

Traffic Signal Priority Through Signal System Control -- The Glendale, California Outlook -- Wayne Ko, Glenn Grayson, Scott Carlson

Background

Glendale, the third most populous (200,000) city in Los Angeles County, is located seven miles northwest of downtown Los Angeles in the foothills of the San Gabriel Mountains. Glendale is situated among four major freeways providing direct and convenient access to the Los Angeles metropolitan area. There are approximately 220 signalized intersections in the City, most of



Figure 1
Downtown Glendale

which are under the control of a BI Tran QuicNet/4 distributed traffic signal control system located in the Glendale traffic operation center (TOC). The City's signalized intersections are equipped with Type 170 controllers with BI Tran 233 firmware. Data communications between field equipment and the TOC are carried on City-owned twisted-pair interconnect cables.

The City of Glendale has its own transit system, the *Beeline* (see www.glendalebeeline.com). Started in 1984 serving the downtown area (Figure 1), the *Beeline* has grown to a citywide system with an annual ridership of 2.2 million passengers. It is currently operating a fleet of 30 buses, mostly mid-sized clean fuel vehicles with a maximum capacity of 42 passengers (Figure 2). Service level includes six local routes covering Glendale and vicinity, as well as two express routes serving the Glendale Transportation Center (GTC). The GTC is an intermodal terminal providing *Beeline* riders with connections to Metrolink commuter rail, Amtrak, and taxis, as well as regional buses operated by the Los Angeles County Metropolitan Transportation Authority (LACMTA).

The need for signal priority

During peak periods, recurring congestion and frequent incidents on the freeways result in heavy congestion on the surface street system as drivers seek alternate routes. The surface streets in the downtown area are additionally impacted by traffic generated by over 7,000,000 square feet of office developments and a regional shopping center, the Glendale Galleria. In 1998, a study was conducted to determine various components of travel time on the *Beeline*^a. The study identified and measured the time spent by *Beeline* buses in various aspects of service, including the amount of time spent waiting at traffic signals. The results of the study indicate that the *Beeline*, especially when in the downtown area, encounters measurable signal delay, accounting for about 12 percent of total running time. By the year 2010 when the Glendale downtown area is fully developed, an estimated 44,920 additional daily trips above existing levels are expected^b. It will not be possible to totally mitigate these impacts with traditional physical intersection improvements. An aggressive mitigation program involving vehicle trip reduction measures, including the improvement of transit services in order to increase ridership, will be necessary to maintain traffic flow. Armed with this information, the City embarked on a project to achieve reductions in travel time by implementing a traffic signal priority (TSP) system on major transit corridors.

A successful transit priority system will enhance transit performance by granting additional and/or reallocating green time at signalized intersections to transit vehicles. In turn, this can contribute to improving the management of the existing transit services, and to making the existing system more cost effective and efficient. The transit priority system can benefit transit travel by reducing signal delay time, improving transit schedule adherence and reliability, promoting on-time performance, decreasing the overall travel time, and increasing ridership and rider satisfaction. Other potential benefits include lowering transit fuel consumption by reducing transit vehicle idling time and delaying capital expenditures by better utilizing the existing transit fleet. After all, increases in transit usage will ultimately reduce private vehicle travel and thereby have a net positive effect on traffic congestion.

To improve the operations of its *Beeline*, Glendale applied for and received funding from the LACMTA to implement a transit priority pilot project. This paper discusses this pilot project now in progress. Currently throughout Los Angeles County, high emphasis is being placed on the use of signal synchronization and bus speed improvement projects to provide additional person-trip capacity on surface streets. In fact, the Glendale TSP project is one of several TSP pilot projects currently being funded by the LACMTA in an effort to identify which systems can best provide TSP for transit. The LACMTA is also sponsoring other TSP projects:

1. The City of Los Angeles is operating a TSP system along two corridors, Ventura Boulevard and Wilshire Boulevard. The system utilizes LA's in-house central traffic control system (ATSAC) and mid-block inductive loops. Buses detected are granted early or extended green signals at the upcoming traffic signal via control commands issued by ATSAC.

2. The LACMTA is developing a multi-jurisdictional TSP system to be implemented in Los Angeles County, the City of Los Angeles, and the City of Inglewood. The buses will be equipped with the logic to determine schedule adherence and will utilize wireless technologies to communicate directly with the controller at the signalized intersection.
3. The City of Long Beach is in the process of securing services of a design-build contractor to make a number of improvements along Anaheim Street. These improvements are targeted at increasing overall transit speeds, reducing travel time and reducing the necessity to add vehicles to combat congestion. A transit priority system is to be designed by the contractor and may interface either with the signal system, or with standalone intersections.



Figure 2
Glendale *Beeline* bus (and MTA bus)

In addition, the City of Glendale Fire Department has long been seeking a traffic signal preemption system for its emergency response fleet. With the continued increase in daily traffic, the response time required by emergency vehicles to navigate through city streets is degrading. During peak periods, with vehicles queuing at signalized intersections, the raised medians on major thoroughfares restrict the ability of emergency responders to cross over into traffic lanes in the opposite direction, which may be unoccupied. A traffic signal preemption system will reduce Code 3 (“lights and siren”) response times by providing the appropriate green signals along an emergency response route. Other well-known advantages of a preemption system are increased traffic safety by eliminating the need for emergency vehicles to enter signalized intersections during a red signal, and the reduction of wear and tear on emergency vehicles through a reduction in “stop and go” driving. Since both transit priority and emergency vehicle preemption involve granting extraordinary signal right-of-way to an eligible vehicle, the City believed it would be logical and cost effective to deploy one common system that has the capability to handle *both* functions. The LACMTA grant was augmented with Glendale Fire Department Capital Improvement Program funding to expand the system concept to cover both functions.

Pilot Project Study Area

This traffic signal priority demonstration project is a small-scale deployment limited to a portion of downtown Glendale, where such system would provide the most benefits to transit services. The main purpose of the project is to demonstrate the feasibility of the technologies and

innovations used in an integrated system that will allow for partial and full signal priority treatment at selected signalized intersections. The system, once proven to be effective, can be inexpensively and easily expanded to include the entire QuicNet/4 coverage area.

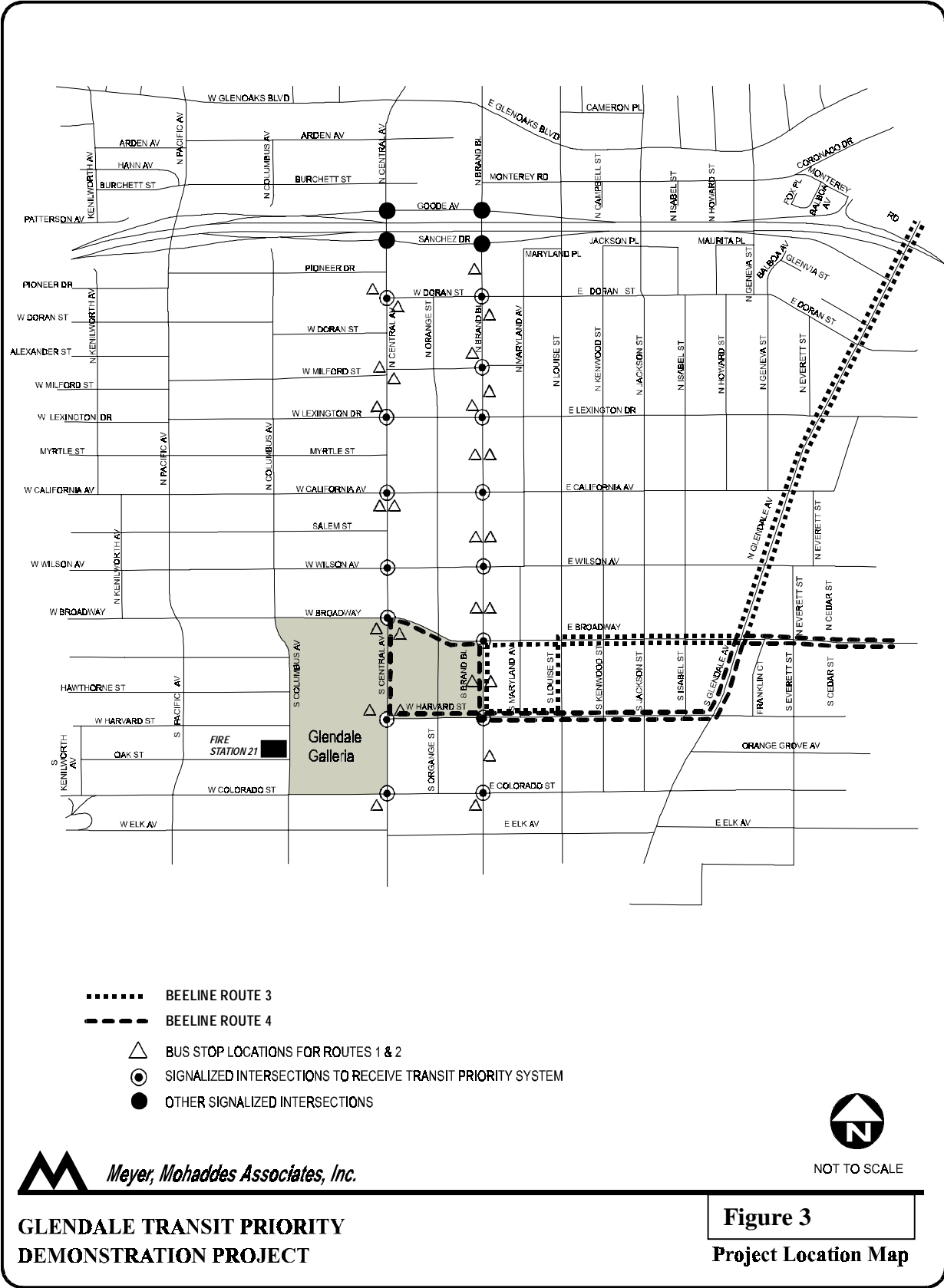
The area selected for the Glendale TSP Pilot Project incorporates 17 signalized intersections along two major transit corridors (North Brand Boulevard and North Central Avenue) in the downtown area (see Figure 3, *Project Location Map*). The pilot project will grant TSP to four fire department emergency vehicles and twenty *Beeline* buses through the 17 intersections along *Beeline* Routes 1 and 2. To eliminate the need to coordinate the project with other agencies, buses operated by LACMTA and signals operated by Caltrans (i.e., freeway-ramp intersections) were not included in this pilot project.

What does the City want for a signal priority system?

Glendale currently has an “off-the-shelf” system for emergency vehicle preemption at two signalized intersections along Verdugo Road in the northern part of the City. That system basically involves equipping an emergency vehicle with a transmitter that would emit optical signals directly from the vehicle to a receiver located at the next upcoming intersection. The controller at the next intersection will then actuate a green signal for the approaching vehicle. That system is functioning well and it accommodates the needs of the emergency responders at those two locations. However, in other areas of the City, especially in downtown, there are a number of factors that make this type of distributed signal priority system less than ideal.

Most of the traffic signals in downtown, as in many other mature communities, were constructed many decades ago, when the area was first developed. Even though many signalized intersection’s hardware, such as the controllers, have been upgraded to accommodate protected/permissive left-turn phasing, the underground conduit systems supporting the signalized intersection are extremely old and they are already at or well above the maximum recommended fill ratio (per National Electrical Code and the California Department of Transportation standards). In many cases, it is impossible to install new wiring for additional field equipment, such as optical receivers, without installing entirely new conduits. Moreover, Brand Boulevard in the downtown area is designated as one of the “signature streets” in the City with uniquely designed decorative sidewalks and streetscapes. It is also located in the central business district with very heavy vehicular and pedestrian activities. Installing underground conduits for the sole purpose of accommodating signal priority equipment at local intersections would be very costly. It would greatly interfere with normal activities in the central business district, creating unnecessary negative financial and political impacts. In addition, some of the downtown intersections are very closely spaced. Finally, the City has the rare opportunity to receive grant funds to implement a signal priority system. It is the intent of the City to develop a system that can be expanded easily in the future with minimum incremental cost. Installing and maintaining large amounts of field equipment at the local intersection level would not be feasible without much larger funding commitments.

The City therefore desires to develop a centralized traffic signal priority system, whereby the QuicNet/4 system located at the TOC provides the necessary functions. The TSP will wirelessly monitor the positions of all selected transit vehicles using Global Positioning System (GPS), utilize a prediction algorithm to calculate the bus arrival time at downstream intersections,



compare the predicted arrival times with the bus schedule, and provide signal priority as needed utilizing the existing signal interconnect communication infrastructure between the traffic control center and signal controllers at local intersections. Similarly, it will also provide signal preemption for emergency vehicles. With this centrally-controlled signal priority system, additional field equipment installations at traffic signals are not necessary and vehicles are not constrained to specific routes. The system can easily be expanded to other QuicNet controlled signalized intersections in the future with minimal effort and resources.

How is the system being deployed?

At the beginning of the project, the transportation consulting firm Meyer, Mohaddes Associates, Inc. (MMA), was selected to conduct a traffic signal priority feasibility study for the City of Glendale. A number of commercially available signal priority systems and associated technologies were reviewed during the process. The study was completed and subsequently a Request for Proposals was issued to a number of vendors. The City was anticipating that various vendors having complimentary products might form partnerships to develop a unique turnkey system that would be applicable to the City's environment. Unfortunately, none of the proposals received adequately addressed all specific issues of the City. After a thorough evaluation of the implementation options, the City decided that the best deployment strategy for this demonstration project would be to undertake the entire project itself with the assistance of consultants for technical issues. The City functions as a project administrator and system integrator, with MMA retained to provide project management, detailed design, oversight, deployment and system testing services.

Members of the Implementation Team

With the assistance of MMA, the City selected a team of designers / developers / implementers to undertake the various component subsystems of the project.

NextBus Information Systems

NextBus is an application service provider that monitors transit vehicle locations using GPS technology and provides arrival time predictions at bus stops on a real-time basis. The City elected to bring NextBus into the project because of its already well-developed arrival prediction algorithms (see www.nextbus.com.) NextBus basically has two responsibilities:

1. Installs a small package of equipment on board the transit vehicle, called the NextBus Tracker Suite (see Figure 4, *NextBus Tracker Suite Unit*.) The Tracker has a GPS-based receiver which produces highly accurate location coordinates of the tracked vehicles and a Cellular Digital Packet Data (CDPD) based modem through which the assembled data packets are transmitted wirelessly. In addition to the Tracker unit inside the bus, two antennas are mounted atop the vehicle – one for the GPS receiver and one for the CDPD radio (see Figure 5, *External Antennas*.)
2. Utilizes a central server to gathers the transit vehicle's current position, speed and heading and calculates the distances to upcoming target points along its route. It then utilizes an algorithm that weights several current and historical factors, and produces prediction of arrival times to the nearest 1 second for the target points



Figure 4
NextBus Tracker Suite Unit



CDPD Antenna

GPS Antenna

Figure 5
External Antennas

For this project, NextBus has enhanced its standard product (i.e., bus stop arrival predictions to the nearest one minute) to also provide the more precise stop line arrival predictions (to the nearest one second). Having these advance predictions is the most important element of a centrally directed transit priority capability. The information must be “in-hand”, and accurate, at the signal system far enough in advance of the bus’s arrival for the signalization to make intelligent advance decisions about how to adjust timing for the arriving bus.

Iteris

Iteris developed the Schedule Comparer and Traffic Signal Priority Decision Maker (SCTDM) for this project, which is a standalone software program running on a dedicated microcomputer platform. The SCTDM is located in the TOC and networked in with the QuicNet/4 system. The SCTDM continuously takes care of 3 tasks in a multitasking manner:

1. Passes along every vehicle position report generated by the tracked buses and emergency vehicles to the QuicNet/4 signal system for subsequent use in the graphical map display at the console.
2. Reads and filters the predicted bus-at-stopline arrival times, compares the bus's location to its on-time scheduled position, and identifies buses that are behind schedule. The SCTDM then passes this information on to the QuicNet/4 system for actual system-to-controller signal priority command.
3. Tracks emergency vehicles and, for those that are in Code 3 response mode, it makes real-time decisions about which signalized intersections need to be preempted for those approaching vehicles. The information is passed on to the QuicNet/4 system for actual system-to-controller preempt command.

BI Tran Systems

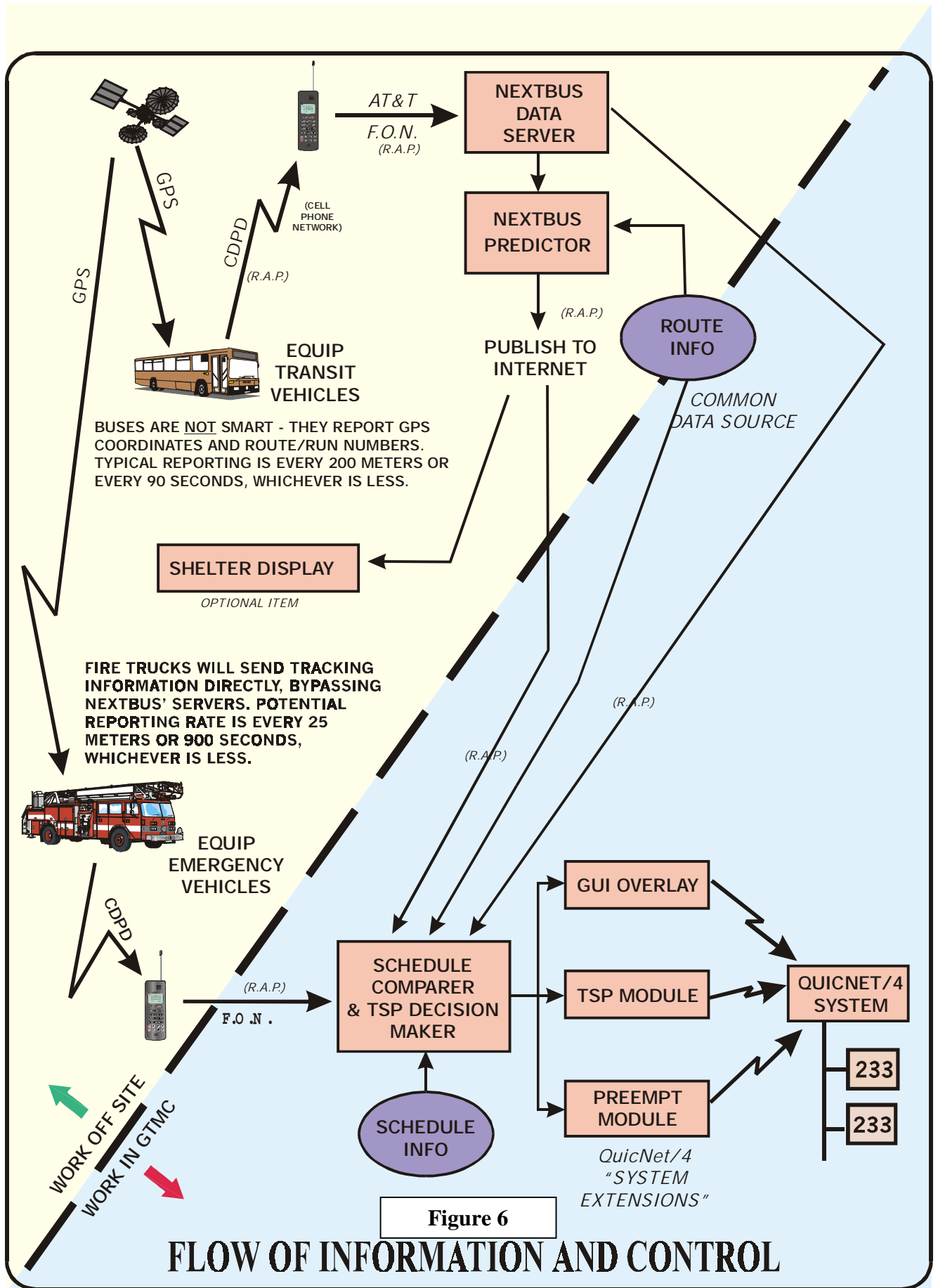
BI Tran Systems, the developer of the QuicNet/4 centralized traffic signal system, was a "natural" choice for the team to provide selected programming enhancements. BI Tran's role in the project is to modify the signal system software to provide 3 additional capabilities:

1. All vehicle location report messages received by QuicNet/4 are to be plotted and updated in real time on the map display of the QuicNet/4 graphical user interface. Both transit vehicles and emergency vehicles can thus be observed by the system operator, for better understanding of the TSP actions that QuicNet/4 is implementing.
2. The system will receive messages that identify individual emergency vehicles which are engaged in a Code 3 sortie, and will individually (and just-in-time) command the traffic signal controller at the intersection being approached to enter an EV preempt sequence.
3. Third, and most difficult, the system will process messages received from the SCTDM that identify behind-schedule buses, and their expected *exact* arrival time (to the nearest second) at upcoming signalized intersections. The signal system will send instructions to a specific target signalized intersection where the local controller will make a determination as to whether to hold an existing green signal or attempt to end a red signal a few seconds early so as to get the late bus through the signal with less delay.

How does the TSP system work?

Step-by-step, the transit priority portion of the TSP system accomplishes its mission using the following sequential steps, as diagrammed in Figure 6, *Flow of Information and Control*:

- The Tracker Suite on board a *Beeline* transit bus receives an update of its X-Y-Z position from 3 or more satellites, and it transmits a coded message to NextBus containing its bus route / run and its precise latitude/longitude position. The Tracker Suite repeats this each time it moves 200 meters away from its position at its last transmission.
- For each new position report received, NextBus produces and sends a message to the Iteris SCTDM containing exact, predicted arrival times for that bus at its next 3 upcoming signalized intersections.



- The SCTDM checks the actual bus position versus its scheduled position to determine whether it is behind schedule. When a bus is later than “x” minutes (a parameter settable by the user), the NextBus-produced predicted arrival times are passed along to the BI Tran QuicNet/4 signal system.
- The QuicNet/4 system immediately passes down to the next upcoming signaled intersection controller the information that a “late” bus is due to arrive at a specific point in time.
- The local intersection controller calculates and compares the “late” bus’s arrival time to its approach’s current green split location (i.e., the location of the green window for that approach). The local controller will then attempt to adjust that green split location by up to 10 seconds (again, a user-settable parameter) to better accommodate the arriving bus. The adjustment may be starting that green earlier, or keeping that green longer, combined with placement of a continuous call for that phase so that it cannot gap out.

Although the emergency vehicle preemption portion of the TSP system uses many of the same communication paths, the actions are quite different. The step-by-step sequence of decisions for preemption are as follows:

- The Tracker Suite on board an emergency vehicle receives an update of its X-Y-Z position from 3 or more satellites, and it transmits a coded message directly to the Iteris SCTDM containing its vehicle ID# and its precise latitude/longitude position. The Tracker Suite repeats this every 5 seconds when the vehicle is moving, and every 15 minutes when not. Also included in the coded message is a data bit toggle switch that identifies whether the emergency vehicle has its lights and siren on.
- For each new position report received where the emergency vehicle is in emergency response mode, the Iteris SCTDM compares its current precise location to each and every signalized intersection in the City. When the SCTDM determines that the emergency vehicle is within 1000 feet of and approaching a signalized intersection, the SCTDM creates and sends an emergency vehicle preempt request for a particular signal approach along to the BI Tran QuicNet/4 signal system.
- The QuicNet/4 system immediately passes down that preemption request to the specified signaled intersection controller.
- That local intersection controller immediately initiates a preemption sequence for the targeted approach.
- Messaging and handshaking between the SCTDM and QuicNet/4 are over a LAN
- Three new “extensions” have been built into QuicNet/4 to handle TSP requirements:
 1. GUI Overlay, to display tracked vehicles in real time
 2. Preempt Module, to issue an emergency vehicle preempt command to a controller
 3. TSP Module, to work in concert with the local controller to adjust the current signal coordination plan to shift the “green window” to better match an approaching bus.

What is the current project status?

In April 2001, the expected latency in passing a message from start to finish through all of the TSP subsystems was tested for adequacy. A test vehicle was equipped with an emergency vehicle Tracker Suite, put into pseudo-Code 3 mode, and run up to and through a targeted test intersection about 15 times. Adjustments were made on the fly during that test, resulting in a successful demonstration of the message-handling capability of the overall TSP, and its

component subsystem-to-subsystem connections. During that test, messages were passed through or over the following communication links:

1. a wireless subscriber network (AT&T Wireless' cellular digital packet data (CDPD) system)
2. a public fiber optic network (AT&T's fiber optic system between a CDPD cell site and an Internet server site)
3. the Internet (to and from specific IP addresses in a streamed manner using UDP communication protocol)
4. through a firewall at the City of Glendale
5. over two LANs in Glendale City Hall, plus finally
6. the City-owned twisted-pair signal system communication network.

Analysis of the results of that field test indicate that the total elapsed time between (a) the position message being transmitted by the test EV, and (b) the controller receiving the preempt command from QuicNet/4, was between 1 and 2 seconds on that day. The system latency was declared to be acceptable. Notwithstanding this test, it is possible for message traffic loads on the Internet, in general, to be very heavy on occasion, resulting in somewhat larger latency. Also, since the primary "mission" of this project is for transit priority, somewhat larger latencies (even up to, say, 5 seconds) would still be acceptable, since the predicted arrival times are what the TSP system uses; those predictions are not harmed significantly by delaying the arrival of the message by several seconds.

What is the conclusion?

Glendale is well underway with the implementation of an innovative traffic signal priority system. The innovation is both in the manner in which the system is being obtained (in-house design and development and deployment), and in the system's concept and architecture (centralized control, messaging through the Internet, and using an Application Service Provider). The project is continuing. The completed deployment of the Glendale TSP is expected in the fall of 2001. For further information which will be available after the conclusion of the pilot project, check the City's website (<http://publicworks.ci.glendale.ca.us>) for the published final report, including a study element that will provide a Before-and-After evaluation of the effectiveness and usefulness of the TSP system. The ground being broken by Glendale, as well as the lessons learned on this project, should be valuable to other communities seeking to deploy a traffic signal priority project for transit and/or emergency vehicles.

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Endnotes

^a Maloney, M and D. Boyle, "Components of Travel Time on the Glendale *Beeline* Bus Network." Journal of the Transportation Research Board 1666, Transportation Research Board (TRB), Washington, DC, USA, pp. 23-27, 1999.

^b City of Glendale, Greater Downtown Strategic Plan—Final Master Environmental Impact Report, Terry A. Hayes Associates, pp.4.5-24, Table 4.5-4, November 1996.