transit-signal priority (TSP) systems use sensors to detect approaching transit vehicles and submit a request to the intersection traffic controller which thereafter modifies the signal timing to reduce transit travel time and reduce delays. TSP has been studied and proposed as an efficient way to improve transit schedule adherence, to reduce transit operation costs and to improve customer ride quality.

Unlike signal pre-emption, which interrupts the normal intersection signal process to provide high priority for emergency vehicles or at a railroad crossing, TSP modifies the normal signal operation in order to accommodate better service for transit vehicles. Various technologies have been developed for bus priority including optical/light, inductance loop, sound, radio and satellite-based detection systems. The TSP planning and implementation handbook provides more information on the subject.

Wireless communication systems have made rapid progress in the past decade and are commercially available in many forms. Signal-priority requests for transit or emergency vehicles can potentially be sent to the signal controller through Wi-Fi or other vehicle-to-infrastructure communication protocol such as the one described in the Vehicle Infrastructure Integration (VII) architecture. The city of Minneapolis recently deployed a Wi-Fi system to provide residents, businesses and visitors with wireless broadband access anywhere in the city.

The Los Angeles County Metropolitan Transportation Authority (LACMTA) has implemented wireless technology in a transit-signal-priority system along a corridor using the IEEE 802.11b protocol. LACMTA recently awarded a multimillion-dollar project to design, deploy and provide ongoing operation and maintenance of bus-signal priority systems at over 200 signalized intersections. Pace, a suburban bus division of the Chicago regional transportation authority, recently selected a contractor to implement wireless TSP systems along three bus routes.

Several years ago, Metro Transit in the Twin Cities performed an evaluation of the Opticom infrared system for providing signal priority to buses on Lake Street in Minneapolis. The Opticom system, ideally designed for emergency-vehicle pre-emption, was not able to adjust the trigger timing when buses approached a nearside bus stop. Buses often missed the provided green period when they were ready to depart after passenger boarding or alighting at nearside bus stops.

**LOCATION NOW KNOWN**

With the recent installation of an AVL system on its fleet, Metro Transit now has the capability to constantly monitor bus locations with respect to their schedules, and to provide more reliable transit service to riders. The AVL system added significant value in transit operation and management. Bus location, travel time, delay and other traffic information are collected and integrated to assist traffic-operation management and to provide additional information to the traveling public.

Minnesota is one of five communities nationwide to receive funding through the U.S. Department of Transportation’s Urban Partnership Agreement (UPA) program to implement and deploy innovative applications to reduce traffic congestion in the Twin Cities. As part of the UPA program, Metro Transit is working with consultants to design and implement a TSP along the Central Avenue or Nicollet Avenue corridors running in parallel to I-35W. Metro Transit’s new wireless TSP will
stop needs to be considered by the signal controller to provide signal priority to the bus in a timely manner.

For the far-side bus stop, a bus passes through the intersection first before its arrival at the stop. Bus travel time to the intersection needs to be considered when providing priority. After receiving a signal-priority request from a bus, the signal controller has to determine whether or not to grant the request. Only one bus gets priority service if there are multiple requests at the same intersection from buses on different approaches. The signal controller ignores all bus-priority requests if there is an emergency vehicle pre-emption request. The signal controller can include the request time, schedule adherence and number of passengers with user-selectable weighting factors for providing signal priority.

**Virtual Ride**

A segment of Franklin Avenue consisting of 22 signalized intersections in Minneapolis was selected for a simulation study. Estimated passenger arrival rates were used to forecast bus dwell time at each stop. A Poisson process was developed to estimate passenger arrivals and boarding or alighting at each stop in the simulation.

The purpose of providing signal priority to a transit vehicle is to minimize its waiting time at intersections. It is thus important to know how much time buses spend waiting at red lights as compared to their total travel times. Collecting actual bus delay times at red signals provided information on the degree of improvement that bus-signal priority could provide to the existing bus operation. By comparing the average intersection delay to the average bus travel time, a bus generally spent on average around 18% to 23% of its travel time (3.3–4.8 minutes) waiting for signal lights at intersections along the study route.

A microscopic traffic simulation package was used to study the effect of TSP. A C++ program also was developed to interface with the simulator. Bus location, speed and bus-stop information was sent to the external bus-signal priority application, and a priority request was sent back to the simulation model. The traffic model was calibrated in order to compare the measures of effectiveness before and after applying the signal-priority strategy. Vehicle travel time, delay, speed and number of stops were measured to evaluate the effectiveness of the transit-priority strategy.

Simulation results indicate that a 12–15% reduction in bus travel time during a.m. peak hours (7 a.m.–9 a.m.) and a 4–11% reduction in p.m. peak hours (4 p.m.–6 p.m.) could be achieved by providing signal priority for buses. Average bus delay time was reduced in the range of 16–20% and 5–14% during a.m. and p.m. peak periods, respectively.

**Hardware on board**

A prototype TSP system was developed and tested to val-
update the signal-priority algorithm. The prototype systems consist of an onboard unit (OBU) and a roadside unit (UMN TSP). The onboard embedded system interfaces with bus AVL and automatic passenger count (APC) systems to obtain vehicle location and passenger count information and then generates a signal-priority request through the wireless communication interface. Door-opening status can be accessed through digital I/O.

The roadside embedded system, or UMN TSP processor, contains the TSP algorithm, traffic-controller interface and wireless communication interface. The roadside system processes the request information from the OBU and includes the signal-controller phase and timing information to determine the appropriate timing to trigger the signal-priority request on the controller.

The signal-priority request output on the roadside equipment was connected to a pre-emption input channel on the signal controller through wiring in the controller cabinet. A program with corresponding delay, dwell, maximum call and extension time of the traffic controller also was configured and activated to accept external pre-emption inputs. The prototype system was deployed and tested at an intersection near the university campus to validate the bus-signal priority algorithm with a green extension and red truncation (or early green) strategy.

The OBU was placed inside a minivan with a GPS receiver and radio antenna mounted on top of the vehicle to simulate a transit vehicle. The OBU interfaces with the GPS and wireless communication systems transmitted vehicle location and other information (such as vehicle ID, route ID, passenger counts, door opening status and so on) to the roadside equipment. The UMN TSP system continuously monitored the vehicle location when it traveled within the communication range of the wireless network. The UMN TSP unit generated signal-priority requests to the traffic-signal controller as called for by the TSP strategy implemented in the embedded system.

The wireless-signal-priority strategy was tested using the Minneapolis Wi-Fi network and a pair of 5.9-GHz DSRC radio modules manufactured by Denso Corp. The DSRC radios
have a coverage distance of about 0.4 mile and data latency of around 3 to 6 milliseconds, while the Wi-Fi network has a data latency ranging from 10 to 40 milliseconds at the test sites.

The field test results demonstrated that the test vehicle was able to successfully submit a signal-priority request through the wireless network as it was traveling toward the intersection instrumented with the UMN TSP. The vehicle initiated travel from a location outside the DSRC radio coverage range. As soon as the vehicle moved within the wireless communication range, the adaptive-signal-priority algorithm began to monitor the location and speed of the test vehicle and submitted a request for priority through the roadside interface to the traffic-signal controller. The traffic-signal controller was able to provide a green extension or red truncation (or early green) to the qualified vehicle as it approached the intersection. The signal-priority request is dropped when the test vehicle passes the intersection or when the call duration reaches the maximum call setting.

Using the Minneapolis Wi-Fi network for TSP application can certainly reduce cost by taking advantage of the existing infrastructure. However, availability of data bandwidth, quality of service, variations of communication latency and concern for data security need to be addressed when choosing the Wi-Fi technology. The DSRC radio is potentially a good option demonstrating excellent performance (short range with fast data communication rate), but the availability of DSRC hardware is currently limited. It is still uncertain whether there will be a national “rollout” of DSRC.

The UMN TSP system uses wireless technology to establish data communication between transit vehicles and roadside systems. It is not limited to any particular wireless technology. Evaluation of the TSP performance along the corridor is ongoing. Performance will be compared with the results from other deployments. The UMN research team will investigate the reliability and explore the limitation of the TSP configuration. The team next plans to examine and evaluate transit-control systems that will be installed on buses in order to compare performance.

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Liao is at the University of Minnesota, Department of Civil Engineering, Minnesota Traffic Observatory.

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