Next Generation Transit Signal Priority with Connected Vehicle Technology

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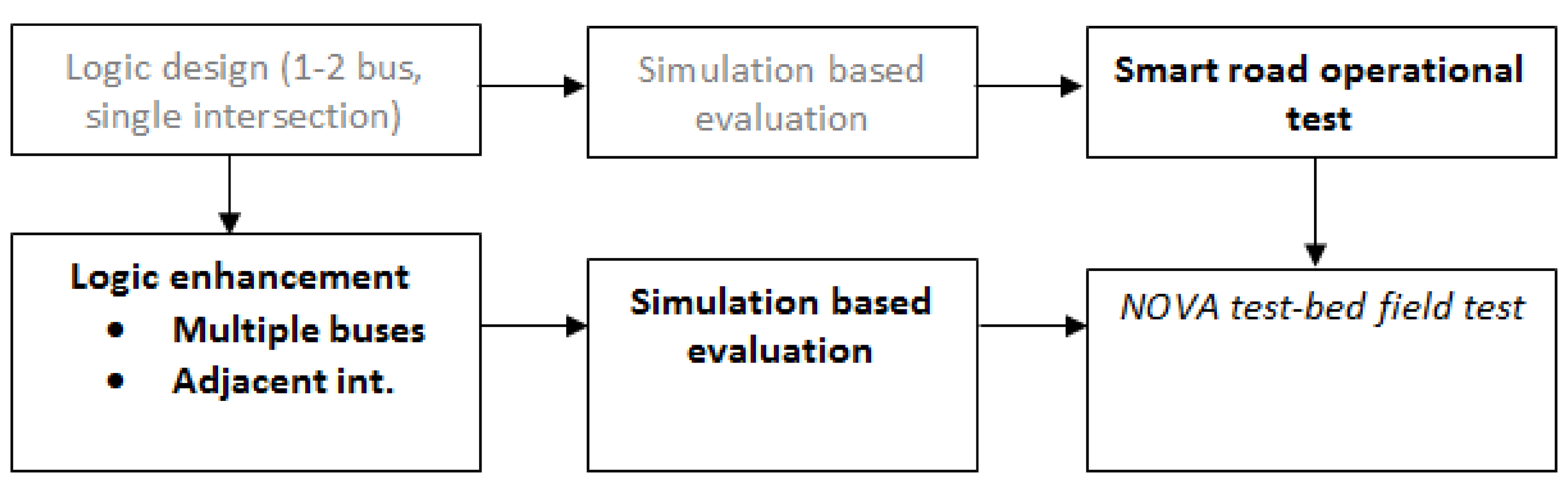
Introduction

For years, Transit Signal Priority (TSP) has been proposed and studied as an efficient way of improving transit operations. It offers preferences to transit vehicles at signalized intersections and has been proven valuable in reducing transit travel time and improving schedule adherence and customer ride quality. Furthermore, it has been shown that TSP has the ability to cancel out the negative effects due to outdated timing plan. The technology has been applied in many cities in Europe, Asia and North America. In the US, Seattle, Portland, Los Angeles, Chicago and other large cities have all implemented the TSP system. Past studies showed that the benefits of TSP in terms of bus travel time savings vary significantly. First, TSP logic is too simple (only green extension of 5 seconds). Second, the progression between adjacent intersections is not coordinated. To be mentioned, there is no study has investigated the coordination of adjacent intersections for TSP. No research has completed combining TSP with connected vehicle technology.

There are also several other challenges for the current TSP to be widely deployed. One big challenge is its adverse effect on side streets. Especially for intersections that are nearly operating at their capacity, the benefit of adding TSP is controversial. Another potential challenge of the current TSP is timing. Because of the uncertainty on bus's arrival time, the TSP procedure usually moves a large portion of the green time from the side streets to the street where a bus is expected to arrive. In some worse cases, bus would arrive in the next cycle without taking advantage of any of the green time extend, while the vehicles on the side street keep waiting and accumulating delay time. Of course, this causes significant adverse effect on traffic condition. Finally, the third challenge is the problem of the conflicting TSP request. It is discovered that the current "first come first serve" way of solving conflicting priority request not only do no benefit but also shows negative impacts to the TSP system. Very few researches have been conducted regarding how to resolve conflicting TSP requests of more than two buses.

Research Objectives

Developing (i) a new TSP method that will fully realize the connected vehicle technology based two-way communications among multiple transit buses and traffic signal, and among the transit buses and vehicles, and (ii) the coordination method accounting for adjacent intersections where transit buses are bounded to travel. The research team will also put effort on evaluating the TSP logic: (iii) perform smart road operational test to ensure the proposed TSP logic harnessed by connected vehicle technology perform as expected, and (iv) field operational test to quantify the benefit of the proposed TSP logic.



Research Project Work Plan

Logic Enhancement

Multiple buses

The multiple buses condition is defined as two or more TSP requests are made at the same time interval. This would be one of the major tasks the team will accomplish in the proposed CVI-UTC project. The TSP strategy adopted here would be an extension of the single-bus scenario which takes advantage of V2I and I2V communications and have the transit and the traffic signal cooperate each other. The challenge here is that there will be many more arrival time scenarios, for example, buses coming from opposite directions and their arrival time ranges might overlap each other, or buses coming from opposite directions and their arrival time ranges do not overlap, or buses coming from perpendicular directions, etc. Correspondingly, there will be many more TSP solutions, for instance, serve one bus, or serve all the buses or serve some of the buses. When serving multiple buses, there will be another question that which bus should be served first. The research team will identify all the possible scenarios of conflicting TSP requests for 3-bus and 4-bus conditions and will determine corresponding TSP solutions. These possible scenarios and TSP solutions will be then archived as a library. Thus, when conflicting TSP requests are made, the TSP logic compares among all available TSP solutions in the library in terms of delay per person and implements the best TSP solution. A possible flow chart of how conflicting TSP request will be handled is presented in the image to the right.

Adjacent intersection

Another major task of this project is to enhance the TSP logic by considering coordination between adjacent intersections. It is important because the travel time savings generated by the previous intersection could be lost if the progression of the TSP bus stops at the next intersection. The research team will identify how adjacent intersections could coordinate with each other in terms of timing plan change. This can be achieved by assigning a progression bandwidth for the TSP bus, and dynamically adjust offsets such that the STP bus will receive green at the downstream intersection without causing additional delay at the downstream intersection.

Smart Road Evaluation

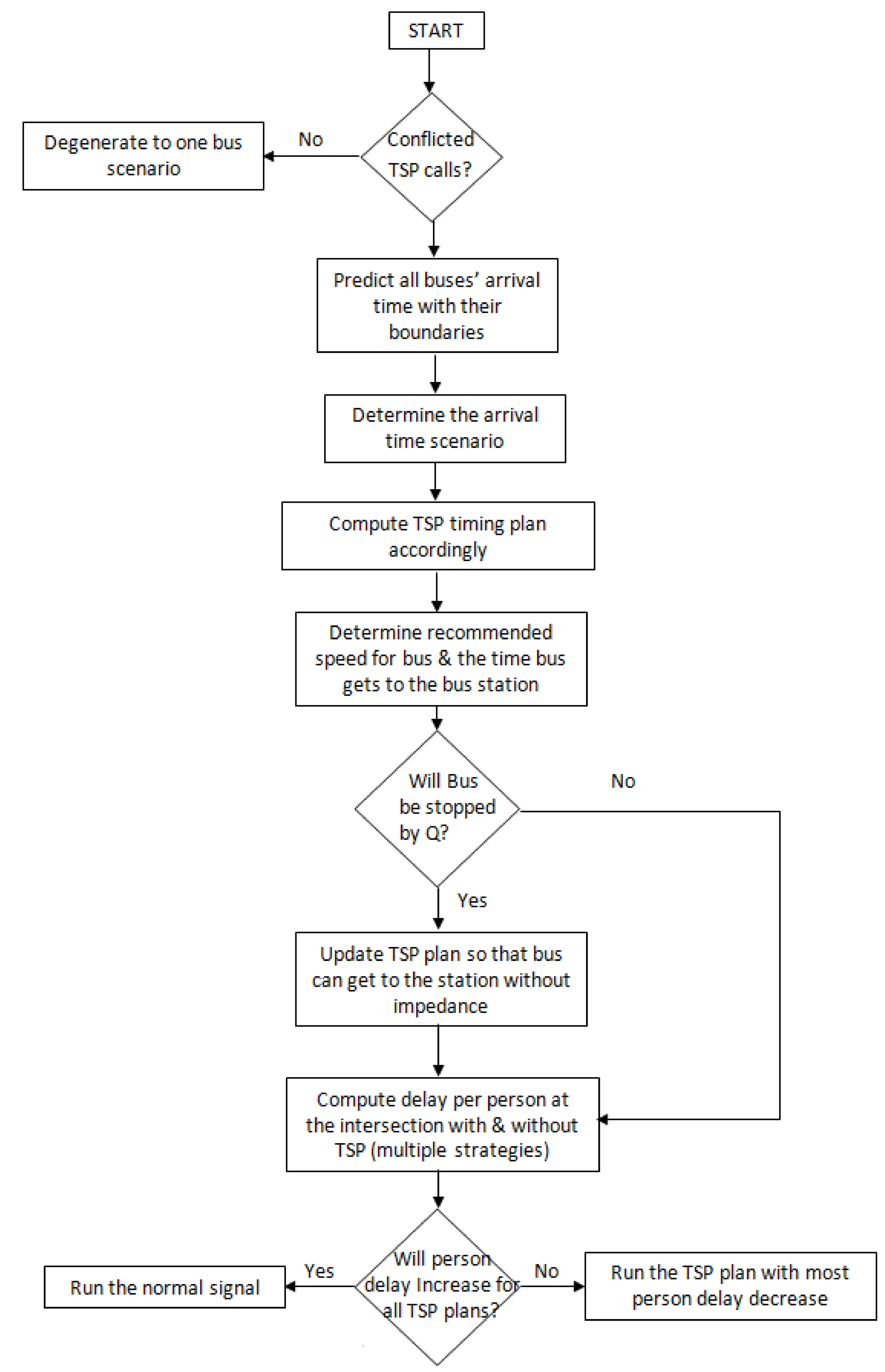
The logic to be developed in this project will be tested within the simulation environment. It is noted that the simulation environment will be developed from the VCTIR project. After successful simulation-based evaluations, the logic will be tested at the Smart Road to ensure the connected vehicle technology harnessed TSP logic performs as expected – critical measures to be closely monitored are positioning errors (especially for the buses), bus travel time corresponding to green window given by TSP, and communications errors and latencies. For the Smart Road field operational test, the research team will develop a unique data format dedicatedly for bus-infrastructure communication to prevent interference to/from other V2V and V2I communications. During the field operational test, three scenarios will be compared: no TSP, conventional TSP (i.e. "green extension" and "red truncation" only) without CV technology, and the proposed next generation TSP with CV technology. Research team will assess travel time savings for buses as well as total person delays to quantify the benefit of the proposed TSP logic.

Northern Virginia Evaluation

Upon successful field operational test at the Smart Road, the project team will work with the Virginia DOT and the City of Fairfax to conduct field operational test of the proposed TSP logic. In this field operational test, the team will compare three scenarios as well (i.e., no TSP, conventional TSP, and the proposed next generation TSP). The team will select a few candidate intersections that have DSRC devices, existing TSP, enough number of buses per hour to generate multiple buses, and closely spaced adjacent intersections. It is noted that the team will consult with the Virginia DOT and the City of Fairfax staff to determine the scope of the field operation test.

Expected Benefits

1. Through the cooperation between the buses and the traffic signal control, it would require less additional green time for TSP and eventually reduces adverse effect on side streets.
2. TSP will be granted only if person delay is not increased due to the TSP. It balances the need between general traffic users and public transportation users.
3. The proposed TSP logic will resolve conflicting TSP requests to maximize the travel time savings while balancing among various traffic users. This will be an improvement from the system that merely implements first come first serve.



Multiple Buses Scenario

CVI UTC — MORGAN STATE UNIVERSITY — VirginiaTech Transportation Institute — University of Virginia