status, which then determines whether any signals should be changed, and passes that information to the simulation program which then advances vehicles for the next time-step.

Benchmark Test on Artificial Network

The first testbed was the artificial network used by Lieberman et al. to test their method of arterial control, RT/IMPOST [3]. It has seven irregularly spaced intersections, spaced approximately 250 to 1200 ft apart. Figure 3 shows the layout of VISSIM simulation model and the hourly approach volumes for cross street at each intersection.

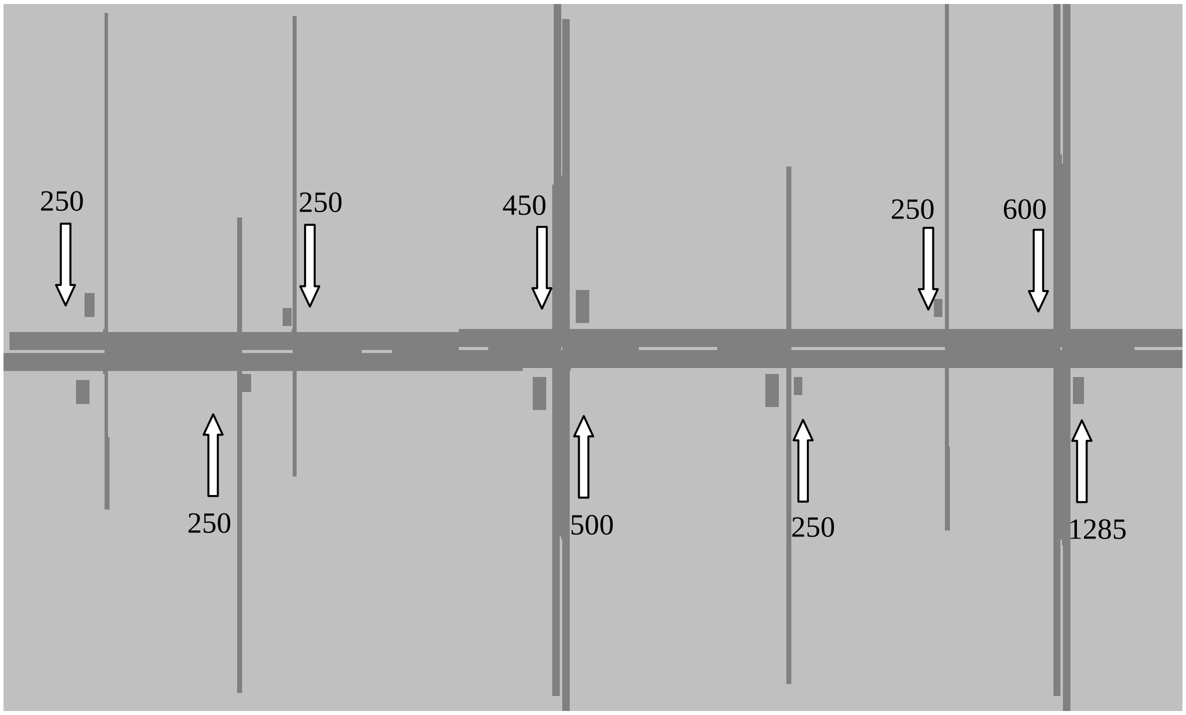

Figure 3: Layout of VISSIM Simulation Model and Hourly Approach Volumes for Cross Street.

The simulation model was calibrated to match the saturation flow rate used by Lieberman et al., who informed us that it was 1800 vehicles per hour per lane (vphpl) (private communication). VISSIM's Wiedemann 74 car-following model was used, which yielded the desired saturation flow rate with average standstill distance (ax) = 6.86 feet, the additive part of desired safety distance (bx_add) = 2.15, and the multiplicative part of desired safety distance (bx_mult) = 3.15. Simulation results indicated that the obtained saturation flow after the model calibration was approximately 1800 vphpl.

Simulations ran for 120 min after a 10 min warm-up period. Inflow volumes for a "moderate flow" period were given in [3], for which v/c at the critical intersection is 0.76; all volumes were scaled up or down for different periods using the transient demand profile shown in Figure 4. It has periods of low, moderate, and heavy flow, then rises to 128% of capacity for 30 minutes before dropping to recovery periods with 76% and 38% of capacity, respectively.

Simulation results using self-organizing logic are given in Figure 5, where they are compared to published results for RT/IMPOST and three standard timing packages, PASSER, TRANSYT, and

SYNCHRO [3]. Self-organizing results were determined as the average of five replications. The coefficient of variation of vehicle delay was 0.068 during the oversaturation period (from 45-75 minutes), 0.043 during the recovery period (from 75-105 minutes), and below 0.150 in other periods when average delay was low.

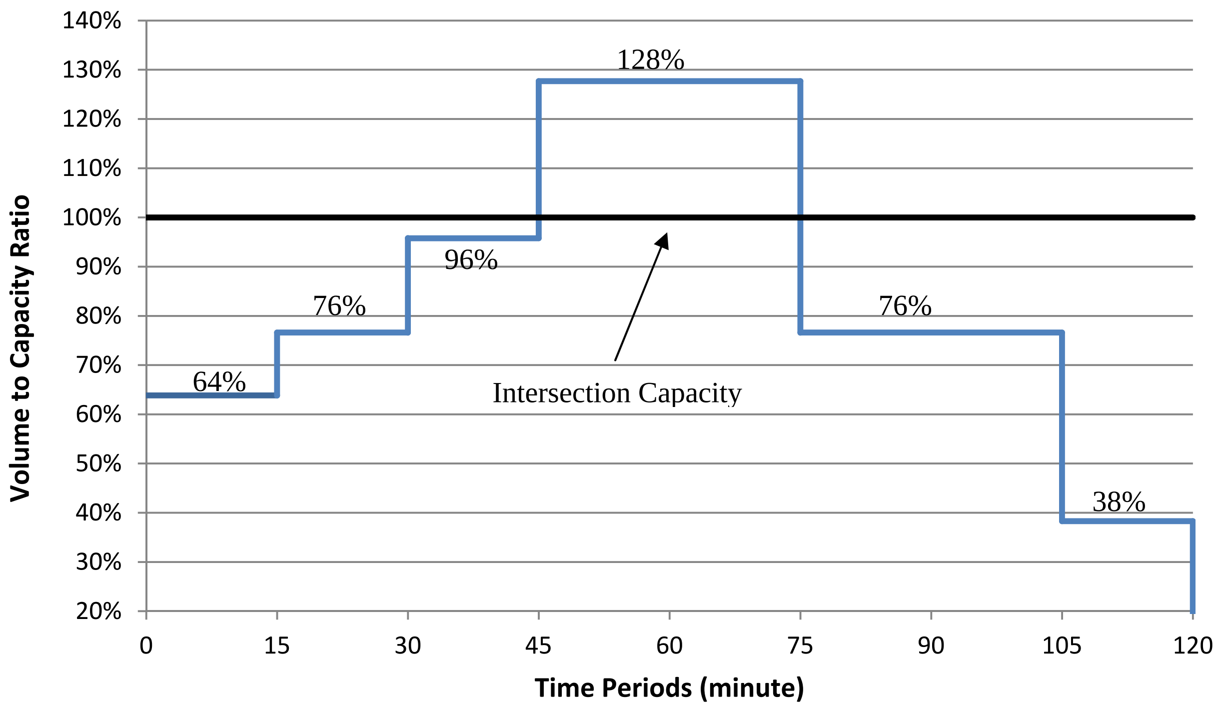

Figure 4: Volume / Capacity Ratio at the Critical Intersection versus Time for the Test Arterial in [3].

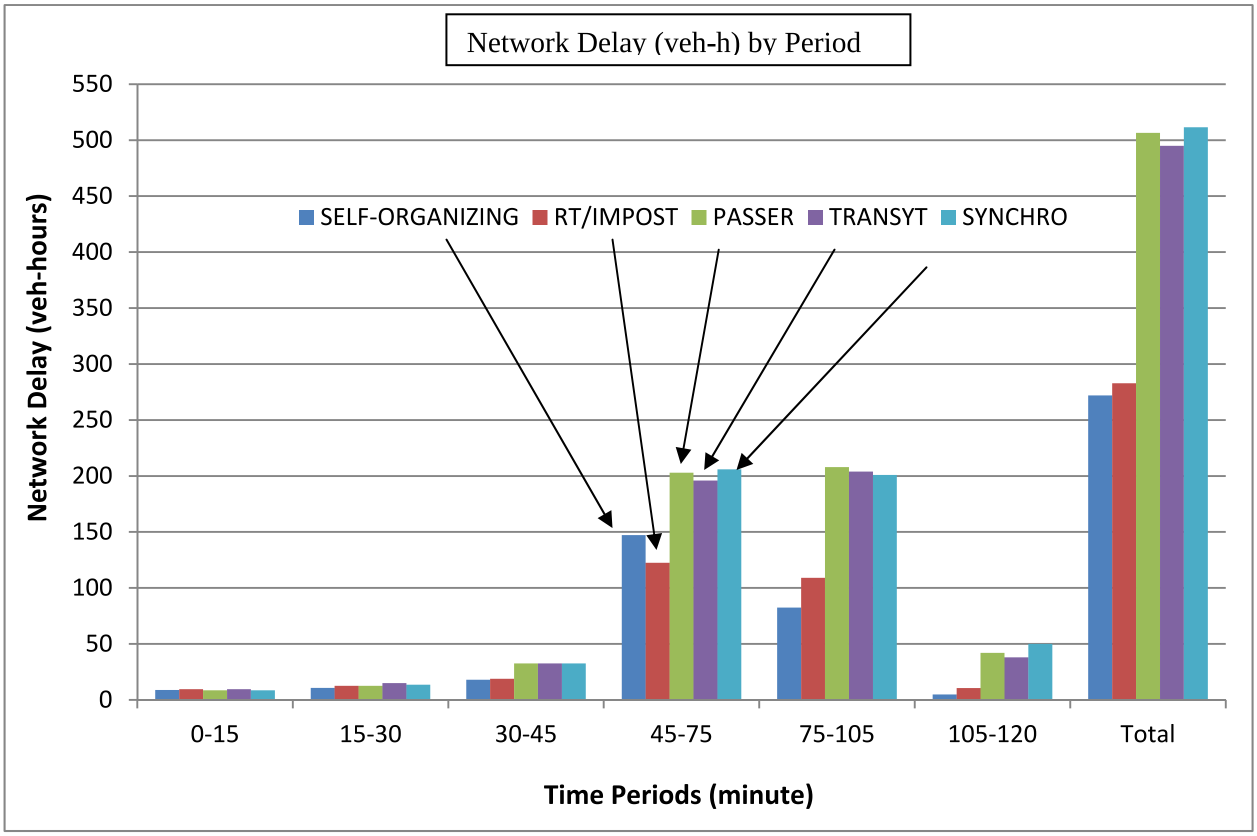

Figure 5: Network Delay (veh-h) by Period for Five Signal Control Models.

Note:
Source for all except self-organizing control is [3]

Both the self-organizing and RT/IMPOST perform much better during the oversaturated period and the recovery periods, a sign of better preserving and using capacity through better queue management. The self-organizing method has greater delay than RT/IMPOST during the oversaturation period, but has less delay during the recovery periods. Overall, self-organizing logic reduced total network delay by more than 45% compared to PASSER, TRANSYT, and SYNCHRO, and approximately 4% compared to RT/IMPOST. The relative parity of the self-organizing logic with RT/IMPOST shows good promise, since RT/IMPOST uses complex optimization calculations while self-organizing logic uses relatively simple first-generation rules that are amenable to refinement and continual improvement.

Tests on Arterials in Massachusetts and Arizona

The second and third tests are of Beacon Street in Brookline, Massachusetts and Rural Road in Tempe, Arizona. Beacon Street is an urban arterial with close and irregular intersection spacing, a tramline in a median reservation, and pedestrian phases on recall. Rural Road is an auto-dominated suburban arterial with wider and more regular intersection spacing making it more amenable to fixed cycle coordination. More detail on the modeled segments can be found in the companion paper [7].

For both streets, measured peak period volumes were scaled so that the critical intersection v/c ratio matched the transient demand profile shown in Figure 6. Results using self-organizing logic were compared to coordinated-actuated control optimized using SYNCHRO for the period of oversaturation average of five replications of each. (Tests made using timing parameters optimized for lower flow yielded even worse results.) All results are the average of five replications.

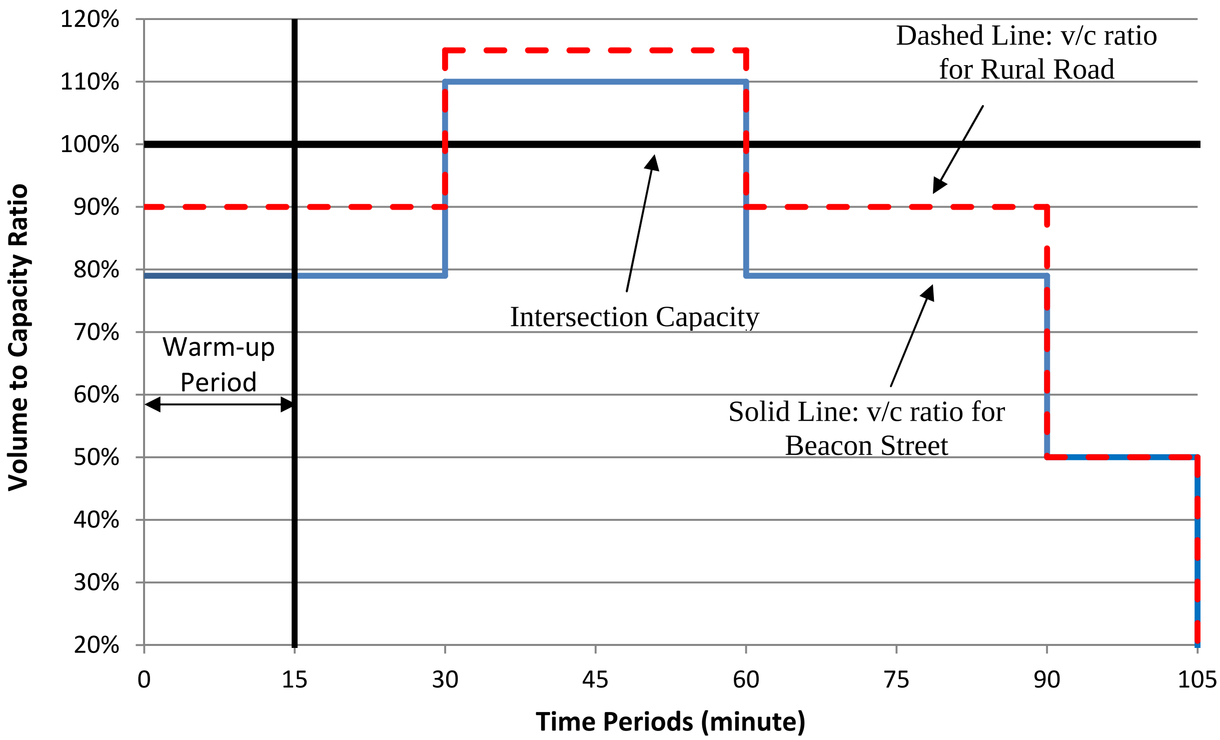

Figure 6: Volume / Capacity Ratio at the Critical Intersection versus Time for Beacon Street (Solid line) and Rural Road (Dashed line).

A delay comparison by period for Beacon Street is given in Table 1. The self-organizing method has far better performance in all periods, including the oversaturation and recovery periods, reflecting the relative success of the self-organizing method at preserving and utilizing capacity. Cycle length for coordinated control was 120 s.

Table 1: Comparison of Total Vehicle Delay for Beacon Street by Time Period for Self-Organizing Control versus Coordinated-Actuated Control Optimized for the Period of Oversaturation (30-60 Minutes).

Time Period (min)	15-30	30-60	60-90	90-105	Overall
Delay (veh-hr), coordinated-actuated	72.8	258.3	223.0	55.6	609.7
Delay (veh-hr), self-organizing	31.7	185.6	149.9	20.8	388.0
Percentage Change	-56.50%	-28.10%	-32.80%	-62.50%	-36.40%

For Rural Road, self-organizing logic reduced total delay by 7.7%, from 342.1 veh-hrs with coordinated-actuated control to 315.8 veh-hrs. This result suggests that even when an arterial has longer intersection spacing that is amenable to fixed cycle coordination and less prone to queue interaction, the fixed cycle coordination can be compromised in favor of a more flexible, decentralized logic without increasing delay.

For further insight into the operation of self-organizing logic, average cycle lengths at the Rural Road intersections are given, by period, in Table 2. During the period of oversaturation, at the critical intersection, the cycle length used by self-organizing control is close to that suggested for coordinated control by SYNCHRO (100 s); but elsewhere and during other periods, the self-organizing method uses substantially shorter cycles. Similarity between some neighboring pairs of intersections reveals a considerable amount of informal synchronization. The first two intersections listed offer an instructive example. In higher demand periods, Warner has almost double the average cycle length as Carver, indicating that most of time they coordinate by having Carver double cycle relative to the Warner ; but during the last, low demand period, they have nearly the same cycle length, indicating that in almost every cycle, Carver waits for Warner so that they cycle at the same rate.

Table 2: Average Cycle Length (s) along Rural Road by Intersection and by Period.

	Time Period (min)			
Intersection	**15-30**	**30-60**	**60-90**	**90-105**
Warner	56.4	75.8	59.8	47.9
Carver	33.5	41.6	48.5	48.2
Elliot	54.9	69.9	59.0	50.2
BellDeMar	46.8	56.9	50.6	42.7
Guadalupe[2]	77.3	95.2	83.7	56.4
Westchester	49.3	57.4	52.7	39.4
Southshore	56.3	58.8	55.0	49.8
Baseline[3]	82.0	88.3	79.6	62.6
Minton[3]	80.6	86.6	77.5	65.2

Notes
1. Cycle length for coordinated-actuated control was 100 s at all intersections
2. Critical intersection
3. Intersections at Baseline and Milton were coupled

Conclusions

Coordinating traffic signals to make sure that an arterial's full capacity is used at bottlenecks should be the first aim of arterial traffic signal control during periods of oversaturation. This research tests the feasibility of accomplishing this goal using decentralized control without fixed cycle coordination, allowing signals to be self-organizing by virtue of the information carried in queues along with peer-to-peer communication without small zones of closely spaced intersections. Tests show large performance gains compared to conventional fixed cycle coordination, and even small gains compared to optimization-based methods. Simulation results indicated that the proposed self-organizing logic reduced average delay by approximately 35% and 8% compared to an optimized coordinated-actuated plan along Beacon Street and Rural Road, respectively. Moreover, the proposed logic, which uses relatively simple first-generation rules, performed slightly better than RT/IMPOST (a delay reduction of 3.8%), which proved to be very efficient in dealing with oversaturated conditions using complex optimization calculations.

We have also proposed rules for combating pocket spillback, including allowing dynamic double realizations, which in simulation tests show a capacity increase comparable to adding an additional turning lane. These results show, for oversaturated as well as undersaturated conditions, the promise of the paradigm of self-organizing signals based on actuated control along with additional rules for arterial coordination. An interesting question for future research is how sensitive the results are to detection errors that lead to errors in determining queue length.

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