Multi-Modal Intelligent Traffic Signal System
System Development, Deployment and Field Test

Project Plan

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Introduction
The University of Arizona has teamed with the University of California at Berkeley - PATH and technical experts from a connected vehicle system equipment manufacturer (Savari) and a traffic signal control system supplier (Econolite) to design, develop, deploy, and field test a multi-modal intelligent traffic signal system that will operate in a connected vehicle environment.

Traffic signal control has experienced very few fundamental improvements in the past 50 years. The principles of movements controlled by intervals of phases and the use of point detection have formed the basis for all traffic signal control. Advances in detection have primarily addressed the application of new technologies such as video, radar, and electromagnetic, or in the detection of pedestrians and bicycles. Advances in signal control logic have primarily focused on enhancing priority control for transit vehicles or adaptively adjusting timing parameters. Tools and methods have been developed to enable traffic engineers’ better use of traffic signal control, but the fundamental logic and operations of the controller have not changed.

Traffic signal control in most urban areas today is dynamic (actuated) in nature and coordinated with other intersections to enable smooth flow, or progression, of traffic. However, these systems depend on loop detectors or video based systems that are located at fixed locations in space to call and extend signal control phases. These detection systems provide basic information such as vehicle count, occupancy, and/or presence/passage information. This limits the use of advanced logic that can potentially be built into modern day traffic signal controllers.

Modern traffic control management systems provide the ability to monitor signal operations, change signal control plans by time of day or in a traffic responsive manner, and some provide adaptive signal timing where the signal timing parameters are adjusted based on traditional vehicle detector data. Traffic management systems provide a traffic engineer the ability to manipulate signals from a central traffic control center, but have limited strategic control capability and rely heavily on the innovation and skill of the traffic signal engineer user.

The advances in Connected Vehicle technologies provide the first real opportunity for transforming traffic signal control in terms of the traffic signal controller logic, operations, and performance. The advent of DSRC and other wireless communications technologies (e.g. LTE) in vehicular communication provides a critical component that, when coupled with meaningful messages (SAE J2735), has the potential to provide
detailed information required for intelligent traffic signal control, multi-modal priority, and performance observation. DSRC can be leveraged to provide real-time knowledge of vehicle class (passenger, transit, emergency, commercial), position, speed, and acceleration on each approach. The widespread availability of other wireless communications media, such as WiFi, 3G/4G, and Bluetooth enable Smartphones, provide coverage for other users, including pedestrians and bicycles. The potential for safer and more efficient multi-modal traffic signal operations is finally possible.

The past several years have been seen considerable innovative research and development into the use of Connected Vehicle technology for traffic signal control. The use of connected vehicle probe data in the development of signal control strategies has been limited. Most of the work has been i) on the potential and limitations of probe data to describe operating conditions in a road network and its relationship to signal control\(^1\), and ii) the potential of using probe data for providing real-time information to drivers, e.g., pilot implementation of speed advisories on head-up displays in Germany\(^2\). Ongoing work at the University of Virginia as part of the FHWA Pooled Fund study has proposed the use of probe data for better queue management and clustering of vehicle platoons\(^3\). Also, in a California PATH study aiming to develop a dynamic all-red extension strategy to reduce red-light-running (RLR) collisions, it was found that using vehicle trajectory data approaching the intersection can improve the prediction of RLR occurrences by up to 40%, compared with conventional point detection from loops.\(^4\) There has been additional development work related to communication standards (SAE), automotive industry developments (CAMP), commercial vehicle systems (CVII), and other efforts to develop transit concepts of operations and emergency services operations. All of these efforts provide critical input into the design of a Multi-Modal Intelligent Traffic Signal System.

The US DOT Mobility Applications template process has identified a minimum set of applications, or capabilities, that a Multi-Modal Intelligent Traffic Signal System should contain. These include:

- Intelligent Traffic Signal System (ISIG)
- Transit Signal Priority (TSP)
- Mobile Accessible Pedestrian Signal System (PED-SIG):
- Emergency Vehicle Preemption (PREEMPT)
- Freight Signal Priority (FSP)

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The Intelligent Traffic Signal System application concept envisions the use of high fidelity real-time data to predict lane dependent vehicle and platoon flow together with data from transit vehicles, freight (trucks), pedestrians, and emergency vehicles to find a system-wide optimal control plan. This application embodies the overall objectives of a Multi-Modal Intelligent Traffic Signal System where information from Transit vehicles (passenger count, schedule adherence or headway compliance, service level), Pedestrians (visually impaired, physically disadvantaged), Emergency Vehicles (position, heading, number of vehicles), and Freight (trucks) are present in the system. The interaction of these applications provides the opportunity and the challenge to provide a transformative capability that will finally (after more than 50 years) change the fundamentals of traffic signal control.

The objectives of this project are:

- To develop a detailed design, construct the software and hardware system, and conduct a field test of a comprehensive traffic signal system that services multiple modes of transportation, including general vehicles, transit, emergency vehicles, freight fleets and pedestrians.

Deliverable Summary:

- Summary Project Plan, 11/1/2013
- Task 1: Project Plan, 11/1/2013
- Task 3: System and Software Development, 10/24/2014
- Task 4: System Integration, Laboratory Testing, 12/5/2014
- Task 6: Field Integration and Testing (AZ), 1/15/2015
- Task 7: Field Integration and Testing (CA), 1/30/2015
- Task 8: System Test and Evaluation (AZ), 4/10/2015
- Task 9: System Test and Evaluation (CA), 4/8/2015
- Task 10: System Demonstration and Final Documentation, 4/15/2015

Task 1 – Project and Systems Engineering Management

The purpose of this task is to provide project management support for all tasks described in this scope of services.

Deliverable: Project Management Plan

Deliverable: Monthly Progress Reports and Quarterly Update Conference Calls

Task 2 – Conduct Detailed System and Software Design

The Phase I Concept of Operations (ConOps) and High Level Design tasks resulted in the identification of twenty-eight (28) key systems components that are responsible for performing the functions required to realize the MMITSS behavior. The system and software design has been divided into two categories of effort. The first category focuses on the detailed design of the system components necessary for supporting an advanced MMITSS system in a connected vehicle environment. The second effort focuses on the core system functions namely, the intelligent traffic signal control and the multi-modal traffic signal priority. These two functions represent the ‘intelligence’ that enables the future traffic control systems to consider and balance traffic demands from all vehicles as
well as serving the priority requests for specified traveler groups at the intersection level, section level and network level.

**Deliverable: Detailed System and Software Designs**

**Deliverable: Core System Functions Report**

**Task 3 – System and Software Development**

An iterative and incremental approach will be used to the system development process. In this approach, called the Unified Process, groups of like system components will be developed together and tested in short development cycles. Each group of like system components is selected so that the entire system functionality will be built starting with the most basic required components then additional functionality added based on the initial components – in an iterative approach. Each set of like components is tested to ensure they provide the defined functionality as well as functioning when integrated with other components.

The first cycle (1) consists of the basic WAVE messaging components required for security, service announcement, and communications between vehicles and the infrastructure. The second cycle (2) consists of the components that share basic vehicle data (BSM) and infrastructure MAP and SPaT data. The third cycle (3) consists of the component to track active vehicles, initial nomadic device application, and the priority request generator and a display on the vehicle node. The fourth cycle (4) consists of the traffic control logic, interface to the traffic signal controller, and getting/sending status information to and from the nomadic device. The fifth cycle (5) consists of the N-level priority policy manager, tracking nomadic devices, nomadic device priority data server, and the main priority request server. The sixth cycle (6) consists of the special authorization service for nomadic devices and the nomadic device priority request server as well as the MMITSS main user interface and configuration manager. The seventh cycle (7) consists of the intersection level performance observer and the section level coordination manager. The eighth cycle (8) consists of the section level performance observer and the section level priority manager. The ninth cycle (9) consists of the system level performance observer. Because the testing that can be done in MMITSS Phase II will be constrained to include a limited number of equipped vehicles, the performance observer functions will be developed to the level needed for these experiments rather than to the level that will eventually be needed for high market penetration conditions.

**Deliverable: An Integrated System consisting of Software and Hardware**

**Task 4 – System Integration, Laboratory Testing and Simulation**

System integration will be conducted to bring the MMITSS hardware and software components together into an integrated system. The integration work includes laboratory, hardware-in-the-loop, and intersection testing. The intersection testing will be accomplished using the PATH RFS intelligent intersection and University of Arizona test intersection (Speedway and Mountain). Limited simulations will be conducted to show expected performance of the MMITSS use cases to local authorities to convince them of the value of field testing these use cases and to assess some performance issues that cannot be tested directly in the field with very limited numbers of equipped vehicles.
**Deliverable: Tools and Testing Notebooks**  
**Deliverable: Limited Simulation Experiments Report**

**Task 5 – Support Impact Assessment (IA) Contractor**

The US DOT has selected and independent Impact Assessment (IA) Contractor. The MMITSS Team will provide data on the Arizona and California Test networks, as well as access and support for the use of the MMITSS systems and documentation suitable for their assessment activities.  
**Deliverable: Before and After Data (through RDE)**  
**Deliverable: All Methods, Algorithms, and Source code (through OSADP)**

**Task 6 and Task 7 – Field Integration and Testing**

The proof-of-concept field operational tests of MMITSS will utilize the California Connected Vehicle (CV) test bed and the Maricopa County Department of Transportation (MCDOT) SMARTDrive Field Test Network. This task defines the key activities to be performed test beds include installing MMITSS hardware and software components (including RSE upgrades, MMITSS Roadside Processors (MRP), networking devices, and central server hardware), and the development of detailed testing procedures to be conducted in Task 8 and 9.  
**Deliverable: Installation and Testing of MMITSS in the Arizona and California Test beds**

**Task 8 and Task 9 – System Test and Evaluation**

A formal system test will be conducted using the two test beds to 1) validate MMITSS functional requirements, 2) assess the system performance, and 3) investigate the impacts of the CV penetration rate (optional depending on the ability to equip passenger vehicles).  
**Deliverable: MMITSS Field Test Plan**  
**Deliverable: MMITSS Field Test Report**

**Task 10 – System Demonstration and Documentation**

A system demonstration will be conducted at each of the field test beds to demonstration the functionality of MMITSS. A project summary report will be developed that details the overall project experience and findings. It will provide a summary and reference to the detailed technical documentation including the detailed software design documents, simulation modeling developments (tools) and simulation experimentation results, laboratory and field test procedures, general impressions and findings, as well as recommendations for future MMITSS development and deployment.  
**Deliverable: Demonstration in the Arizona Test Bed**  
**Deliverable: Demonstration in the California Test Bed**  
**Deliverable: Project Summary Report**