Multi Modal Intelligent Traffic Signal System

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Connected Vehicles and Infrastructure Systems

Vehicle(s)... + Connected Vehicle Equipment
On Board Unit (OBU)
After Market Safety Device (ASD)

DSRC 5.9 GHz Radio
- BSM/SRM
- Signal Phase and Timing (SPaT)
- MAP

Cooperative Applications:
- Transit Priority
- Truck Priority
- Emergency Vehicle Priority
- Adaptive Signal Control
- Pedestrian Application

Connected Vehicle Infrastructure Equipment
Road Side Unit (RSU)

MAP Data
Digital Description of Roadway
(D. Kelley, 2012)
Connected Vehicles
Technology, Equipment and Standards

SAE J2735 Message Set
SAE J2945/0 Minimum Performance Requirements

5.9 GHz DSRC Wireless
IEEE 1609

Connected Vehicle Infrastructure Equipment
Road Side Unit (RSU)

Ethernet IEEE 802.3

DSRC Roadside Unit (RSU)
Specifications Document v4.1
(USDOT October 31, 2016)

NTCIP 1202, 1211 Messages
Basic Mobility Applications...
(not vehicle safety)

• What traffic signal applications could be built using BSM/MAP/SPaT data?
  • Performance Observation
    • Travel Time, Delay, Stop, Arrival on Red, Arrival on Green, Queue Length,…..
    • By Movement (e.g. thru, left turn, right turn)
    • By Mode (vehicles, transit, trucks, pedestrians, bicycles,....)
  • Basic Traffic Control
    • Phase Call, Phase Extend, Dilemma Zone Protection
  • Adaptive Traffic Control
    • Dynamic Phase Time (Green Allocation)
    • Optimal Signal Timing
  • Priority for Special Modes of Vehicles
    • Emergency Vehicles, Transit, Trucks, Pedestrians
The Multi Modal Intelligent Traffic Signal System Program

Funded as Connected Vehicle Pooled Fund Project (FHWA, MCDOT, Caltrans, VDOT, FDOT, MnDOT, TxDOT,...)

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  - Medhi Zamanapour (NAS/FHWA, PhD 2016)

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  - David Nelson (Hardware Engr)

- **Maricopa County DOT (Faisal Saleem), California DOT (Greg Larson)**
- **UVA** (Brian Smith, Hyungjun Park), **Virginia DOT** (Virginia Lingham)
MMITSS Basic Concepts

Priority Hierarchy
- Rail Crossings
- Emergency Vehicles
- Freight
- Coordination
- Transit
  - BRT
  - Express
  - Local (Late)
- Passenger Vehicles
- Pedestrians

Section 1
- Priority for
  - Freight
Priority Hierarchy
- Rail Crossings
- Emergency Vehicles
- Transit
  - BRT
  - Express
  - Local (Late)
- Pedestrians
- Passenger Vehicles
- Freight

Section 2
- Priority for
  - Transit
  - Pedestrians
MMITSS Basic Concepts

Real-Time Performance Measures – by mode, by movement
- Volume (mean, variance)
- Delay (mean, variance)
- Travel Time (mean, variance)
- Throughput (mean, variance)
- Stops (mean, variance)
MMITSS Characteristics

- Uses Connected Vehicle Data
  - BSM, MAP, SRM, SSM, (SPaT)
- ISIG: Adaptive Control
  - RT-TRACS, RHODES, COP, OPAC,…
- PRIORITY (EVP, TSP, FSP): Priority Request Server (MRP)/Generator (OBU)
  - TCRP A-16, NCHRP 3-66, NTCIP 1211
- PEDSIG
  - Smartphone APP
MMITSS Software (AZ)
MMITSS Priority Control

• Integrated approach to Signal Control and Prioritization
• Consistent with NTCIP SCP 1211 Standard (2014)
• Key Features
  • Accommodate Multiple Active Priority Requests from Different Modes
    • N-Level Priority Hierarchy
  • Coordination within the Priority Control Framework
Basic Operational Concept: Priority Control

- When a vehicle enters/remains in the range of an RSU
  1. Hears (Listens for...)
     - MAP/SPaT
     - WAVE Service Announcement (go to channel XX to talk)
  2. Computes Position on MAP, Desired Service Time (ETA), Desired Ingress and Egress (maybe)
  3. Sends a Signal Request Message (SRM)
  4. Receives Signal Status Message (SSM* - confirmation)
  5. Passes through intersection
  6. Sends a Cancel Signal Request Message (SRM)
Visualization tool for priority algorithm: Time-Phase Diagram

Phases in Ring 1
- P1
- P2
- P3
- P4

Phases in Ring 2
- P5
- P6
- P7
- P8

Time (second)

Delay
Flexible Implementation Algorithm (Zamanipour et al., 2016)

• Critical points for one request

CLP1: \( \max \{FL1, BL3\} \)
CLP2: \( \max \{FL2, BL2\} \)
CLP3: \( \max \{FL3, BL1\} \)
CLP4: BR1

CRP1: \( \min \{FR1, BR4\} \)
CRP2: \( \min \{FR2, BR3\} \)
CRP3: \( \min \{FR3, BR2\} \)
CRP4: BR1
Arizona Connected Vehicle Test Bed
Anthem, AZ

DSRC Installations:
11 Signalized Intersection
6 Freeway Interchanges
10 Freeway Locations
Approx. 25,000 Residents
Approx. 10,000 Vehicles

1 2018 Expansion Project (ADOT)
Field Testing Scenarios, March 3rd and 4th 2015
Designed and Conducted by Leidos (IA Contractor)

- 2 trucks with priority in northbound/southbound
- 2 buses with priority in eastbound/westbound
- 10 rounds of testing
- 6 regular vehicles

Source: Leidos Field Test Plan
Field Test Result for Transit Priority

<table>
<thead>
<tr>
<th></th>
<th>Baseline (2 buses without Priority Requests for 10 Round Trips)</th>
<th>TSP (2 buses with Priority Requests for 10 Round Trips)</th>
<th>Improvement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average TT (sec)</td>
<td>850.12</td>
<td>762.56</td>
<td>-10.3</td>
</tr>
<tr>
<td>TT Standard Deviation</td>
<td>91.13</td>
<td>53.48</td>
<td>-41.3</td>
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</tbody>
</table>
Time-Space Diagram without MMITSS

- Daisy Mountain and Gavilan Peak Northbound Movement
- Number of Stops: 5, Number of Queue Encounters: 1
  - Using BSMs sent from Truck #1

Truck #1

Wednesday Afternoon: 1:30 pm - 5:00 pm
Time-Space Diagram with MMITSS

- Daisy Mountain and Gavilan Peak Northbound Movement
- Number of Stops: 1, Number of Queue Encounters: 2
  - Using BSMs sent from Truck #1

Truck #1
Tuesday Afternoon: 1:30 pm - 5:00 pm
Findings for Freight Priority

<table>
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<tr>
<th></th>
<th>Baseline (2 trucks without Priority for 10 Round Trips)</th>
<th>FSP (2 trucks with Priority for 10 Round Trips)</th>
<th>Improvement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average TT (sec)</td>
<td>182.42</td>
<td>175.44</td>
<td>-3.84</td>
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<tr>
<td>TT Standard Deviation</td>
<td>36.28</td>
<td>28.37</td>
<td>-21.78</td>
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</table>
MMITSS Pedestrian Smartphone App

Allows Pedestrian to receive auditory and haptic feedback
- Align with Crosswalk
- Send Call for Service
- Be given WALK
- PedCLEAR Countdown

Savari SmartCross (SBIR) Application Architecture
MMITSS Phase I - Products

- Concept of Operations Document
  - Stakeholder Report (Input)
- MMITSS Systems Requirements Document
- MMITSS Design Document
MMITSS Phase II - Products

• Two MMITSS Prototypes
  • MMITSS-AZ: Integrated MMITSS with adaptive control
  • MMITSS-CA: Add-on MMITSS interfaced with legacy traffic controller

• Detailed System and Software Design Document

• System Integration and Laboratory Testing
  • Arizona Connected Vehicle Simulation Platform
  • PATH Richmond Field Station Testing Intersection

• Field Integration and Testing

• System Test and Evaluation (Priority Only)
  • Leidos Impact Assessment Report

• System Demonstration(s) and Final Report
MMITSS Phase III: Deployment Readiness Enhancements
Started February 2018

• Required Upgrades/Improvements
  • Upgrade to 2016 SAE J2735 Standard
  • Upgrade to RSU 4.1 Specification
  • Code Improvements/Clean Up/Documentation Improvements
  • Enhanced Performance Measures
  • Interface to USDOT Operational Data Environment (ODE)

• Desired Upgrades/Improvements
  • Traffic Control Enhancements
    • Integrated Priority/Coordination/Adaptive
    • Section-Level Priority
  • Usability
    • User Interface - Configuration/Operation
  • Security (Message Signing)

• Task 4 – Field Test and Demonstration
  • 90-Day Field Operational Test

• Task 5 – Technical Assistance to Deploy MMITSS
  • Support another deployment
Desired: MMITSS Usability

• **Objective**
  • How would a traffic agency configure, operate, monitor MMITSS?
    • Consideration for deployability
  • What features need to be added to support usability?
  • Are these for the MMITSS Team or for adopters?
    • E.g. Siemens RSU interface approach
Growing Towards Deployment: Impact

- Connected Vehicles are a Tool for Solving Transportation Problems
  - Safety
  - Mobility
  - Environment
- Building Partnerships
  - Transit
  - Freight
  - Emergency Services
  - Pedestrians
  - Parking Services
- Meeting Challenges
  - Market Penetration
  - MAP data

MMITSS Project Discussion/Plan
MMITSS Project Proposal Developed
MMITSS (AZ) Project Active
MMITSS (CA) Project Active

Map showing project locations: Portland NTIC, San Diego Port (FSP), Caltrans/PATH (199), UDOT (35), CDOT, MCDOT (19+11), ADOT (14), PAG/Tucson (10), ASWARTCOLUMBUS (FSP), THEA CV Pilot Project.
Lessons Learned/Observations

• **Standards**
  - Provide interfaces for system integration/deployment
  - NTCIP, IEEE, SAE

• **CV Data can improve traffic control**
  - Performance Observations
  - New generation of traffic control algorithms
  - Controllers supporting SPaT (NTCIP 1203 v3)

• **Deployment Challenges**
  - Market Penetration
    - Special Fleets – EV, Transit, Freight, Public Service, ..... 
    - Adoption by OEMs (Toyota, GM, ....) [NHTSA Mandate]
  - MAP Data
    - What fidelity?
    - How to build/develop?
Questions? Discussion

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