TRAFFIC SIGNAL CONTROL ALGORITHMS UTILIZING UNIQUE INTELLIDRIVE℠ CAPABILITIES

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ABSTRACT

Traffic signal control algorithms have traditionally been limited by detection capabilities. Traffic signal timings are based largely on historic turning movement volumes, and actuation comes via in-pavement sensors and video detection, which can only detect presence. In contrast, new data made available with IntelliDrive℠ is much more robust, and has the potential to provide in many cases individual vehicles' speed, heading, location, and lane. IntelliDrive℠ also allows some degree of feedback from the signal controller to the vehicle's driver. Three new signal control algorithms were developed specifically to utilize the new data made available by IntelliDrive℠ and to implement strategies that are either impossible or cost prohibitive with detector data alone. The three algorithms developed were an oversaturated conditions algorithm, a vehicle clustering algorithm, and a predictive microscopic simulation algorithm. When tested using microscopic simulation, the oversaturated algorithm reduced delay by 28% when compared to traditional actuated signal control, while the vehicle clustering and predictive microscopic simulation algorithms improved delay by 6% and 8% respectively. However, the most value came from the algorithms' ability to adapt to irregular traffic conditions. When mainline volumes were increased by 20% and 25% respectively, the vehicle clustering algorithm experienced 24.6% improvement and predictive microscopic algorithm experienced 25.8% improvement in delay over the original timing plan.

Vehicle Clustering Algorithm

The vehicle clustering algorithm (VCA) assigns groups of vehicles to platoons using k-means clustering. Priority at a signal is given to the platoon with the combined greatest time spent either waiting or approaching the signal. Once the phase has been selected, the algorithm uses location of vehicles to determine when the original queue has cleared. Once the queue clears, the algorithm then determines an optimum gap-out time based on the locations and speeds of approaching platoons for that phase. Vehicles are provided with speed advisories when applicable to ensure they stay within the "green band." Figure 1 shows the processes involved in the algorithm.

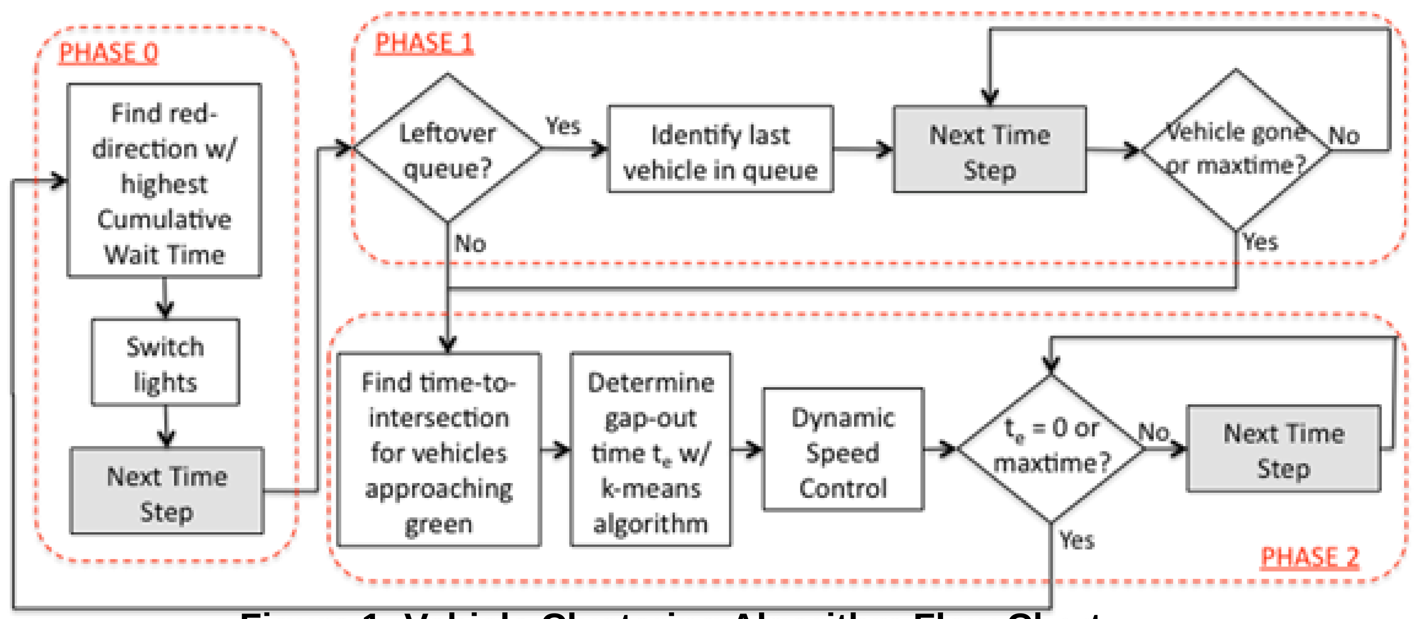

Figure 1: Vehicle Clustering Algorithm Flow Chart

The vehicle clustering algorithm was evaluated using microscopic simulation, and was tested at several different IntelliDrive℠ equipment market penetration rates. The VCA shows improvements across several metrics at 50% and greater market penetration rates.

Penetration	Average Values	Delay [s]	Stopped Delay [s]	Speed [mph]	Fuel Consumption [l]
-	*Actuated*	*58.43*	*33.48*	*27.81*	*2736.72*
100%	VCA2	54.44	22.42	28.61	3016.58
	% Difference	**-6.83%**	**-33.03%**	**2.88%**	**10.23%**
75%	VCA2	54.66	22.99	28.59	3032.74
	% Difference	**-6.45%**	**-31.33%**	**2.80%**	**10.82%**
50%	VCA2	56.12	24.99	28.34	3028.58
	% Difference	**-3.95%**	**-25.36%**	**1.91%**	**10.66%**
25%	VCA2	76.09	46.59	25.33	3058.65
	% Difference	**30.22%**	**39.16%**	**-8.92%**	**11.76%**

Figure 2: Percent Changes in Performance of VCA based on Market Penetration Rates

Predictive Microscopic Simulation Algorithm

The predictive microscopic simulation algorithm (PMSA) is a dynamic, autonomous traffic control strategy using the "rolling horizon" scheme, where the signal is optimized to reduce delay over a very short fixed period of time in the future, called the horizon. As time moves forward, the horizon "rolls" forward as well.

Traditionally rolling horizon has used upstream detectors to estimate anticipated vehicle delay. In contrast, the PMSA uses the following steps:

- Use the speed, heading, and location of all IntelliDrive℠-equipped vehicles to populate a microscopic simulation model of the intersection, as shown in Figure 3.
- Simulates vehicle positions 15 seconds into the future, including the necessary yellow and red time for a signal change.
- Repeat the simulation for every potential possible phase that the current signal timing plan allows, including the current phase.
- Select the phase with the lowest predicted cumulative as the next phase. Each phase has a maximum red time of 120 seconds.

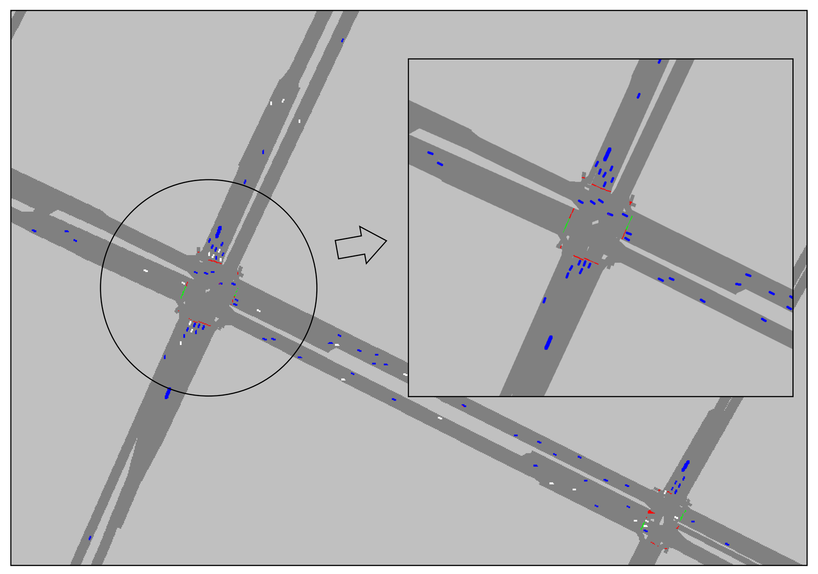

Figure 3: Populating a Model of the Intersection with Communicating Vehicles

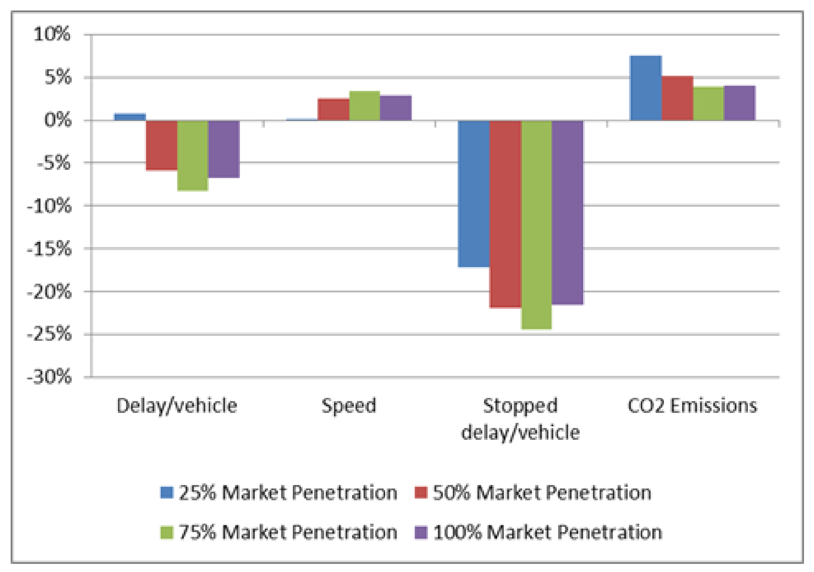

Figure 4: Percent Changes in Performance of PMSA based on Market Penetration Rates

The PMSA was evaluated using microscopic simulation, and was tested at various levels of IntelliDrive℠ equipment market penetration. The results, shown in Figure 4, indicate significant improvements across several metrics when compared to coordinated-actuated signal control.

When the same simulation was run with mainline volumes increased 25% (a realistic fluctuation), the PMSA was able to adapt to the increase in traffic, and at only 50% market penetration was able to reduce delay by 25.8%.

Oversaturated Conditions Algorithm

The oversaturated conditions algorithm uses the detailed vehicular data available in an IntelliDrive℠ environment to address signal system inefficiencies that result from spillback during oversaturated conditions. For more information, visit the ITS Development and Applications poster session (TRB Event 390), booth F06, or see the paper #11-2649 "Application of IntelliDrive℠ to Address Oversaturated Conditions on Arterials."

Compatibility with IntelliDrive℠

All algorithms evaluated in this document are fully compatible with IntelliDrive℠ as outlined in the 2009 Society of Automotive Engineers (SAE) J2735 Dedicated Short Range Communications (DSRC) Message Set Dictionary. All algorithms require vehicle speed, position, and heading. This data are required at most once per second. In the SAE J2735 standard, this data are transmitted from the vehicle at least every second, and sometimes as often as 10 times per second, as part of the Basic Safety Message.

The vehicle clustering algorithm provides speed advisories for vehicle approaching an intersection to encourage platoon formation and discourage unnecessary accelerations and decelerations. While there is no direct data element in SAE J2735 for speed advisories, one can be developed by processing other data elements. The required data elements involve the Map Data (MAP) and Signal Phase and Timing (SPAT) messages.