

Using IntelliDriveSM Connectivity to Improve Mobility and Environmental Preservation at Signalized Intersections

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ABSTRACT

The recent interest in IntelliDrive(SM) and vehicle connectivity has gone past previous notions of automatic collision notification, internet browsing and off board navigation. Now, in addition to applying the 5.9 GHz ITS band for cooperative collision avoidance, other applications using connectivity between the vehicle and signalized intersections have emerged. Contemporary applications enhancing fuel economy and reducing green house gases (GHG) are the subject of current research and development. Cooperation between vehicle electronics and intelligent traffic management systems could change the landscape for addressing future ECO (economical and ecological) requirements. This manuscript will outline development within one automotive supplier targeted at using connectivity as an enabling technology for sustaining the vision of smart and green transportation systems.

CURRENT SITUATION/PROBLEM DESCRIPTION

Based on a 2008 Texas Transportation Institute report for the United States, greater than \$87B and more than 4B hours are wasted per year due to inefficient transportation networks^①. Given that for the foreseeable future Americans will continue to use autos, buses and trucks for transporting goods and people, constructive solutions for improving the mobility efficiency of the nation's roadways, highways, arterials, and surface streets will be necessary. There is simply not enough land or money to continue to add lanes; the transportation system must become much more efficient.

Several techniques are currently in place to assist in mobility efficiency: ramp metering, travel time websites and actuated

intersections. The USDOT has initiated a substantial ITS research program entitled IntelliDriveSM based on the belief that connectivity between vehicles and between vehicles and infrastructure can improve the present situation even further. The connectivity solution can provide localized and network wide information allowing transportation engineers to optimize traffic flow and efficiency to improve mobility, optimize fuel use and minimize harmful vehicle emissions.

But let's bring this to a more personal level. Have you ever experienced the case when arriving at a stop light, you see no other vehicle in the vicinity, but you wait for the "normal" signal cycle? It seems like a waste of time, fuel and an unnecessary burden on the environment. Have you ever been on a major surface street with a green light ahead, only to see the light cycle change to red upon your approach, with no one present on the cross streets? Or the vehicle that is at the cross street is only waiting for right turn on red, but activates the actuated intersection, requiring you and other cars travelling in your direction to stop? What a waste! And furthermore, how about the occasions when you drive down a major urban arterial and catch stop light after stop light at each intersection. Isn't there a better way?

ROOT CAUSES

The problems described above appear to be due to mistiming between the signal phase and the arriving traffic. At un-actuated intersections, this may be due to instantaneous traffic flow patterns that are different from those used to set the signal cycles. In adaptive systems, the controller is made aware of approaching vehicles through loop detection, radar detection or CCTV image processing. Such systems may be effective at detecting vehicle presence, but aren't able to make estimates of vehicle type, vehicle dynamics (e.g., acceleration, brake pressure, yaw rate or path prediction) and

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turn signal indicators. Moreover, timing coordination between signals on arterials or system wide for urban grids may be computationally difficult to optimize and adapt for large cities.^②

COUNTERMEASURES

In this paper, we describe two methods (Red Light Pre-emption and Green Light Extension) under development to improve flow within individual signal controlled intersections and along urban arterials. We believe that the best way to optimize traffic efficiency is to provide the control mechanisms with the most accurate and timely information possible. It's not essential to have a central traffic control system^③ in place. In some large networks, that would not be optimum, in fact.

In the solutions we propose, we use IntelliDriveSM connectivity to communicate full BSM (Basic Safety Message) information to the signal controller, updated not just once, but at a 5 or 10 Hz rate. As a result, we know not only how many cars are approaching in which lane, but also whether they are accelerating, braking, and/or planning to turn (using vehicle dynamics and state). We can also gain indications about the vehicle classification. For example, two fully loaded semi-tractor trailer trucks in a left hand queue lane require longer intersection clearance times than a Chevy Camaro and Ford Mustang. This way, the traffic controller can obtain much more timely data about the area traffic status, and effectively adapt signal timing according to instantaneous traffic flow, including red light pre-emption and green light extension.

Red Light Pre-emption and Green Light Extension

IntelliDriveSM system technology has been introduced by the US Department of Transportation as a transformative connectivity system of solutions set out to improve the safety, mobility and environmental stewardship for tomorrow's livable and sustainable communities. One way to improve urban system efficiency is to minimize sustained vehicle stops at red light signals where one might more efficiently proceed if no safety issues were created.

The application described utilizes much of the system functionality that would already be in place for IntelliDriveSM based V2X safety applications including accurate vehicular positioning, two way wireless message exchange and coordination between roadside traffic control and the vehicle. This is meant to accomplish safety optimization while at the same time increased throughput to minimize wasted time, fuel and GHG emissions while vehicles are stopped at red light approaches. Such a solution will require coordination of the behavior of vehicles and

signal controllers based on information exchange including present and predicted future intersection state maps for optimum safety and efficiency.

Today's actuated intersections can already provide many elements of the fundamental functions of the pre-emption application concept. At traffic actuated intersections, the signal timing changes from cycle to cycle depending on the detected approach of vehicular or pedestrian traffic. Cycle times and green extension times are most often pre-determined by models for intersection throughput (e.g., Minimum Delay Model^④ and Hybrid Model^⑤). What we propose to do with IntelliDriveSM connectivity is to adapt the appropriate cycle times and extensions to achieve the "state optimum". This concept provides the opportunity to modify traffic control parameters based not on average but instantaneous flow data obtained from oncoming vehicle (later pedestrian, bicycle, motorcycle, and so on) broadcast messages. IntelliDriveSM data could be used either alone or in combination with other more traditional sensors in actuated intersection equipment and accommodate short term fluctuations in traffic flow.

There are standard methods for dealing with dynamic traffic flow. Minimizing delays by using statistical models for closed form or iterative optimizations to achieve the desired operational characteristics of individual intersections and networked control have been used. We will utilize IntelliDriveSM 5.9 GHz based WAVE/DSRC communications systems to transfer data about the vehicles to the intersection controller through the Road Side Equipment (RSE). In the system described, only a single simple intersection model with a fully actuated controller is contemplated. We use only one approach from each of four directions at a perpendicular intersection with a single red, yellow, green signal matched to each approach. For a visual example see [Figure 1](#). Of course, much more elaborate intersections and controller programming is possible, but our idea is to begin to understand how such simple systems interact and affect driver behavior before moving on to more complex situations. A strong requirement of the architectural approach is enabling extensibility of the algorithm to support intersections with multiple approaches and movements.

We will use fully actuated operation characterized by all phase timing controlled by detector activations and/or IntelliDriveSM Basic Safety Messages (BSMs) from approaching vehicles. In our specific demonstration case, we have what amounts to a continuous detector as IntelliDriveSM equipped vehicles broadcast their instantaneous location coordinates and velocity vectors multiple times per second. Such information may or may not trigger a red light pre-emption and / or a green light extension, depending on the signal phase timing and approach positions and velocities of other oncoming vehicles.