TRAFFIC SIGNAL CONTROL WITH CONNECTED VEHICLES

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ABSTRACT

In 2009, Americans lost 4.8 billion hours of time and 3.9 billion gallons of fuel to congestion. A significant part of this was due to lost time at traffic signals. Unfortunately, most traffic signal timing plans are designed to minimize vehicles' lost time based on the volumes seen in the past, not the present. In-pavement loop detectors and video detection are sometimes used to make small adjustments to the timing plan, but are too inaccurate, expensive, and limited in physical range too provide the level of detection needed to adapt to traffic in real time.

However, an emerging technology known as connected vehicles combines several advances such as wireless communications, on-board computer processing, advanced vehicle sensors, GPS, and smart infrastructure to provide a networked environment. In a connected vehicle environment, vehicles anywhere within 300 meters of an intersection could communicate continuously with a traffic signal through a dedicated wireless channel. The traffic control logic developed here uses this new data (i.e. precise vehicle locations, headings, and speeds) to minimize the vehicle delay and adapt instantly to changing conditions. An evaluation of the new control algorithm shows an 8% improvement in delay and a 24% improvement in vehicles' time stopped.

Background

Traffic signal control is limited by its detection technology. The most advanced traffic signals today use either induction loop detectors buried in the pavement, or video detection where a change in pixel color indicates the presence of a vehicle. Both technologies have shortcomings, and neither can reliably monitor traffic beyond a few point locations. Without better detection, traffic signal timing plans generally are designed to serve the traffic patterns measured in the past, and are unable to fully adapt to immediate traffic demand.

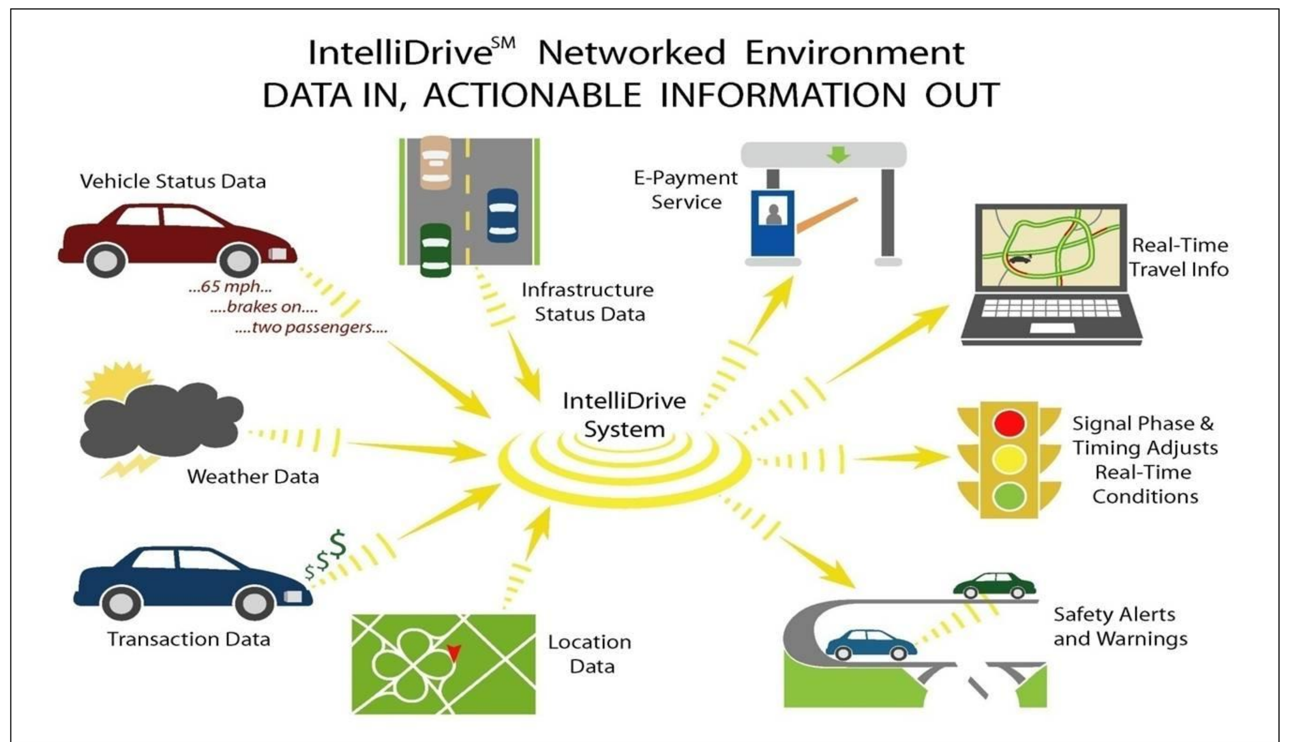


Figure 1: Overview of a connected vehicle system (previously IntelliDrive)

Figure 2: Road-side equipment collected vehicle information in the field

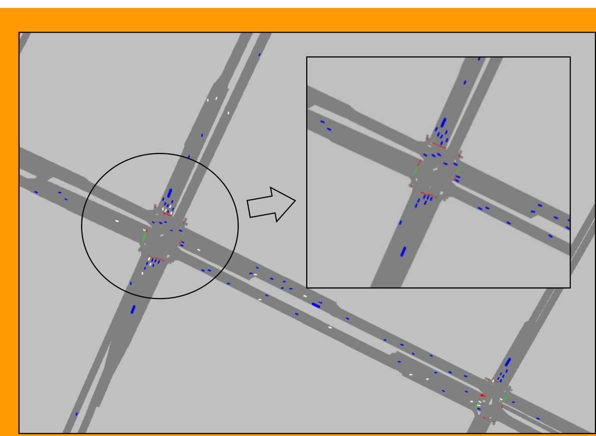
A concept known as "connected vehicles" (described in Figure 1) allows vehicles to wirelessly communicate their locations, speeds, and headings to equipment on the roadside. This information is then sent to a traffic signal, which uses the information to adjust a timing plan. A proof-of-concept test was conducted in Detroit, MI in 2009, and Figure 2 shows the equipment used to collect vehicle data from the roadside. This research is one of the first attempts to apply this technology to traffic signal control.

Predictive Microscopic Simulation Algorithm

The traffic control strategy presented here is the predictive microscopic simulation algorithm (PMSA), named because it *predicts* the locations of vehicles a short time into the future using *microscopic simulation* based on possible signal phasings and current vehicle trajectories. The algorithm uses the "rolling horizon" strategy, where the signal is optimized to reduce delay over a very short period of time in the future, called the horizon. As time moves forward, the horizon "rolls" forward as well. The algorithm consists of the following four steps.

STEP 1

Use the speed, heading, and location of all equipped vehicles to populate a microscopic simulation model of the intersection.

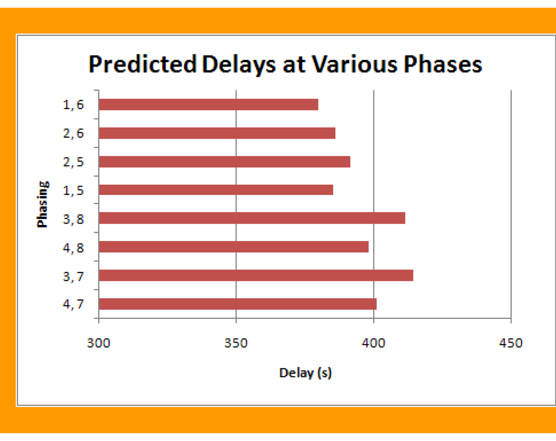


STEP 2

Simulate vehicle positions 15 seconds into the future, including the necessary yellow and red time for a signal change.

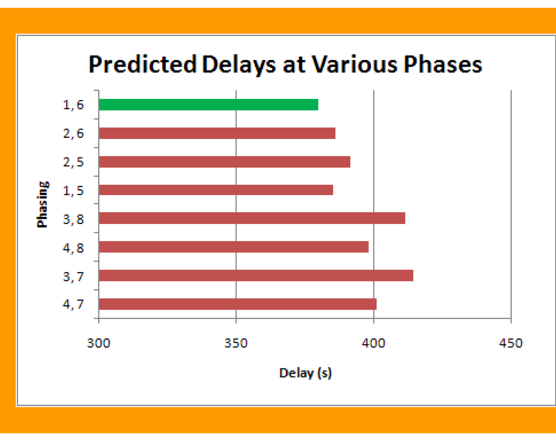
STEP 3

Repeat the simulation for every potential possible phase that the current signal timing plan allows, including the current phase.



STEP 4

Select the phase with the lowest predicted cumulative delay as the next phase. Each phase has a maximum red time of 120 seconds.



Evaluation Results

The PMSA was evaluated using microscopic simulation, and was tested at various levels of communications market penetration. The results, shown in Figure 3, indicate significant improvements across several metrics when compared to coordinated-actuated signal control. The increase in CO2 emissions is due to increased acceleration and deceleration, which is inefficient for internal combustion engines. The increase in emissions may be negated with the proliferation of hybrid and electric vehicles, which are much more efficient with starts and stops.

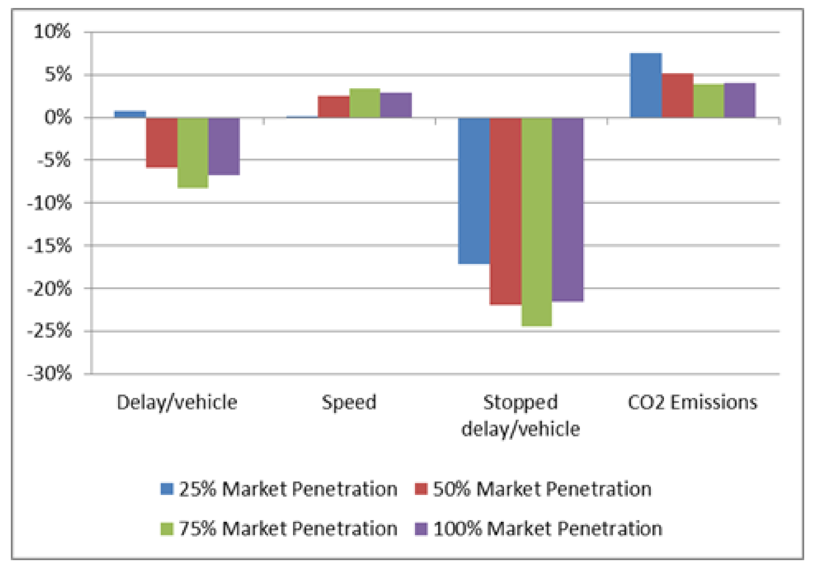


Figure 3: PMSA Evaluation Results

Conclusions

The PMSA, by using predicted vehicle movements based on their current trajectories, has the potential to outperform coordinated-actuated systems, and was able to reduce delay by 8.3% at 75% market penetration in simulations. Although the algorithm shows several limitations, e.g. long pedestrian clearance times and vehicles stops, adjustments to its objective function may address these shortcomings.