Transit Signal Priority for Silicon Valley Bus Rapid Transit

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1. Introduction

Santa Clara Valley Transportation Authority (VTA) has embarked upon the deployment of bus rapid transit (BRT) on its major bus corridor, the Line 22 corridor. Line 22 is the backbone of the VTA bus network, providing service along the east-west length of the Santa Clara Valley between the transit center at Eastridge Shopping Center in San Jose and the Caltrain station in Menlo Park (in San Mateo County). Line 22 is twenty-seven miles long and is illustrated in Figure 1. Buses run every 10 minutes during weekdays, primarily along King Road, Santa Clara Street, The Alameda and El Camino Real (SR 82). Line 22 serves the cities of San Jose, Santa Clara, Sunnyvale, Mountain View, Los Altos, Palo Alto, and Menlo Park. It is VTA's most heavily used line, carrying over 23,000 riders daily and representing 16% of VTA's total bus ridership. The line operates near capacity with many buses at standing room only.

Line 300, a limited stop express service along generally the same corridor, supplements line 22. Lines 22/300 connect with regional rail services as well as 55 VTA bus lines. A major connection occurs in downtown San Jose, where Line 22 intersects the north-south Guadalupe Light Rail Line. VTA's vision for Line 22 is that it operates as a "BRT Corridor." To achieve this vision, VTA will implement a variety of improvements over the next four years by providing:

- faster, more reliable service; and
- better passenger and security at stops

A complete package of improvements will be needed to transform Line 22 into a BRT corridor. The design elements will be consistent and integrated to provide BRT service with a distinct identity. This package will include a combination of the following features:

- advanced communications system;
- signal prioritization for buses to reduce delay;
- improved passenger facilities at stops;
- bulb-outs at selected bus stops;
- queue bypass lanes at congested locations;
- high capacity, easy-access, and cleaner buses; and
- more frequent and direct service.

This paper provides an overview of the project and detailed discussion on the signal priority for buses system under development for the corridor. The initial signal priority implementation will include 27 signals over a distance of six miles, grouped into three subsystems.

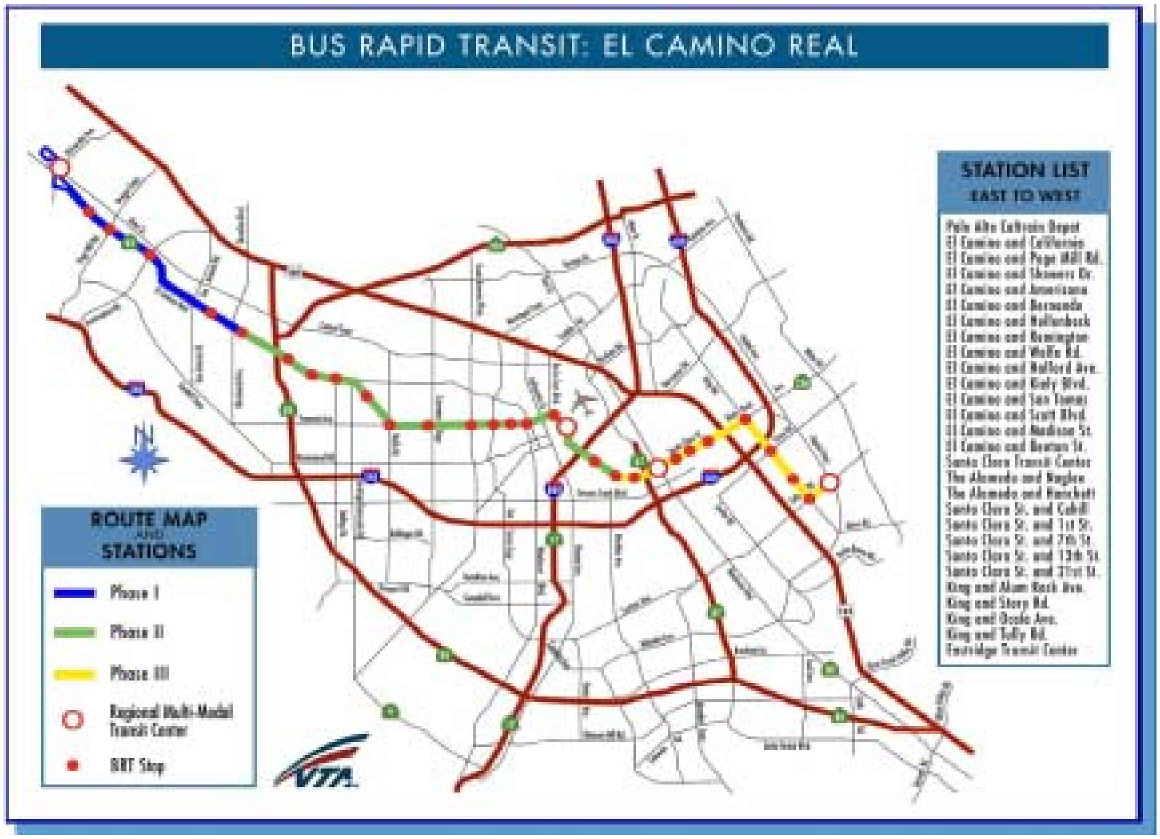

Figure 1 - Line 22 Location Map

2. Silicon Valley BRT Elements

The transit signal priority (TSP) discussed in this paper is part of a comprehensive BRT program for the Line 22 Corridor that includes the following elements:

- New Buses - VTA is operating new articulated buses with a higher passenger capacity than the existing buses. This allows higher productivity in terms of passengers per trip and shorter dwell times at stops due to improved boarding/alighting characteristics for the low-floor, articulated bus.

- Improved Bus Stops - To improve passenger comfort and safety while waiting for buses, new shelters and real-time information signs are proposed. Envisioned are bulb-outs at bus stops to provide a larger area for passengers to wait for buses and to reduce delay for buses re-entering the traffic stream.

- Priority Treatment at Traffic Signals – To improve service reliability and reduce delays at intersections, TSP is being implemented at intersections in the BRT corridor. This is accomplished by incorporating a number of user-definable parameters in the local traffic signal controller software. A major feature of the system, by integrating signal priority calls with bus schedules, is to provide TSP only when a bus is behind schedule.

- Bulbouts – To improve bus access to and departures from stops especially in heavy traffic, bulbouts are proposed (see for example, Fitzpatrick, *et.al.,* 2002). Bulbouts help reduce bus delay and the risk of a collision when re-entering the traffic stream. On heavily trafficked roads with "moderate" speed limits and signal spacing, it is overall better to have the bus stop in the traffic lane and accept the lower utilization of that lane and/or the delay to following vehicles.

- Queue Bypass Lanes – To provide an opportunity for buses to move to the front of the queue, bypass lanes have been implemented at two locations along the Line 22 corridor. Implementation of bypass lanes is most cost effective where the necessary right of way take is zero or minimal and bus delays due to excessive queuing and congestion is high. A low-cost approach for providing such bypass opportunities for buses is to allow through buses to use an existing right turn lane.

3. Transit Signal Priority Operations

Implementation of TSP requires consideration of traffic signal operations and detection of the transit vehicle. The initial Line 22 implementation takes a simple approach that uses Model 170 traffic signal controllers, existing detector loops and low-cost, off-the-shelf detection technology. The remainder of this section covers traffic signal operations with TSP, the detection system for TSP and the TSP operating principles. It should be noted that TSP in the bus signal priority "flavor" is generally milder in application than is railroad preemption or rail signal priority. The greater mass and absence of maneuverability for rail vehicles generate safety concerns that warrant near absolute priority; however, the greater flexibility of bus operations provides an opportunity to generate significant speed and schedule adherence gains through only marginal modifications to signal phase and cycle length.

Traffic Signal Operations with TSP

The proposed approach for traffic signal operations with TSP employs window stretching in response to a priority request call. A priority request call received during the red phase for bus movements results in reduction of time allocated to movements that conflict with bus movements to make active the bus movement green phase earlier than normal. A call during the phase green for bus movements results in extension of the bus movement green phase. This is illustrated conceptually in Figure 2. This TSP configuration is only used with far side and mid-block stops.

The initial implementation of BRT for Line 22 is located along a corridor where California State Department of Transportation (Caltrans) operates almost all of the signals. The Caltrans signals are operated by Model 170E controllers operating Caltrans C-8 local traffic signal controller software. The enhancements for TSP have been incorporated by updating the C-8 software to provide the window stretching described earlier. In the Caltrans controllers, window stretching is accomplished by accelerating the local cycle timer in the controller. The acceleration rate is a user settable parameter. For example, an acceleration rate of 20 percent results in 1.2 seconds of clock time incrementing in the controller in a one-second period.

The recovery time required between subsequent priority calls serviced is defined by the allowable priority call frequency, a user settable parameter in the local controller software. The basic system relies upon the signal being in coordination to provide priority for buses. Additional enhancements to allow TSP operation at isolated signals (i.e., signals that are not coordinated) and at signals without stopline loops have been developed.

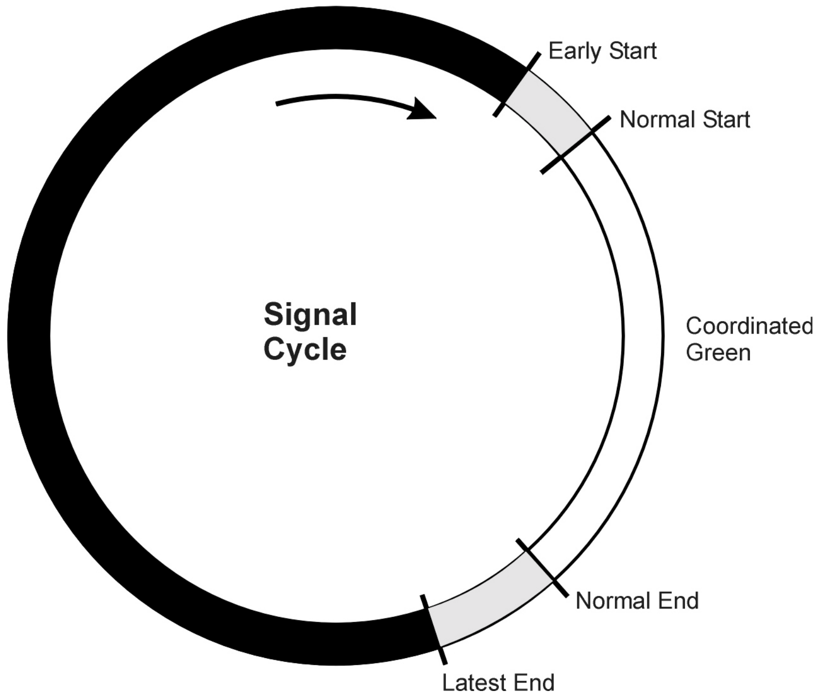

Figure 2 - Window Stretching for Bus Priority

Figure 3 shows a high-level flow chart for the initial implementation of TSP in the Line 22 corridor. The flow chart generally describes the process from the single call for priority placed from an advance detector loop to checkout or termination of the call for priority.

Detection System for TSP

Detection of buses is accomplished via a transponder installed on the underside of the bus as shown in Figure 4. Each transponder has a unique vehicle identification number. The signal from the transponder is transmitted to the traffic signal controller via the in-pavement loop and a detector sensor unit capable of processing both the ordinary vehicle call and the request for priority call.

In the initial Line 22 implementation, existing detector loops, both advance and stopline, are employed. The existing advance loops are generally closer than ideal, but far enough back to detect a bus before the length of the queue on red would prevent detection. The priority request call is cancelled via “checkout” at an existing stopline detector. Ideally, the “checkout” detector should be beyond the stopline, but use of the existing stopline loops is able to provide an acceptable level of service. The detector arrangement is illustrated in Figure 5.

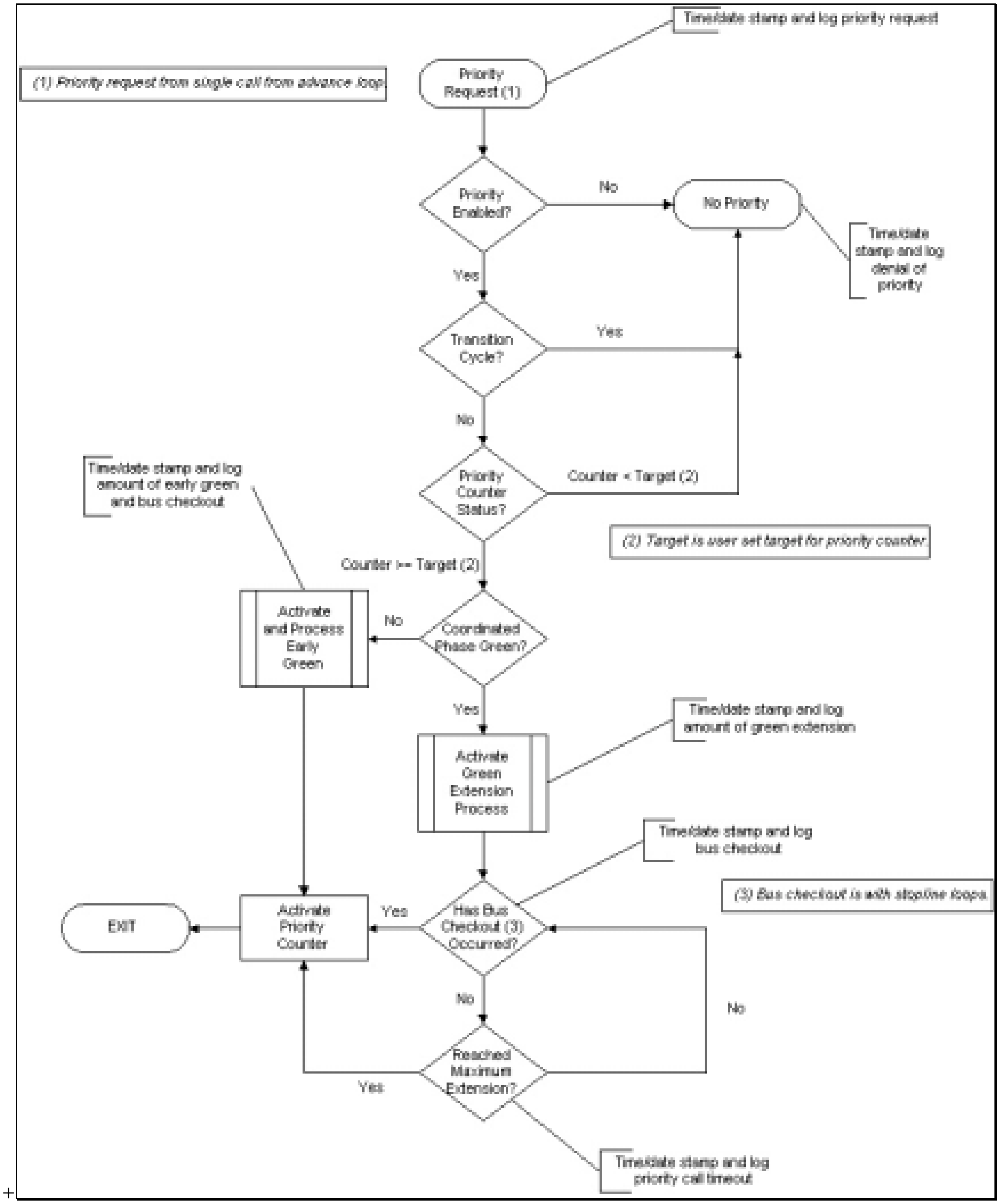

Figure 3 – TSP Flow Chart

Figure 4 - Transponder Mounted on Underside of Bus

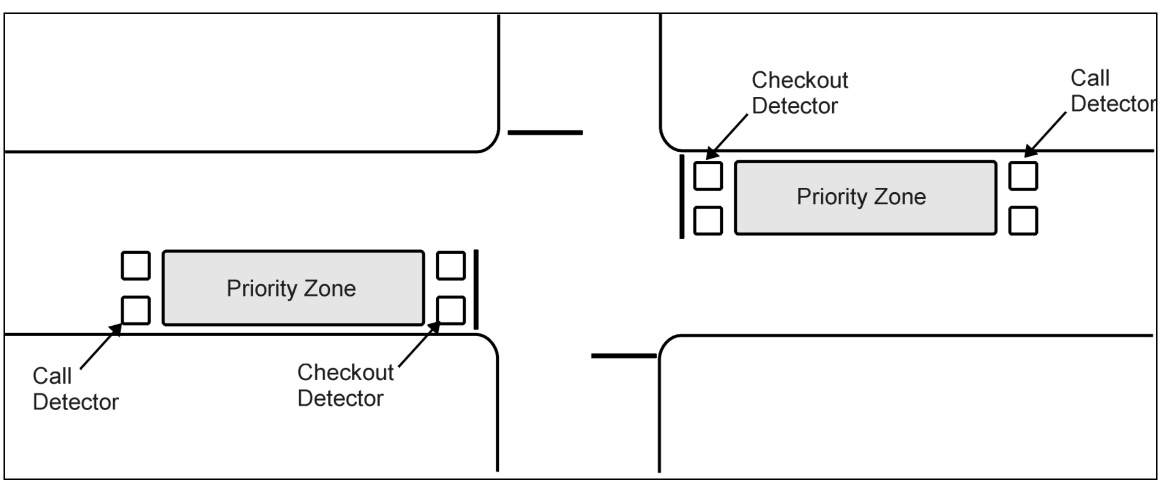

Figure 5 - Layout of Bus Detection

TSP Operating Principles

Based upon draft TSP operating guidelines from Caltrans, TSP operating principles for the corridor have been developed. The understanding is that these operating principles are subject to modification based on the findings of the initial implementation. These operating principles are described in Table 1.

Table 1 – TSP Operating Principles

1. Priority for Late Buses – Only buses that are late by a defined amount of time will be granted signal priority. VTA is working to implement this capability through the bus's on-board AVL system.
2. Priority Call Frequency – The local controller has a user settable parameter for specifying how frequently requests for priority will be granted. This parameter works by monitoring a counter that is incremented each time the local cycle timer zero point is surpassed after a priority call. The default for this parameter is to grant a priority call every other traffic signal cycle.
3. Priority During Transition – Requests for priority while the local controller is in transition will be recognized, but not granted. For example, after a priority call is processed, the controller will have to transition to get back into step. During this time, priority requests received will be recognized, but not granted. However, a transition signal cycle that passes the local cycle timer zero point will increment the priority frequency counter.
4. Priority After Preemption or Power Failure – A railroad or emergency vehicle preemption or a "long" power failure is typically followed by a transition period. The operating principles for priority during transition govern during these instances.
5. Priority Call on Coordinated Signal Phases – A priority call can either extend the coordinated phases (typically phases 2 and 6 in Caltrans controllers) or bring the coordinated phase up early. Green extension is achieved by holding the coordinated phase green for a user set amount of time or until a checkout call is received. Early green is achieved by shortening remaining non-coordinated phase green intervals by a settable percentage as feasible.
6. Phase Skipping – Skipping of phases or phase intervals is not permitted.
7. Manual Operation – Manual operation by a bus operator is not possible.
8. Review of Operations – Review of TSP operations is to take place every 60 days by Caltrans and VTA.

The ability to only request priority when a bus is behind schedule by a predetermined amount is being implemented on the buses. The buses have an on-board AVL system that monitors the bus's schedule adherence. While the bus is on schedule, the power to the transponder is switched off. When the bus falls behind schedule by some user-defined amount of time, the AVL system switches on the power to the transponder.

System Infrastructure

The archiving of time and date stamps and logging of other information will take place in a "super" master computer residing with the field master controller. The system will be connected back to Caltrans' central office in Oakland via a frame relay link. Figure 6 shows the complete system infrastructure, including the communications links between the field devices and Caltrans' central office in Oakland, California and VTA's offices in San Jose, California.

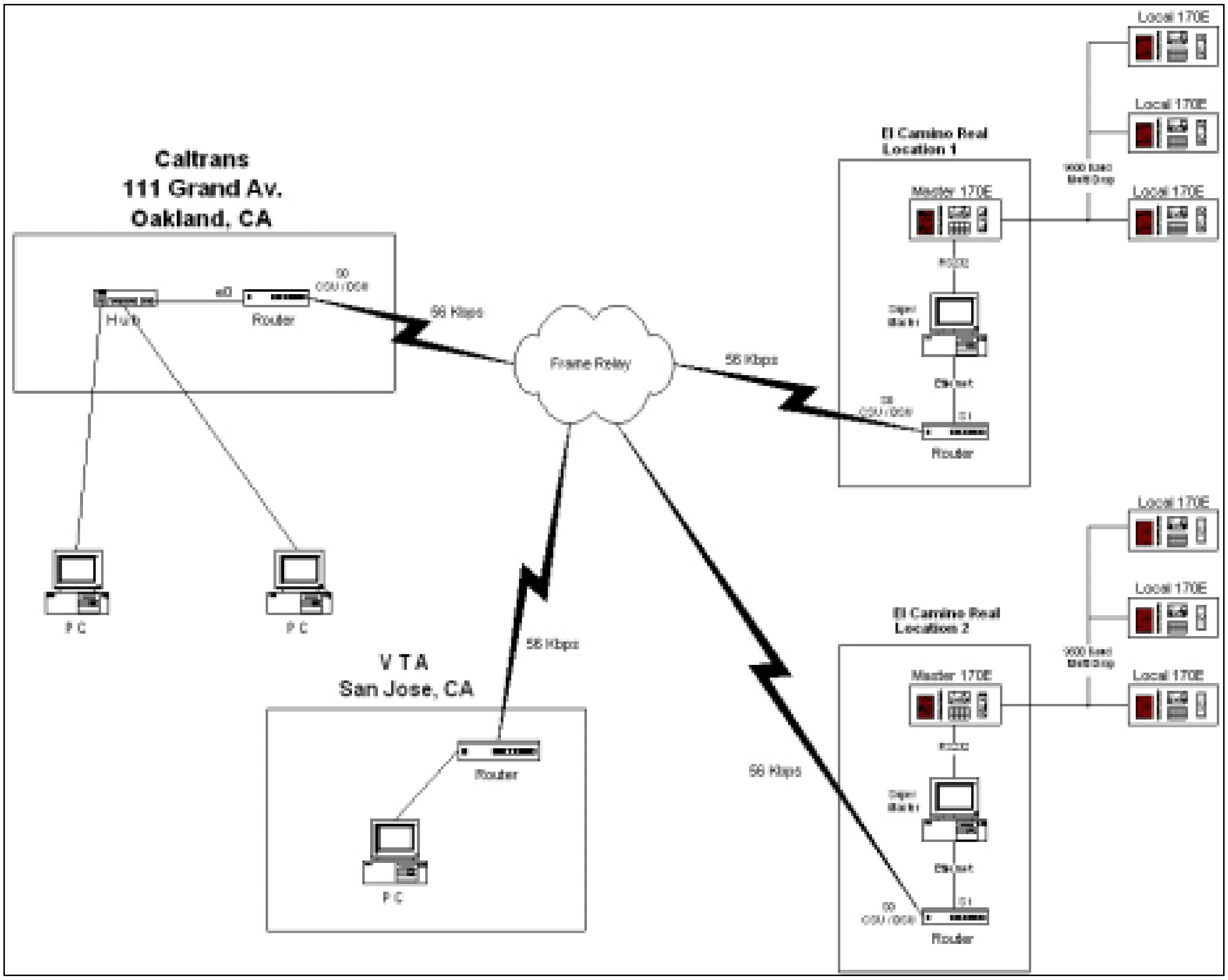

Figure 6 – System Infrastructure

4. Next Project Steps

Transit signal priority is an essential element of the Line 22 Bus Rapid Transit project. Without exclusive rights-of-way, TSP is the only available means of providing the "rapid"—which, in any case, is a relative term—in bus rapid transit.

Because no regional standard for traffic signal controller exists in Santa Clara County, a significant effort will be made to assess the TSP capabilities of the installed controllers in the VTA service area. Given the number of municipal jurisdictions involved, expansion of TSP functionality beyond the current corridor will require extensive software modification and/or hardware upgrade.

Additional corridors are being considered for BRT development. Some of these are equipped with Caltrans 170 controllers and are candidates for early TSP implementation. Others corridors are equipped with controllers from a variety of manufacturers and involve multiple production series. Because of hardware or software limitations, it is believed that a number of corridors will require traffic control upgrading in order to provide comprehensive TSP operation. Further evaluation of TSP potential is underway; it is expected that new generations of controllers will be produced with TSP-capable hardware and software, and that eventually all controllers in the VTA service area will be able to provide TSP as part of their basic function.

VTA is cooperating with Caltrans and UC-Berkeley PATH to evaluate the TSP operation along El Camino Real. PATH will conduct an assessment of TSP against several measures of effectiveness, and evaluate the operation of queue jump lanes in conjunction with TSP in order to assess the cost-effectiveness of supplemental physical improvements to transit operations.

5. Building on Previous Work

This is not the first time signal priority has been implemented in a Model 170 controller. In 1987, DKS Associates assisted BI Tran Systems to develop and implement signal priority for the light rail system in Sacramento, employing either partial priority with similar window stretching or full priority. (See Fehon, *et.al.* 1989) A similar arrangement of advance loops and checkout loops is used in that system. The Sacramento system was relatively simple, with detection limited to loops connected to the intersection being controlled.

A more advanced arrangement was implemented on the Long Beach-Los Angeles Light Rail, employing additional equipment to relay detection and timing information to downstream intersections. (See Taylor, *et.al.* 1989) This type of approach will be useful for bus priority with closely spaced signals. Fortunately, the initial Line 22 implementation covers sections where most of the signal spacing is relatively long, and downstream repeating of detection is not necessary.

VTA is already operating TSP with its light rail transit (LRT) system. This TSP is similar in nature to that operated in Sacramento, Long Beach and Los Angeles. VTA plans on building upon this hands-on experience with LRT TSP as it develops its TSP for buses.

6. Institutional Issues

So far, there has been a strong spirit of cooperation among the agencies. VTA, as operators of the transit system, desire as much signal priority for buses behind schedule as possible, and to have as many queue bypass lanes and bulb-outs as needed. Caltrans staff has supported the use of priority, with a keen interest in the conducting of a comprehensive evaluation of TSP. The following are some of the key institutional issues for continued developed of TSP:

The deployment of TSP and other BRT elements requires close coordination between the agencies that have jurisdiction over roadway operations and maintenance and the agency responsible for providing transit service. Each agency must recognize the constraints and needs of the other partnering agencies early in the TSP development process. Agencies responsible for roadway operations will react differently to the different BRT treatments.

It's likely that not all BRT treatments will work with the same level of effectiveness throughout the target corridor. The application of queue bypass lanes and bulbouts needs to be evaluated on a location-by-location basis.

Maintenance of TSP infrastructure needs to be an early consideration. For the Line 22 project, the desire to minimize loop detector maintenance was a reason for using existing loop detectors as much as possible.

Both roadway and transit agencies need to be flexible in their approach's for deploying TSP. Early in the Line 22 project, there was discussion on how often TSP should be allowed and whether TSP should be tied to bus loading. The decision to provide TSP should not be tied to bus loading. Even a bus with very few passengers that is running behind schedule could have an impact on the reliability of the overall system. The frequency of TSP is likely not a major issue along the initial implementation of Line 22 BRT. This is because many of the buses requesting TSP due so at a time that requires no change to the signal timing.

7. Summary and Conclusions

Many measures can be taken to improve the attractiveness and performance of buses. Some of these can be implemented with little or no impact on other traffic, while others involve trade offs between the two. BRT is gaining popularity as a means of improving transit, and VTA has sponsored an alliance of jurisdictions to demonstrate what can be achieved when complementary elements are put in place together. The results of the evaluation will be useful for determining the extent to which these elements are suitable for Silicon Valley and other similar communities.

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