11. TRANSIT SIGNAL PRIORITY

Transit Signal Priority is employed at signalized intersections to provide priority to transit vehicles (buses) thereby reducing the total travel time. TSP technology can be provided at intersection in two levels: Always-on or Conditional priority. Always-on Priority requests priority to all transit vehicles. Conditional Priority requests priority based on various factors such as schedule variance, scheduled headway variance, passenger load, time of day, direction of route, etc. In order to minimize traffic impacts and maximize the benefits due to TSP, local jurisdictions and transit operators prefer to have the option of seeking / requesting TSP only when certain conditions are met. For example, TSP would only be requested if the sbX vehicle is behind schedule.

The objective of the sbX System is implementing conditional TSP, and the selected technology should be able to communicate or interface with the transit operations management system. Omnitrans has recently acquired a Continental TransitMaster™ System and the proposed TSP approach has been designed to take advantage of TransitMaster™ capabilities.

Figure 11-1 illustrates the four functions in the Transit signal priority process. Figure 11-2 illustrates the technical approach recommended for TSP deployment for the sbX corridors. Under the proposed approach, TSP functions will be executed by on-bus systems, bus-to-intersection communications, and traffic controller equipment.

Figure 11-1: TSP Functions

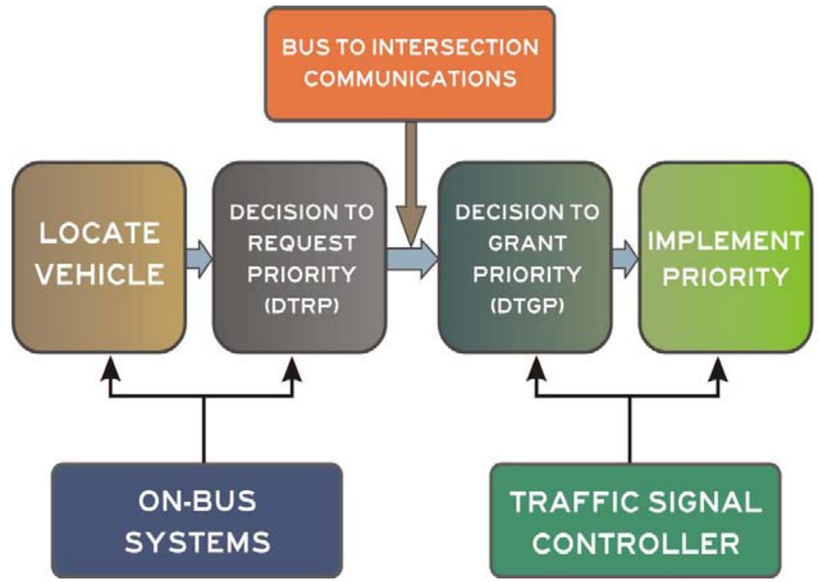

Figure 11-2: TSP Decision Process

11.1 Transit Signal Priority Architecture

Under the proposed TSP system architecture, buses are equipped with TransitMaster™ on-bus systems that communicate with the intersection controllers using an IEEE 802.11b/g Wireless Local Area Network (WLAN). Once in the corridor, TSP-equipped buses request priority by sending specific check-in, position update, and checkout messages to the intersections. The traffic controllers then process the messages and implement priority for the buses according to criteria set for granting such priority. The TSP Parameters will be jointly determined by Omnitrans and the respective cities prior to deploying the system.

Priority may be requested at signalized intersections equipped with the TSP Components and granted based on parameters determined by Omnitrans and the respective cities. When the

TransitMaster on-bus system decides to request priority, communications are initiated with the intersection where priority is requested. Three messages are transmitted for each priority request, two check-in messages and one check-out message, using the on-board IEEE 802.11b/g radio. As currently configured, the three messages are as follows:

- **Message 1:** The on-bus system sends a check-in message to TSP-equipped intersections using the WLAN. The message is typically sent when the bus is an estimated 20 seconds away from the intersection. At 30 miles per hour, this is a distance of about 900′ from the intersection.
- **Message 2:** An update message is sent to the intersection five seconds later. This is done primarily for redundancy, to ensure that the request for priority is received by the intersection, but could also be used to update the estimated time of arrival accounting for any traffic conditions that the bus experiences as it approaches the intersection if supported by the intersection controller firmware.
- **Message 3:** Finally, as the bus leaves the intersection, a check-out message is sent allowing the intersection controller to cancel any additional priority strategies that it may be employing. This will reduce the impact of providing priority to the bus on traffic signal operations.

The system architecture provides for health and performance monitoring of the TSP systems by the respective cities and Omnitrans. Data is extracted from the signal priority data network and sent through the sbX station area T-1 communications network to the TSP Network Monitor data server. The TSP Network Monitor provides for network monitoring, maintenance planning, and historical data reporting. For health monitoring purposes, network devices can be accessed once they are on the network by sending requests through the T-1 communications network to the signal priority data network. Each segment of the TSP WLAN will have two network drop points connected back to the Network Monitor data server.

As already stated, the proposed system architecture employs a WLAN to provide for communications between mobile network clients, that is, TSP-equipped sbX vehicle, and intersection traffic signal controllers equipped with wireless antennas, receivers, and terminal servers ("intersection clients"). The WLAN has been developed using the IEEE 802.11b/g specification. The WLAN consists of a network of devices known as access points (AP) that are connected together using both wired, where available, and wireless communications. Each AP manages a number of wireless mobile and intersection clients associated to it by authenticating a client's right to be utilizing the network and to broker network communications between the client and other network devices.

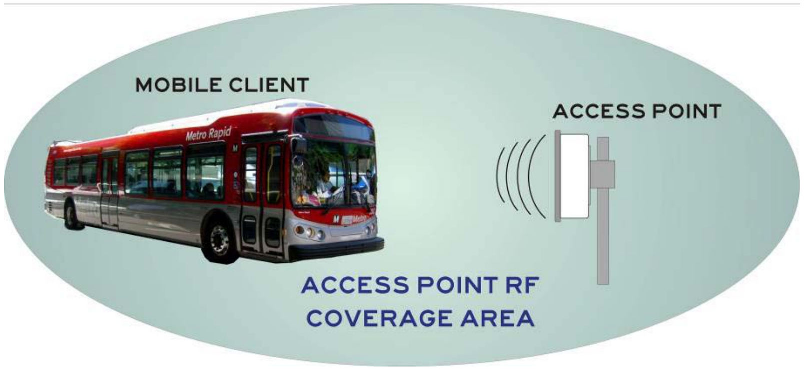

Figure 11-3: Mobile Client Communicating with Access Point

The mobile clients, sbX vehicles, may move around within an AP's coverage area and be provided with network services as depicted in Figure 11-3.

With the correct antennas and configuration, a single AP can provide network service to a radius of up to about one mile and, in some circumstances, perhaps even longer distances along bus transit corridors. Clearly, this distance is inadequate to provide communications for an entire bus line. Extended coverage is obtained by deploying multiple APs so that the individual coverage areas are overlapped. When deployed along a bus transit corridor, the coverage areas of the individual access points overlap to provide reliable and continuous communications between the buses and intersection controllers while buses are traversing the corridor as depicted in Figure 11-4.

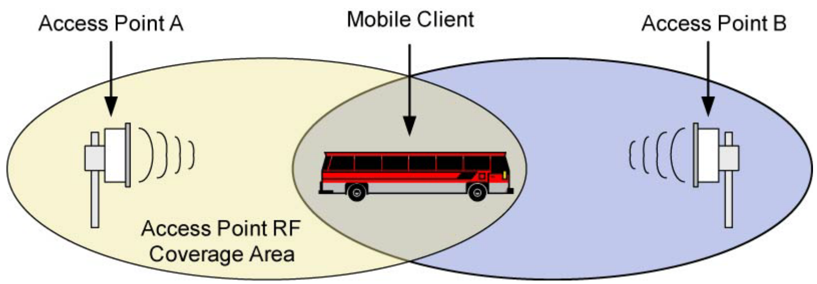

Figure 11-4: Mobile Client Communicating with Multiple Access Points

By installing a series of APs with overlapping coverage areas, continuous network access for buses along the corridor can be created. These extended networks require that the equipment be configured so that a mobile client can now be served by two or more APs at any one time, allowing a mobile client to move between the coverage areas of multiple APs with seamless communications throughout a bus transit corridor. Using a combination of hardware and software on both the clients and the APs, mobile clients are provided with continuous network access allowing the signal priority equipped buses to be unaware of any changes or transitions between the various APs in a wireless network.

To create the corridor-wide wireless network and allow for the seamless roaming of mobile clients, the APs are interconnected using wireless network bridges. A network bridge is a specialized WLAN device that provides point-to-point wireless communications required to connect multiple APs and provide for seamless communications in signal priority equipped corridors when wired signal interconnect is not available for use. For this project, network bridges that provide both wireless bridging and AP functionality are used. Once a wireless network infrastructure link is established, the AP/bridge device functions as an AP to accept mobile and intersection clients as well as to connect the AP with adjacent APs as depicted in Figure 11-5.

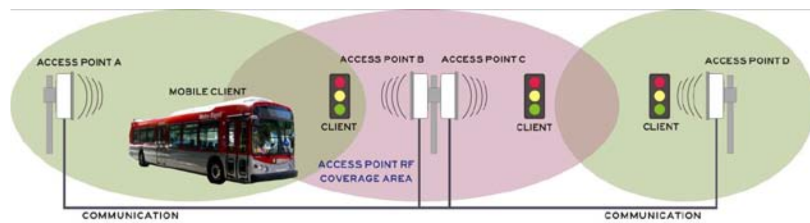

Figure 11-5: Wireless Network Bridges Connecting Multiple Access Points

11.2 TSP System Design

The implementation of bus signal priority systems along an sbX corridor requires the installation of communications equipment and traffic signal control equipment upgrades at intersections along the corridor as well as software upgrades to the TransitMaster on-bus and fixed end systems for TSP functions. The following sections provide a brief overview of the overall network design, types of hardware and software that need to be deployed at intersections in the corridor, and TransitMaster software modifications.

11.2.1 Access Point/Bridge Intersections

This is the most common type of intersection configuration for a network access point. At these intersections, network bridges will be installed and configured for both AP and bridge functionalities. The WLAN hardware establishes the necessary network infrastructure by creating a wireless bridge to the adjacent APs. The AP hardware is installed on existing signal poles at the intersection, providing WLAN coverage for mobile and intersection clients in the vicinity of the AP.

Network AP/bridges are required at roughly every third or fourth signalized intersection, on the average. The AP/bridges have been installed on traffic signal poles or signal pole mast arms at the maximum possible height. Typical installations are shown in Figure 11-6. Installation requires mounting the AP/bridge with its integrated antenna on the signal pole or signal pole mast arm and running coax cable from the bridge enclosure to the intersection controller cabinet where additional network hardware is installed, including a terminal server, network switch, and power supply equipment for the pole-mounted hardware.

Figure 11-6: Typical WLAN AP/Bridge Equipment Installations

The AP/Bridge equipment will be installed as high as possible on the traffic signal pole or on the signal mast arm in order to obtain an unobstructed line of sight to the adjacent APs and intersection clients and to minimize interference from surrounding vegetation and any other physical obstructions. For these intersections, line of sight is important in order to establish wireless links to the adjacent APs as well as coverage for the intersection and mobile clients.

At intersections equipped with Type 332 controller cabinets, the WLAN hardware is installed on a custom-fabricated aluminum panel that is attached to the cabinet frame on the back side of the cabinet and hinged so that signal technicians can easily move the WLAN hardware out of the way when necessary for signal maintenance. The WLAN hardware includes a terminal server, network switch, and power supply equipment. Details of the panel are shown in Figure 11-7.

Figure 11-7: AP/Bridge Equipment Panel In Type 332 Traffic Cabinet

11.2.2 Access Point / Bridge with Network Monitor Drop Intersections

As noted earlier, each network segment is connected to the TSP Network Monitor data server for network monitoring, maintenance, and data collection.

These intersections will be equipped the same as the AP/Bridge or AP/Signal Interconnect intersections. At these locations adjacent to sbX stations, a connection will be installed from the equipment panel inside the traffic signal controller cabinet or in the backpack enclosure attached to the traffic signal controller cabinet to the TSP Network Monitor data server using the BRT station area T-1 communications network. Installation details at the traffic signal controller cabinet are the same as for the AP/Bridge or AP/Signal Interconnect intersections with the network monitoring communications hardware.

11.2.3 Client Intersections

At intersections between APs where buses will request priority, only client hardware is required. At these locations, terminal servers that convert the IP-based communications data packets, received from access point to which each client is associated, to serial data for input to the traffic signal controllers are installed in the traffic controller cabinet. The serial port on the terminal server will be used for communications with a serial port on the traffic signal controller. Using its wireless communications features, the terminal server will also be able to access the corridor WLAN as a network client. Terminal servers can be attached directly to the rack inside a 332 cabinet without interfering with traffic signal maintenance as shown in Figure 11-8.

In addition, an antenna will be mounted on top of the cabinet, as shown in Figure 11-8, with antenna cabling to the terminal server. At certain locations where the traffic signal cabinet is located on the side street or otherwise obstructed by buildings, the antenna for the terminal server will be installed on a traffic signal pole at the intersection. At these locations, the signal strength at the controller cabinet is too low for a reliable connection to the WLAN network.

Figure 11-8: Terminal Server and Cabinet-Mounted Antenna

11.2.4 Intersection Traffic Signal Hardware

Intersection signal controller hardware and software modifications would be necessary for the intersections along sbX corridor. The modifications would include upgrading the signal controller equipment as necessary, upgrading signal controller firmware as necessary to accommodate wireless bus-to-intersection communications, and modifying signal timing with

TSP parameters. Each of the modifications is necessary to provide full system implementation at each intersection.

Signal timing for bus signal priority will be performed by the respective cities for the intersections in each of these cities. Timing will be based on rules set by the cities and typically provide for green extension, early green return, and limitations on granting priority for consecutive cycles in order to maintain progression.

11.2.5 TransitMaster On-Bus Systems Modifications

The existing TransitMaster on-bus systems will be upgraded for TSP functions, including wireless bus-to-intersection communications, to request priority. The existing IEEE 802.11b/g radio already installed as part of the TransitMaster will be employed for bus-to-intersection communications.

11.3 Traffic Signals, Control System and Standards

Buses will operate via a combination of standard traffic signal controls and special sbX signals. Basic signal prioritization for buses is to be implemented along the major arterials of the sbX network.

Existing traffic signals, cabinet, controller, as well as conduit may require modification to provide the hardware and software capabilities for signal prioritization and for additional signal phases. Signal pole relocation and mast-arm modifications may be required due to the proposed implementation of sbX dedicated lanes and bus only signals.

Incorporation of new signals meeting municipal traffic control standards will be developed in coordination with the traffic departments of each local municipality along corridor.