Unique Strategies used to Successfully Implement Emergency Vehicle Preemption Operation within the Seattle CBD

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Abstract

This paper discusses the unique design strategies used for the emergency vehicle preemption system within downtown Seattle. Emergency vehicle priority is a simple but important operational tool implemented by many agencies to aid emergency vehicles through traffic signals, allowing the vehicles to avoid delay and reduce response times. The City was using traditional hard-wired preempt systems, which by a push of a button would turn one or more traffic signals green in the priority direction allowing emergency vehicles to travel through the intersection or corridor without signal delay. Although this type of system produces high reliability for the emergency vehicle, it imposes significant delays to vehicle and pedestrian traffic and can cause lasting effects.

This project aimed at moving away from the existing system to develop a more responsive system that will provide both reliable service to the emergency vehicles and help minimize delay for vehicles and pedestrians. The implementation of a responsive on-street system within a CBD environment can be difficult to accomplish. Some of the constraints found in a built-up urban environment that make on-street vehicle detection difficult to operate effectively include line-of-site blockage from trees, hills and buildings, short city blocks, parked vehicles and trucks, and side mounted signal equipment. This discussion presents the unique strategies used to effectively design the system while minimizing the need for conduit installation by utilizing the City's existing signal interconnect and conduit system. The system was implemented on four major emergency routes covering over 40 traffic signals within the Seattle CBD.

Introduction

This paper discusses the unique strategies used to implement an on-street emergency vehicle detection system along four major corridors within downtown Seattle. This project was one of the many surface street improvement projects that were constructed in preparation of the closure of the King County Metro bus tunnel for retrofitting for Light Rail operations. During the tunnel closure, buses were moved to the surface streets and 3rd Avenue, one of the major north-south corridors through downtown was converted primarily to a transit only facility during peak hours. With the added buses on the network and the change in operation of 3rd Avenue, general purpose traffic would be forced to divert to other north-south roadways, such as 1st Avenue and 4th Avenue. These two corridors serve as primary routes for emergency vehicles through downtown. With the added traffic to these main corridors, any unnecessary delay can cause lasting effects. This paper presents the design strategies used to successfully replace the existing hard-wired preemption system in downtown with a goal to provide a dynamic preemption system with high reliability and versatility to emergency vehicles as well as help limit the impact to vehicle and pedestrian traffic.

Existing System

Emergency vehicle preemption is a simple but important operational tool implemented by many agencies to aid emergency vehicles through traffic signals, allowing the vehicles to avoid signal delay and reduce response times. The City of Seattle was using a traditional hard-wired preempt system which was controlled at the fire stations. When an emergency call was received and emergency vehicles dispatched, the preemption was activated by a push of a button at the station. This button would turn one or more traffic signals green in the priority direction and would remain in preempt until the call was removed. This system provided high reliability for the emergency vehicles, but imposed significant delay to general purpose and pedestrian traffic during the preemption, and would produce congestion that had lasting effects on the network. For example, if an emergency vehicle is to travel the length of 4th Avenue, all traffic signals along the route would stay in the preemption phase for the length of the trip, delaying side street vehicles and pedestrians. Assuming the emergency vehicles travel at the speed limit, the preemption period could last 4 minutes or more.

Project Objective

This project aimed at moving away from the existing system to develop a more responsive system that would provide both reliable service to emergency vehicles and help minimize delay for general purpose vehicles and pedestrians. The City currently has adopted 3M Opticom™ detection equipment as their standard for emergency vehicle preemption and this equipment was used for the design. The City also wanted to utilize existing infrastructure where possible to help minimize the cost of the project. The following sections describe the equipment used for the design as well as the unique strategies used to solve some of the inherent constraints found when trying to implement on-street vehicle detection within a CBD environment.

General Opticom^{TM} Equipment and Operation

The design incorporated 3M Opticom^{TM} equipment which is a City of Seattle standard for emergency vehicle detection. The standard equipment and operation of the Opticom^{TM} detection system includes emitters mounted on the front of the emergency vehicles that send optical signals to detectors that are mounted at or near the intersection. Standard detector mounting is either on a signal span wire or signal mast arm centered over the approach lanes that provide direct, unobstructed line-of-site to the approach vehicles. Auxiliary detectors can also be installed to provide more advanced detection if needed. Once the detector receives the optical signal, it transforms the optical signal into an electrical signal and transmits this signal along a cable to a phase selector or discriminator for processing located inside the traffic signal controller cabinet. The phase selector in turn communicates to the traffic signal controller and requests preemption. The benefits of this system over the existing hardwired system is that once the vehicle passes through the intersection, the signal is no longer detected and the call is dropped. This allows the signal to only be in preemption as long as needed for the emergency vehicle to clear the intersection, limiting the delay of side street vehicles and pedestrians.

Figure 1: Opticom^{TM} Detection Operation
Source: http://solutions.3m.com

Design Constraints

The implementation of an on-street detection system that requires unobstructed direct line-of-site within a built-up CBD environment can be difficult to accomplish due to the physical characteristics. This was true in the downtown Seattle area as well. The Opticom^{TM} detectors have a specific horizontal and vertical cone of vision, which varies with detector type. If this vision is obstructed, then the signal emitted from the emergency vehicle will not be detected and preemption will not be provided. Some of the physical characteristics found in the Seattle CBD that impacted line-of-site included street trees, buildings, congested streets with large trucks, curves and hills. Another factor that affects detection range is the detector mounting locations. Many intersections in downtown Seattle have their signal equipment side mounted rather than over the roadway. This type of signal layout limits the options for mounting the detectors over the roadway. Mounting detectors on the side of the roadway have reduced vision over the roadway, and the detection zone is more likely to be affected by street trees and parked vehicles. Wide one-way streets can also pose a problem for single detectors mounted at intersections. Due to the limited cone of vision of the detectors, vehicles may not be detected across all lanes of traffic.

Design Basics

Once the design constraints were identified, it was possible to begin outlining the operational criteria based on these constraints and the detection equipment capabilities.

A meeting was held with the City of Seattle and the Seattle Fire Department to review the following design elements:

- Design speed of the system
- Strategy for transitioning to preemption phase
- Calculating how far in advance of the intersection vehicles need to be detected based on the design speed and the transition time of the traffic signal.
- Determining the appropriate detector type and placement to acquire the desired detection range

The design speed was discussed and agreed to be set at the roadway speed limit which is 35 mph throughout downtown. A higher design speed was considered but was not chosen because it is not desirable for emergency vehicles to travel faster than the speed limit with the high vehicle and pedestrian traffic in the CBD. Once the design speed was determined, it was necessary to calculate how far in advance emergency vehicles needed to be detected. This calculation depends on the strategy used to transition from the current phase to the preemption phase. All traffic signals in the downtown are pre-timed with fixed Walk and Don’t Walk times for each pedestrian phase. The City agreed to allow the Walk times to be truncated when a preemption call is received, but would not allow the Don’t Walk times to be truncated because they did not want pedestrians trapped in the crosswalk. With this strategy, the preemption phase would not be activated until the Don’t Walk time and Clearance Interval are finished on the opposing phase. It was also determined that the preemption phase should be activated at least one block prior to the intersection. This would allow queued vehicles to clear the intersection prior to the emergency vehicle arriving and also prevent the need for the emergency vehicle to slow down while waiting for the signal to transition.

Given these requirements it was calculated that the emergency vehicles should be detected at least 1200 feet or approximately four blocks in advance of the intersection. The Opticom™ vehicle detectors have a settable range from 200 to 2500 feet, so assuming ideal conditions the detectors would be able to detect the desired 1200 feet. Unfortunately, with the physical constraints listed above, a single detector at the intersections was not adequate to acquire the desired detection range at many locations. To obtain the required detection range supplemental detection would be needed in advance of the intersection.

The type of detector was also discussed with City staff. Opticom™ detectors are available in three Model types depending on the application. It was determined that the design would utilize the Model 721 Opticom™ detector, which is a one channel duel direction detector, but can be used for one direction applications. Aligning the detection tubes in a single direction as shown in the graphic to the left, can provide double the cone of detection both horizontally and vertically when compared to a single cone detector. This detector configuration provides an even wider reception angle at short ranges due to internal detector reflections. This detector configuration proved useful where wider detection ranges were needed, such as along wide one-way roadways found in the CBD.

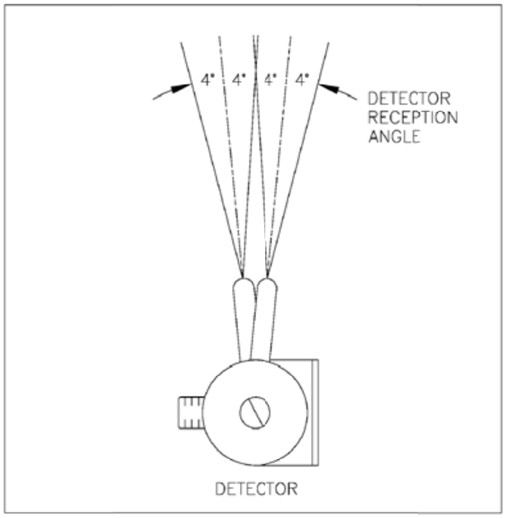

Figure 2: Model 721 Reception Angle
Source: 3M Opticom™ Priority Control System Installation Instructions Manual

Detection Strategy

Based on the constraints both in the detector equipment and the physical characteristics in downtown Seattle, it was found that one detector would not provide adequate detection range at many locations. Installing auxiliary detectors in advance of the intersection requires a hard wired connection between the detector and the phase selector located in the signal controller cabinet. To limit the need for new conduit and additional equipment a unique strategy was developed to cascade detection calls between intersections instead of installing traditional auxiliary detectors. This strategy would allow the primary detector at an intersection to serve as the auxiliary detector for one or more intersections downstream. For a detector signal to be cascaded from one intersection to another, a communication link needed to be established between the phase selectors at each intersection. This could be accomplished by using traditional hard wired interconnect, wireless technology, or communications through a centrally controlled Traffic Management Center (TMC). An extensive inventory was done throughout the City to determine what existing communications infrastructure was available. The City's first choice for communications between intersections was to use the existing 18-pair copper interconnect cable that was used for their existing fire preemption system. The City identified two spare pairs that were available and could be dedicated for system interconnect. The City's second choice was to install new interconnect cable in existing conduit where the 18-pair preempt cable was not available. Finally, new interconnect cable installed in new conduit was done as a last resort where no other options were available. The City decided not to pursue the wireless option or communications through the TMC due to possible reliability

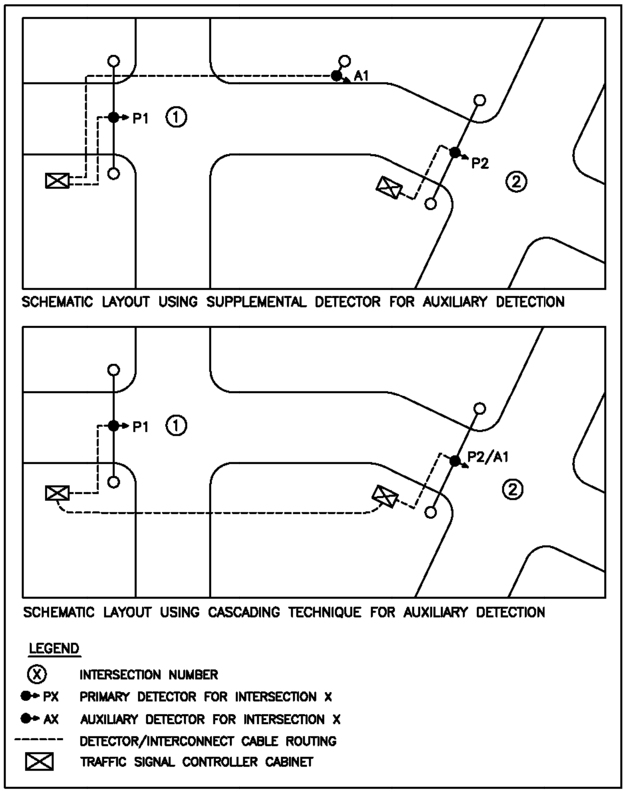

Figure 3: Auxiliary Detection Techniques

issues. Figure 3 shows the schematic layout and detector assignment for both the cascading technique and the use of additional detectors for auxiliary detection.

Once the communication paths were identified, cascading preemption calls was accomplished by using a simple solid state 24V DC relay in the controller cabinet. We were able to transmit the preempt signal from one intersection to another, thus sending a preemption request to the phase selector. Figure 4 displays the detector network that was designed to provide an adequate detection range at each intersection. This schematic shows each detector on the network and how it connects to the intersection(s). It also details the interconnect means between intersections.

The mounting strategy varied by location and affected the need for cascading calls. Intersections with signal equipment mounted on span wire allowed the detector to be installed over the roadway limiting the need for cascading. At locations with signal equipment mounted on poles on the side of the roadway, detectors were mounted on these poles allowing convenient wiring to the controller cabinet. Side mounted detectors are much more susceptible to site obstructions and needed cascading to provide adequate detection range.

Using the cascading technique did not completely solve the issue of site obstructions. If the signal from the emitter on the emergency vehicle is obstructed it is possible that the preemption could be dropped prior to the emergency vehicle clearing the intersection. To help solve this problem the “Hold” function present in the phase selector was used. This function allows the user to set a hold on the call, which will hold the preemption call a user defined time once the signal is no longer detected. If the call is re-detected during the hold timer, the preemption will be re-activated. The hold time was set at approximately the time it takes an emergency vehicle to travel one block (approximately 300 feet) at the design speed. Using this function also prevents the preemption from dropping when the emergency vehicle is within 200 feet of the detector, which is outside the detectable range of the detector (detection range is between 200 and 2500 feet).

Conclusion

The cascading technique proved to be a simple but efficient strategy that was ideal for closely spaced interconnected intersections, which are characteristics commonly found in a CBD environment. Using this technique, we were able to limit the number of detectors installed in the field by using a single detector as the primary detector at the intersection and as an auxiliary detector for multiple intersections downstream. The system was able to utilize the City’s existing communications infrastructure limiting the amount of new conduit needed. The Opticom^{TM} detection system was successfully installed at 40 intersections within the CBD and amounts to approximately 21,000 feet or 4 miles of detection coverage by length, and only approximately 850 feet of trenching for new conduit was needed. The system also helps limit the delay incurred by vehicle and pedestrian traffic when compared to the City’s existing hard-wired system by providing preemption only when the emergency vehicles are within the designed detection range.

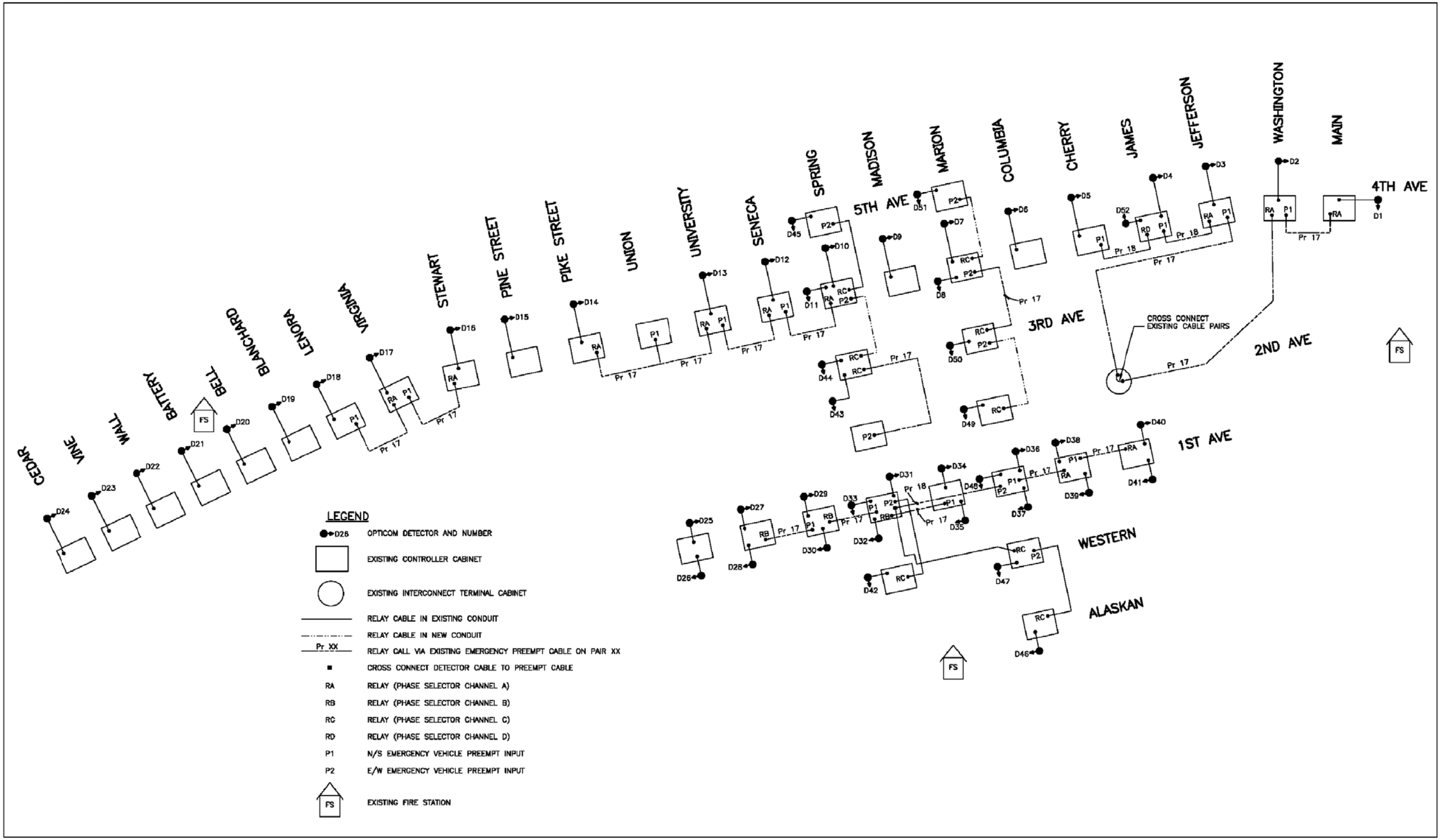

Figure 4: Detector Call Cascading Schematic