The Multi Modal Intelligent Traffic Signal System (MMITSS): A Connected Vehicle Dynamic Mobility Application

Larry Head
University of Arizona
Connected and Automated Vehicle Systems

Connected Vehicles

Automated Driving Vehicles

Connected Travelers

Connected Infrastructure

Photo Source: http://www.its.dot.gov
Connected Vehicles

- **Purpose:**
  - Safety
  - Mobility
  - Environment

- **Basic Safety Message (BSM)**
  - Temporary ID (ensure privacy)
  - Position (GPS)
  - Motion
    - Speed
    - Heading
    - Steering Wheel Angle
    - Acceleration
  - Brakes
  - Vehicle Size
  - Mode (vehicle, transit, truck, EV, ...)

DSRC
5.9 GHz Wireless
Basic Safety Message (SAE J2735 BSM)
Broadcast 10 times/second (10 HZ)
Connected Vehicles and Infrastructure Systems

Vehicle(s)...
+ Connected Vehicle Equipment

On Board Unit (OBU)
After Market Safety Device (ASD)

Connected Vehicle Infrastructure Equipment
Road Side Unit (RSU)

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

Cooperative Applications:
- Truck Priority
- Transit Priority
- Emergency Vehicle Priority

MAP Data
Digital Description of Roadway
(D. Kelley, 2012)
DSRC Channels

Latency vs. Communications Technologies For IntelliDrive<sup>SM</sup>

### Active Safety Latency Requirements (secs)

<table>
<thead>
<tr>
<th>Service</th>
<th>Latency (secs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Signal Violation Warning</td>
<td>0.1</td>
</tr>
<tr>
<td>Curve Speed Warning</td>
<td>1.0</td>
</tr>
<tr>
<td>Emergency Electronic Brake Lights</td>
<td>0.1</td>
</tr>
<tr>
<td>Pre-Crash Sensing</td>
<td>0.02</td>
</tr>
<tr>
<td>Cooperative Forward Collision Warning</td>
<td>0.1</td>
</tr>
<tr>
<td>Left Turn Assistant</td>
<td>0.1</td>
</tr>
<tr>
<td>Lane Change Warning</td>
<td>0.1</td>
</tr>
<tr>
<td>Stop Sign Movement Assistance</td>
<td>0.1</td>
</tr>
</tbody>
</table>

**Most Stringent latency requirement for Active Safety**

- 5.9 GHz DSRC (.0002 secs)

**Least stringent latency requirement for Active Safety**

- 1 sec

---

Communications Technologies

- Two-Way Satellite (60+ secs)
- Terrestrial Digital Radio & Satellite Digital Audio Radio (10 - 20 secs)
- WiFi 802.11 (3 - 5 secs)
- Bluetooth (3 - 4 secs)
- Cellular (1.5 - 3.5 secs)
- WiMax (1.5 - 3.5 secs)

Note: Y-axis not to scale for illustration purposes

Data source: Vehicle Safety Communications Project – Final Report

June 21, 2016

University of Arizona 2016
DSRC Range ~ 300m
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

June 21, 2016
MMITSS Team

• Technical
  • University of Arizona (Prime)
  • University of California Berkeley (PATH)
  • Savari
  • Econolite

• Sponsors
  • Pooled Fund Project
    • FHWA
    • Virginia DOT/UVA
    • Maricopa County DOT
    • Caltrans
    • Minnesota DOT
    • Florida DOT
    • Michigan DOT
MMITSS Basic Concepts

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

Traffic Control System

Section 1
- Priority for
  - Freight

June 21, 2016

University of Arizona 2016
A Traffic Control System

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

Section 2
- Priority for
  - Transit
  - Pedestrians
Real-Time Performance Measures – by mode, by movement
• Volume (mean, variance)
• Delay (mean, variance)
• Travel Time (mean, variance)
• Throughput (mean, variance)
• Stops (mean, variance)

System Performance Measures
• Market Penetration
• Radio Range (meters)
• MAP Accuracy
• Security Violations
• ilities – Availability, Reliability, Serviceability, ....
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

June 21, 2016
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)
  5. If needed, update the Signal Request Message (SRM)
  6. Passes through intersection
  7. Sends a Cancel Signal Request Message (SRM)
Simulation Example/Results

- Priority eligible requests from Transit (2) and Trucks (1)
- Transits headway is 10 minutes, requesting phase (2, 6)
- Trucks are compose 6% of vehicles, requesting phase (4, 8)
Simulation Results

• Priority Request Table

<table>
<thead>
<tr>
<th>Request</th>
<th>Range (seconds)</th>
<th>Requested Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Transit#1</td>
<td>[10,15]</td>
<td>2</td>
</tr>
<tr>
<td>2 Transit#2</td>
<td>[42, 47]</td>
<td>6</td>
</tr>
<tr>
<td>3 Truck</td>
<td>[50, 60]</td>
<td>4</td>
</tr>
</tbody>
</table>
Preliminary Numerical Results: Impact of Weight Selection on Policy

- Comparing average truck and average transit delay with and without priority

Avgerag Delay

Medhi Zamanipour, PhD Student
University of Arizona 2016
Arizona Connected Vehicle Test Network – Anthem, AZ
MMITSS Pedestrian Smartphone App

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

Sara Khosravi, PhD Student

Savari SmartCross (SBIR) Application Architecture
Connected Vehicles for Freight Priority

• How can connected vehicle create an effective environment for BRT Operations?
  • Traffic Signal Priority
    • Trucks < Transit < ......
  • Shared Lanes
    • Increase overall roadway capacity
  • Intermittent Priority
    • Shared lane use with Freight/Transit Priority
Changzhou, China

Wei Wu, Tongji University
Current Truck (Bus) Lane Operation

- Exclusive Truck Lane (BRT)
- Other vehicles are not allowed to use the lane
- Headway between transit vehicles determine lane utilization
Intermittent Truck (Bus) Lane Operation Without CV Technologies

- Shared Truck Lane (BRT)
- Network divided into segments
- Information provided using infrastructure based signs
- Non-Transit vehicles allowed to use shared lane

Eichler & Deganzo, 2006, TR-B
Connected Vehicle Concept: BLIP

- Shared Truck (Bus) Lane (BRT)
- Only Connected Vehicles can use the Shared Lane
- Information provided using Vehicle-to-Vehicle Communications
- Dynamic headway can depend on traffic congestion or other factors
BLIP: Bus Lanes with Intermittent Priority

- VISSIM Simulation
  Connected Vehicle (CV) Demonstration

- Red Bus: BRT (Bus Rapid Transit)
- Yellow Bus: regular bus
- Yellow Cars: regular cars, can not enter the BRT lane
- Green Cars: CVs
- Red Cars: CVs that are required to get out of the BRT lane
- Blue Cars: CVs allowed use of the BRT lane
VISSIM Visualization of BLIP
BLIP: Bus (Truck) Lanes with Intermittent Priority

- Some performance observations
  - Basic Behavior with Exclusive Lane
BLIP: Bus (Truck) Lanes with Intermittent Priority

- Some performance observations
  - Basic Behavior 300 meter shared lane (CV)
BLIP: Bus (Truck) Lanes with Intermittent Priority

- Some performance observations
  - Effect of CV Penetration Rate

![Graph showing effect of CV Penetration Rate on Average Delay](image-url)

- Graph with X-axis labeled CV Penetration and Y-axis labeled Average Delay (sec/veh)
- Legend for BRT, Car, CV, Bus
- Data points for S=0.9
Other Freight Priority Concepts

- Dynamic Lane Usage (similar to Bus Lanes)
- Freight Dilemma Zone Protection
- Dynamic Change and Clearance Intervals
Observations

• Connected Vehicles provide ability to KNOW the location and mode of vehicles at intersections
  • Intelligent Signal Control
  • Priority Control (EV, Transit, Trucks)
  • Pedestrian Access
  • Performance Observation

• Connected Vehicle create a cooperative environment for effectively using the roadway capacity
  • Exclusive Freight/BRT/Transit Lanes
  • Shared Freight/BRT Lanes
  • Mixed Operations
Questions?
Discussion

Larry Head
Systems and Industrial Engineering
University of Arizona
klhead@email.arizona.edu
(520) 621-2264