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# Signal priority technology to put buses on the fast track

Chen-Fu Liao and Gary Davis are University of Minnesota researchers using intelligent transportation systems technologies to make bus transportation faster and more reliable. Combining newly available technologies such as onboard GPS and advanced traffic signal control systems, Davis and Liao's bus signal priority system will subtly adjust the operation of traffic signals along bus routes so that buses carrying passengers receive fewer red signals—with minimal disruption to other traffic.

Ever since the first horse-drawn "omnibuses" went into service on the streets of European cities more than 150 years ago, urban residents have relied on buses to get them around town. Today, the bus is a key part of the public transportation system in thousands of cities around the world—and in many cities, bus systems are the only form of public transportation.

Much of the success of buses is no doubt due to the inherent flexibility and low cost of operating on regular streets rather than on rails or other dedicated facilities. This flexibility, however, comes with a price: a bus carrying 40 passengers is subject to the same congestion and other traffic conditions as a private automobile with a single occupant.

### Buses and fire trucks

The idea of preempting the normal operation of traffic signals in order to help certain vehicles move through intersections has been widely applied in the area of emergency vehicle operations. Such systems currently enjoy wide popularity because they can reduce emergency response times.

One commercial example is the Opticom system, built by 3M, which uses an infrared emitter mounted on fire trucks and ambulances to activate special sensors on signal structures. As an emergency vehicle approaches an intersection, coded pulses from the emitter tell the signal to depart from its normal timing scheme and display a green light for a fixed period of time.

*Chen-Fu Liao works on advanced traffic control techniques in the ITS Laboratory.*

However, the approach taken by Opticom and similar commercial systems has proven to be ill-suited to the needs of bus operations. In particular, the strategy of providing a green light for a fixed period of time, while suitable for emergency vehicles that travel quickly and without stopping, is problematic in the case of buses. Many bus stops are located immediately before intersections. These "near side" stops cause problems for fixed-interval signal preemption systems, because buses may stop to pick up passengers before proceeding through the intersection.

Current systems designed for emergency vehicles do not take this kind of movement into account, causing the green signal phase to expire while the bus is still picking up passengers. In other instances, a bus stop may be located on the far side of an intersection, or the intersection may have no bus stops nearby. These factors complicate the parameters of bus movement, making fixed-interval signal preemption impractical for transit vehicles.

### The priority approach

Metro Transit, the transit agency serving the Minneapolis-St. Paul metropolitan area, has recently installed Automatic Vehicle Location (AVL) systems in its fleet of buses in an effort to improve service quality. These systems

**(continued)**

## Researcher Spotlight: Gary Davis

Gary Davis is a civil engineer whose work focuses on making roads safer. But he doesn't design better bridges, or synthesize new paving materials. Instead, Davis is a leader in understanding the causes of road crashes—research that plays a key role in the ITS Institute's vision of technology enhancing safety and mobility.

*Gary Davis*

One of the most significant challenges researchers face in searching for the root causes of common traffic crashes is developing accurate and statistically valid methods of analyzing data from crash reports and records. Davis's work combines rigorous methods of statistical analysis with models of collision scenarios in order to reveal how various factors—such as vehicle speed—affect different kinds of crashes.

In a field where data generally arrives in the form of quantitative measurements, Davis's work takes on human behavior as a necessary component of understanding crash causes. With an academic background that includes a graduate degree in experimental psychology in addition to M.S. and Ph.D. degrees in civil engineering, Davis brings a unique set of skills to ITS Institute research.

Currently, Davis is contributing to several ITS Institute research initiatives, including Intersection Decision Support for rural crash prevention. In that project, Davis has led the statistical modeling of intersection crashes to identify sites for the deployment of novel crash-reduction systems, as well as predicting the possible effects of such systems after installation based on analysis of available traffic records.

Davis is also a member of the research team for the Access to Destinations Study, which examines links between transportation demand, network growth, and land use across the metropolitan Minneapolis-St. Paul region.

utilize Global Positioning System receivers to determine the exact position of each bus. This information is commonly used by bus operations centers to determine whether buses are adhering to their schedules, and can also be used to provide updates on arrival times at major transit stations.

Davis and Liao are working to coordinate the operation of computerized traffic signal controllers with the movements of buses using wireless data transmission. Two protocols currently support this type of communication: the consumer-oriented wireless computer networking protocol such as IEEE 802.11a, b, and g, and the 802.11p Dedicated Short Range Communication (DSRC) protocol designed specifically for use in vehicle-to-vehicle and vehicle-infrastructure communications.

Communication between vehicles and infrastructure systems is a very active area in ITS research, with much current work being carried out under the auspices of the federally funded Vehicle Infrastructure Integration (VII) initiative. Other research in this area focuses on using such communication to help prevent collisions and to gather better information about traffic conditions and vehicle operations.

Davis and Liao's signal priority system is fundamentally different from the simple signaling system used by emergency vehicles.

Rather than automatically changing the state of a traffic signal in response to the presence of a bus, the experimental system gives individual traffic signal controllers the ability to decide how to respond to an approaching transit vehicle. Because only one bus at a time can receive priority, the signal controller takes into account three key factors in determining which request to grant:

- The time when priority was requested;
- The amount by which any bus is behind schedule (zero if the bus is ahead of schedule);
- The number of passengers on the bus.

An embedded controller feeds this information, along with the speed and location of the bus and predicted levels of traffic delay, into a digital model of bus movements around the intersection. This model includes the location of bus stops relative to the intersection and the predicted "dwell time" of a bus halting at the stop to pick up or discharge passengers. A request for signal preemption from an emergency vehicle would overrule bus signal priority.

The model enables the signal controller to predict the state of the traffic signal at the time the bus requesting signal priority arrives at the intersection. If there is a sufficient green signal interval for the bus to pass through the intersection, then the signal controller does not alter signal timing. However, if the bus arrives at a point in the signal phase with insufficient green time to pass through the intersection, the controller determines how to alter the signal timing—either by extending the green-signal interval or truncating the red-signal interval.

Returning a preempted signal to its normal timing following a preemption request is important to avoid disruption of traffic flow. Although some previous priority strategies required several signal cycles to accomplish this, Davis and Liao's system is designed to resynchronize a signal with those of neighboring intersections in a single cycle by reducing the length of the green signal phase and ignoring preemption requests during the recovery cycle.

### Testing in the simulator

One of the chief challenges facing engineers developing complex traffic-control systems is the need for calibration and testing. Simply unleashing a set of unproven algorithms in the real world, where buses full of harried commuters negotiate rush-hour traffic snarls, is not a good option. Instead, Davis and Liao turned to the traffic simulation capabilities of the ITS Laboratory, where Liao is senior systems engineer.

The priority strategy, implemented in the C++ programming language, was applied to a model of a specific transit corridor in Minneapolis using the AIMSUN traffic simulator and historical traffic data provided by the area's traffic detector network and by manual counts at unsignalized intersections. Graduate student HunWen Tao assisted with preparation of data for the simulation. Traffic data generated by the simulation for both morning and evening peak traffic periods showed the effects of transit signal priority on buses and on overall traffic flow.

Analysis of the simulation results showed a consistent decrease in bus travel times during both morning and evening rush hour conditions, despite the heavier volumes present on the corridor in the evening. Delays experienced by non-transit vehicles, on the other hand, were slightly increased by the signal priority strategy.

### Future directions

While any deployment of transit signal priority in the Twin Cities area is still some time off, Davis and Liao say they hope to work with Metro Transit to explore ways of implementing their work to improve transit service in the Twin Cities. The next phase of their research will focus on developing a prototype system to further validate signal priority using wireless communication.

Integration of transit signal priority with the federal Vehicle Infrastructure Integration initiative will also be an important part of future work. As specialized wireless protocols for communication between vehicles and infrastructure facilities become available, Davis and Liao will work to ensure that their system is compatible.

## 2006 Advanced Transportation Technologies Seminar Series

The ITS Institute's Advanced Transportation Technologies Seminar Series began in September with presentations by Frank Douma of the Humphrey Institute of Public Affairs on the use of ITS technologies to better serve diverse populations. On September 26, senior research scientist Rob Foss of the University of North Carolina's Highway Safety Research Center spoke on the role of driver behavior in motor vehicle crashes.

Seminars are held on alternate Tuesdays on the University of Minnesota Campus and Web video streams are available both live and as archives. For more information, visit the Institute's Web site at www.its.umn.edu/seminars.

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