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

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Connected and Automated Vehicle Systems

Connected Vehicles

Automated Driving Vehicles

Connected Travelers

Connected Infrastructure

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

Connected Vehicles

DSRC
5.9 GHz Wireless

Basic Safety Message
(SAE J2735 BSM)
Broadcast 10 times/second
(10 HZ)

- 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,…)

Connected Vehicles and Infrastructure Systems

Vehicle(s)…

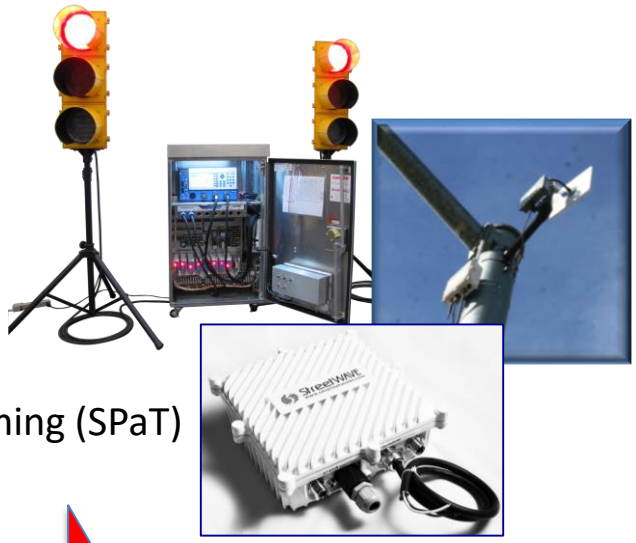
+

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



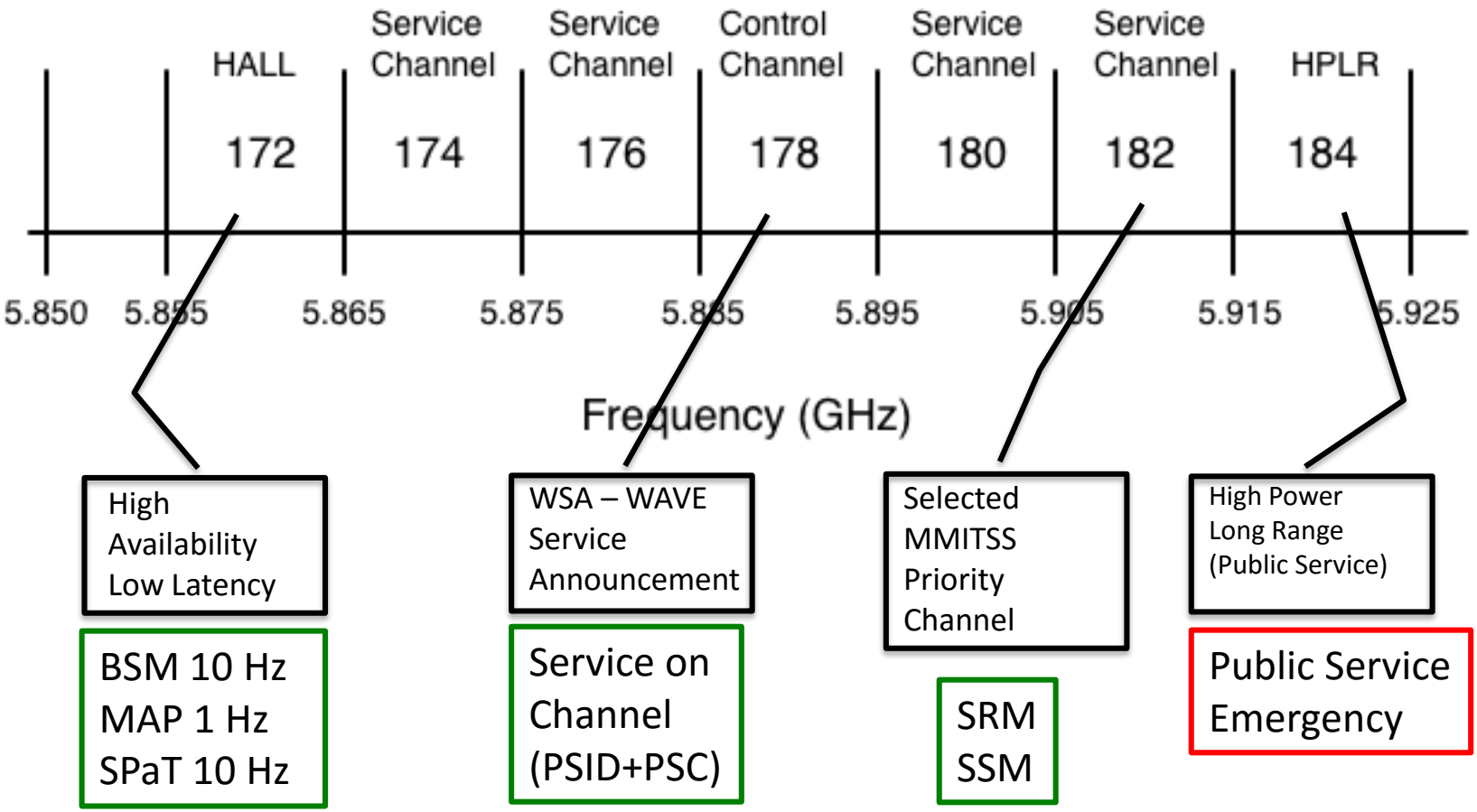
Connected Vehicle Infrastructure Equipment
Road Side Unit (RSU)

Cooperative Applications:

- Truck Priority
- Transit Priority
- Emergency Vehicle Priority

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

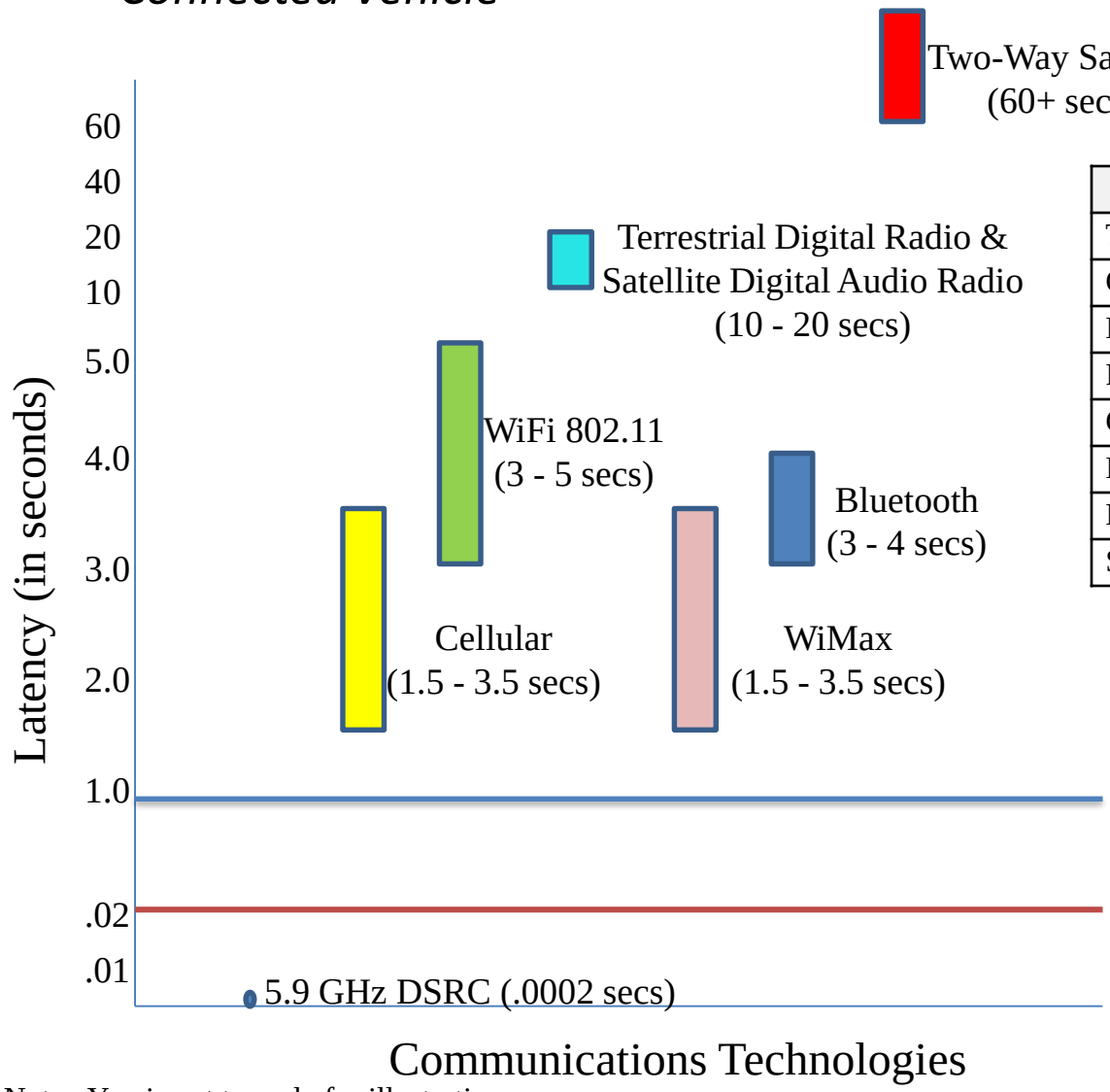
DSRC Channels



Source: Delgrossi, L. and T. Zhang, Vehicle Safety Communications: Protocols, Security, and Privacy, Wiley, 2012.

From US DOT Briefings on Connected Vehicle

Latency vs. Communications Technologies For IntelliDrive℠



Active Safety Latency Requirements (secs)	
Traffic Signal Violation Warning	0.1
Curve Speed Warning	1.0
Emergency Electronic Brake Lights	0.1
Pre-Crash Sensing	0.02
Cooperative Forward Collision Warning	0.1
Left Turn Assistant	0.1
Lane Change Warning	0.1
Stop Sign Movement Assistance	0.1

Least stringent latency requirement for Active Safety (1 sec)

Most Stringent latency requirement for Active Safety (.02 sec)

Note: Y-axis not to scale for illustration purposes

DSRC Range ~ 300m

Basic Mobility Applications…
(not vehicle safety)

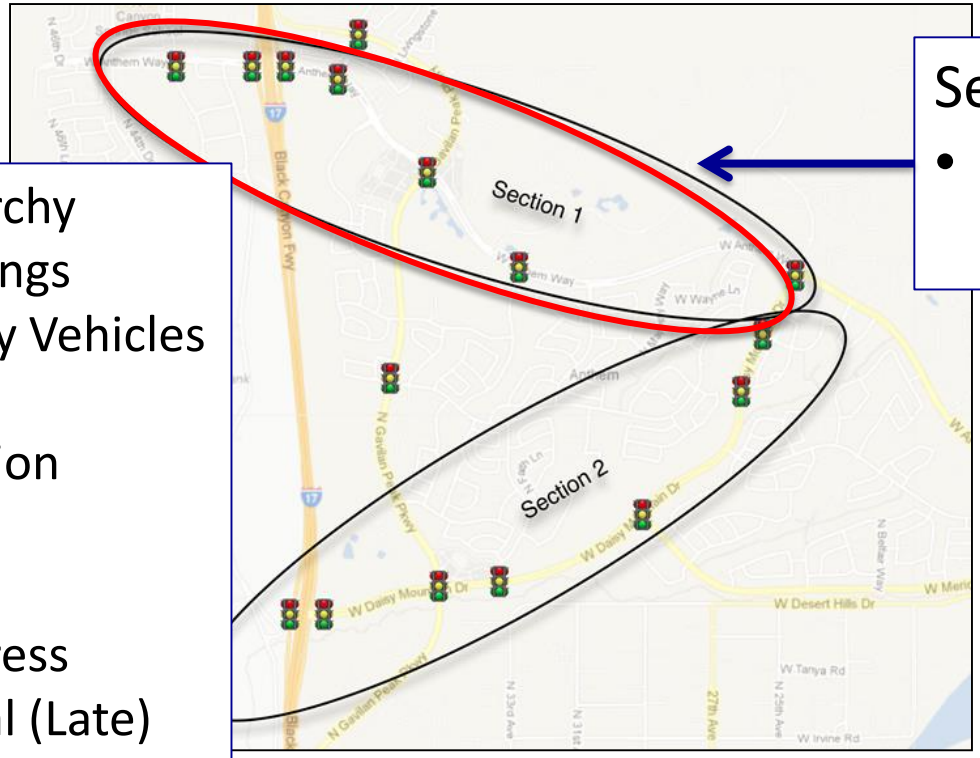
- What traffic signal applications could be built using BSM/MAP/SPaT data?
  - Performance **Observation**
    - Travel Time, Delay, Stop, Arrival on Red, Arrival on Green, Queue Length,…..
    - By Movement (e.g. thru, left turn, right turn)
    - By Mode (vehicles, transit, trucks, pedestrians, bicycles,…)
  - 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

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

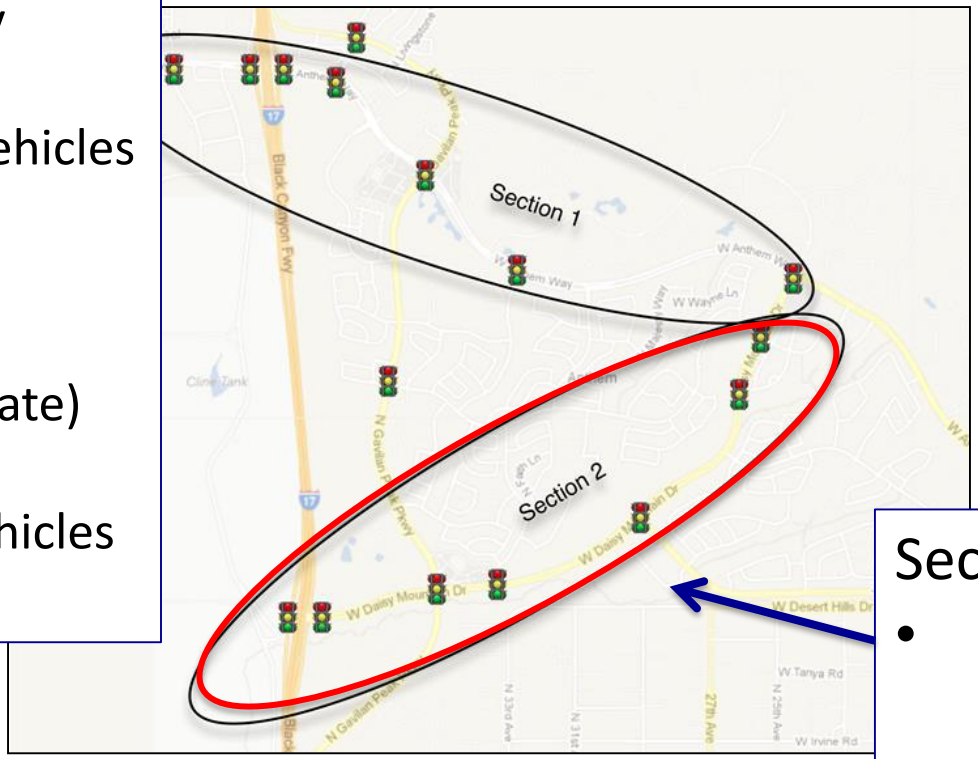


Traffic Control System

Section 1
- Priority for
  - Freight

MMITSS Basic Concepts

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



A Traffic Control System

Section 2
- Priority for
  - Transit
  - Pedestrians

MMITSS Basic Concepts

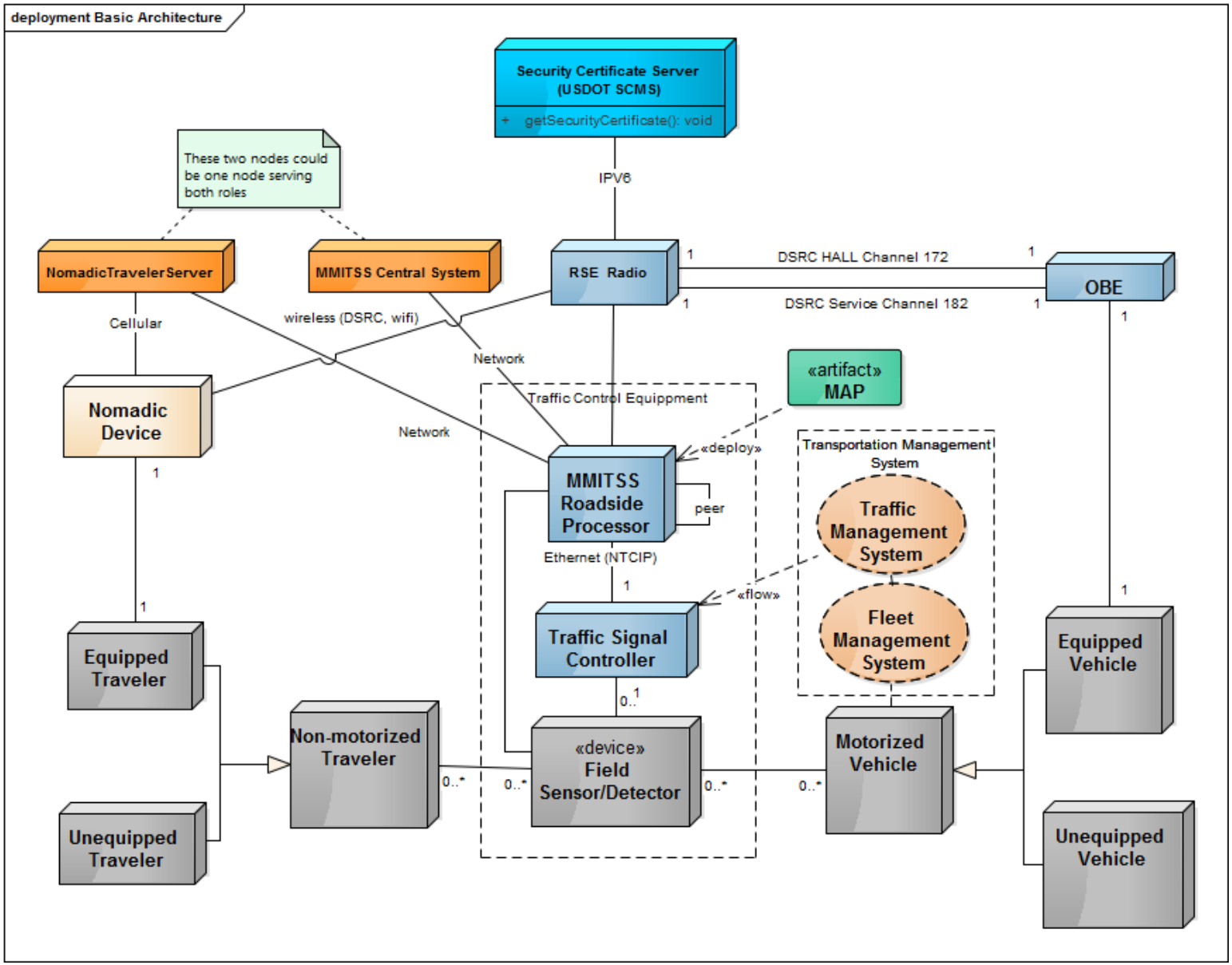
Real-Time Performance Measures – by mode, by movement

- Volume (mean, variance)
- Delay (mean, variance)
- Travel Time (mean, variance)
- Throughput (mean, variance)
- Stops (mean, variance)

System Performance Measures

- Market Penetration
- Radio Range (meters)
- MAP Accuracy
- Security Violations
- ilities – Availability, Reliability, Serviceability, ….

MMITSS Architecture



MMITSS Priority Control

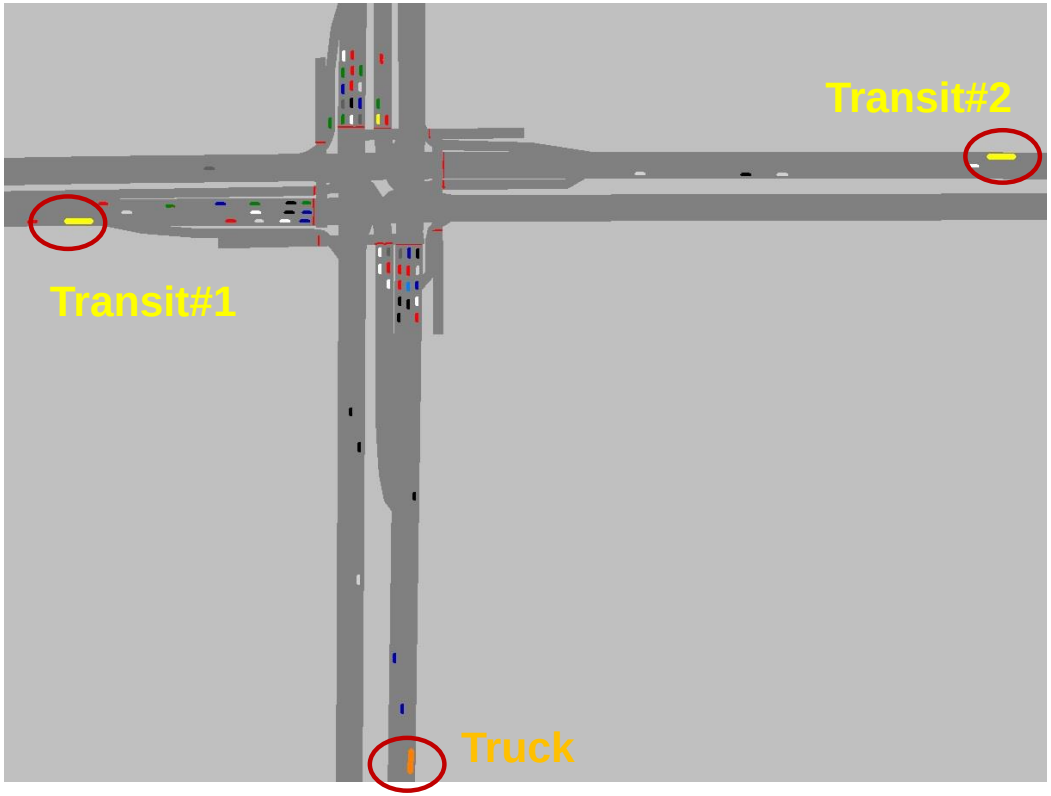
- Integrated approach to Signal Control and Prioritization
- Consistent with NTCIP SCP 1211 Standard (2014)
- Key Features
  - Accommodate Multiple Active Priority Requests from Different Modes
    - N-Level Priority Hierarchy
  - Coordination within the Priority Control Framework

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)
  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)



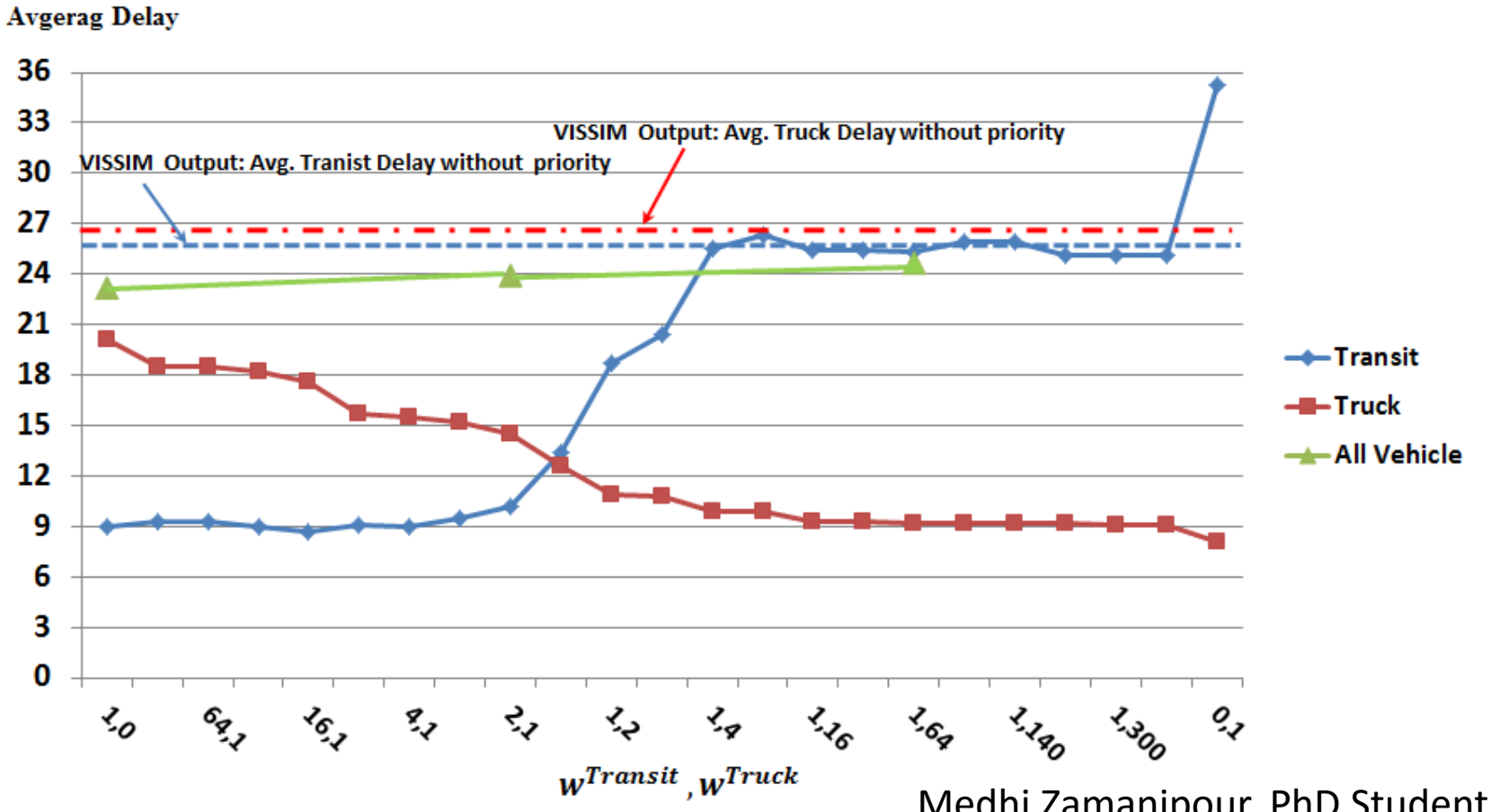
Simulation Results

- Priority Request Table

	Request	Range (seconds)	Requested Phase
1	Transit#1	[10,15]	2
2	Transit#2	[42, 47]	6
3	Truck	[50, 60]	4

Preliminary Numerical Results: Impact of Weight Selection on Policy

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

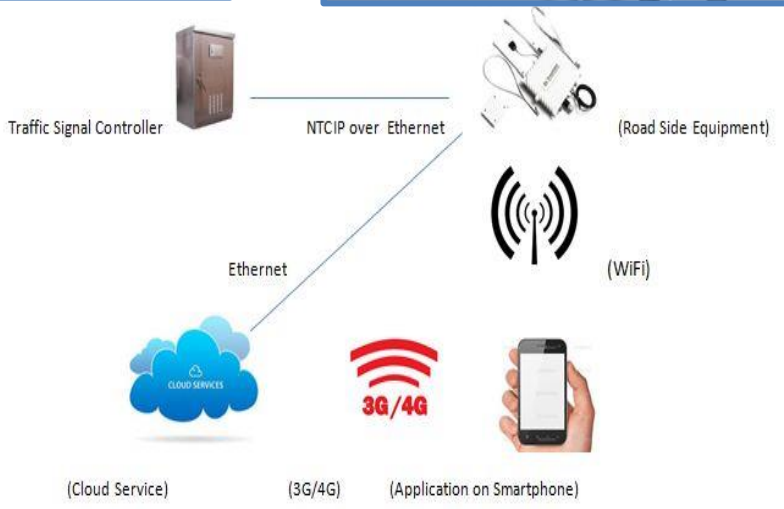


Medhi Zamanipour, PhD Student
University of Arizona 2016

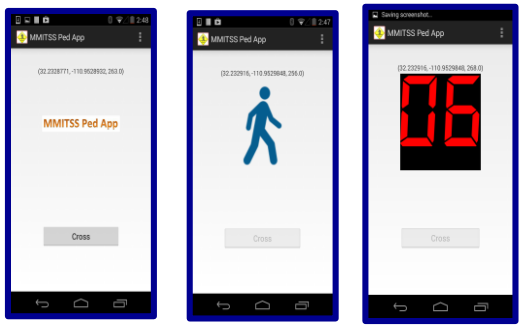
Arizona Connected Vehicle Test Network – Anthem, AZ

+ ARIZONA + ADOT

MMITSS Pedestrian Smartphone App



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

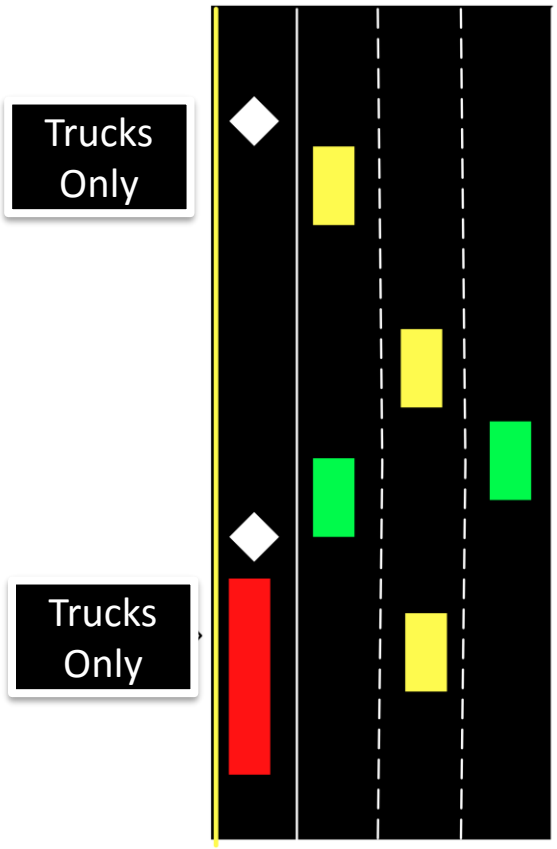
Connected Vehicles for Freight Priority

- 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

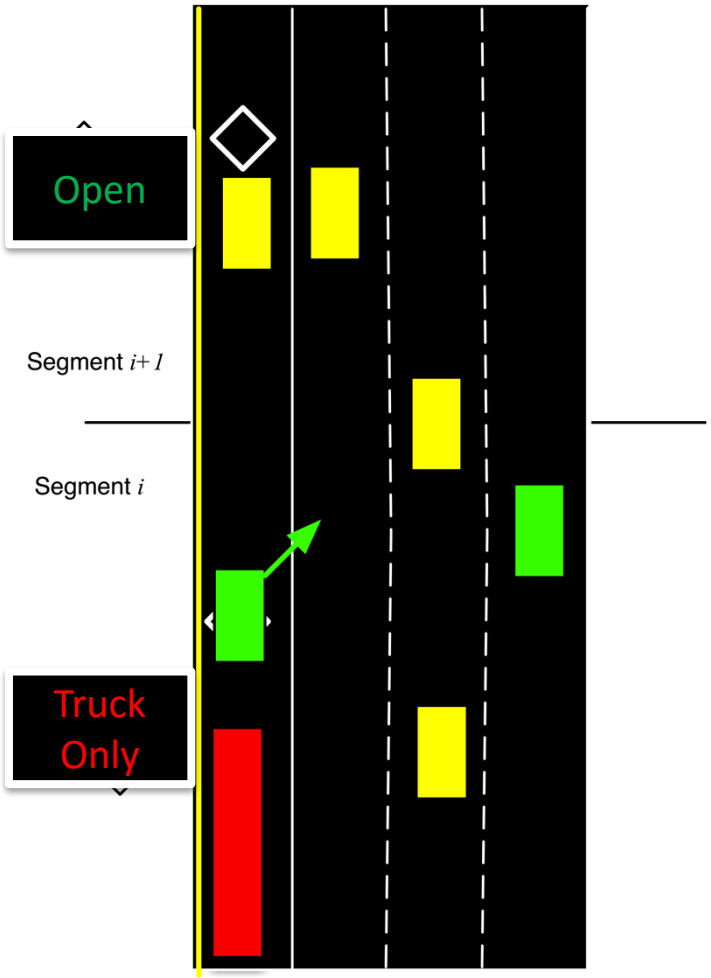
Wei Wu, Tongji University

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

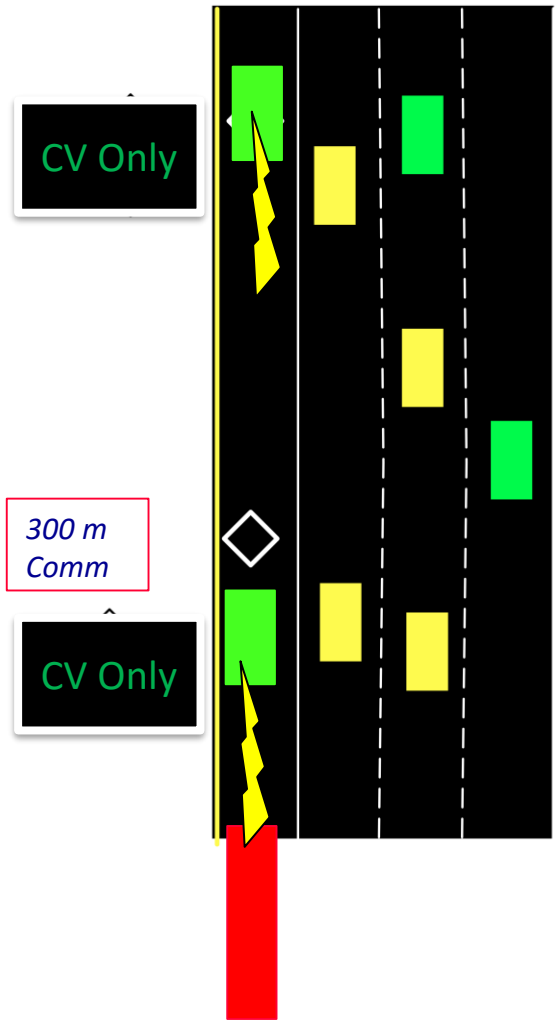
Intermittent Truck (Bus) Lane Operation Without CV Technologies



- 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

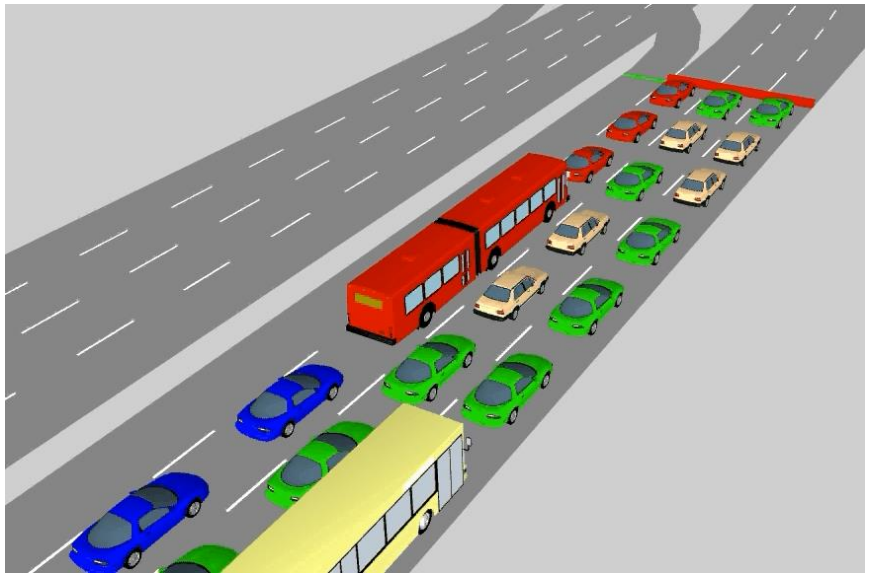
Connected Vehicle Concept: BLIP



- 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

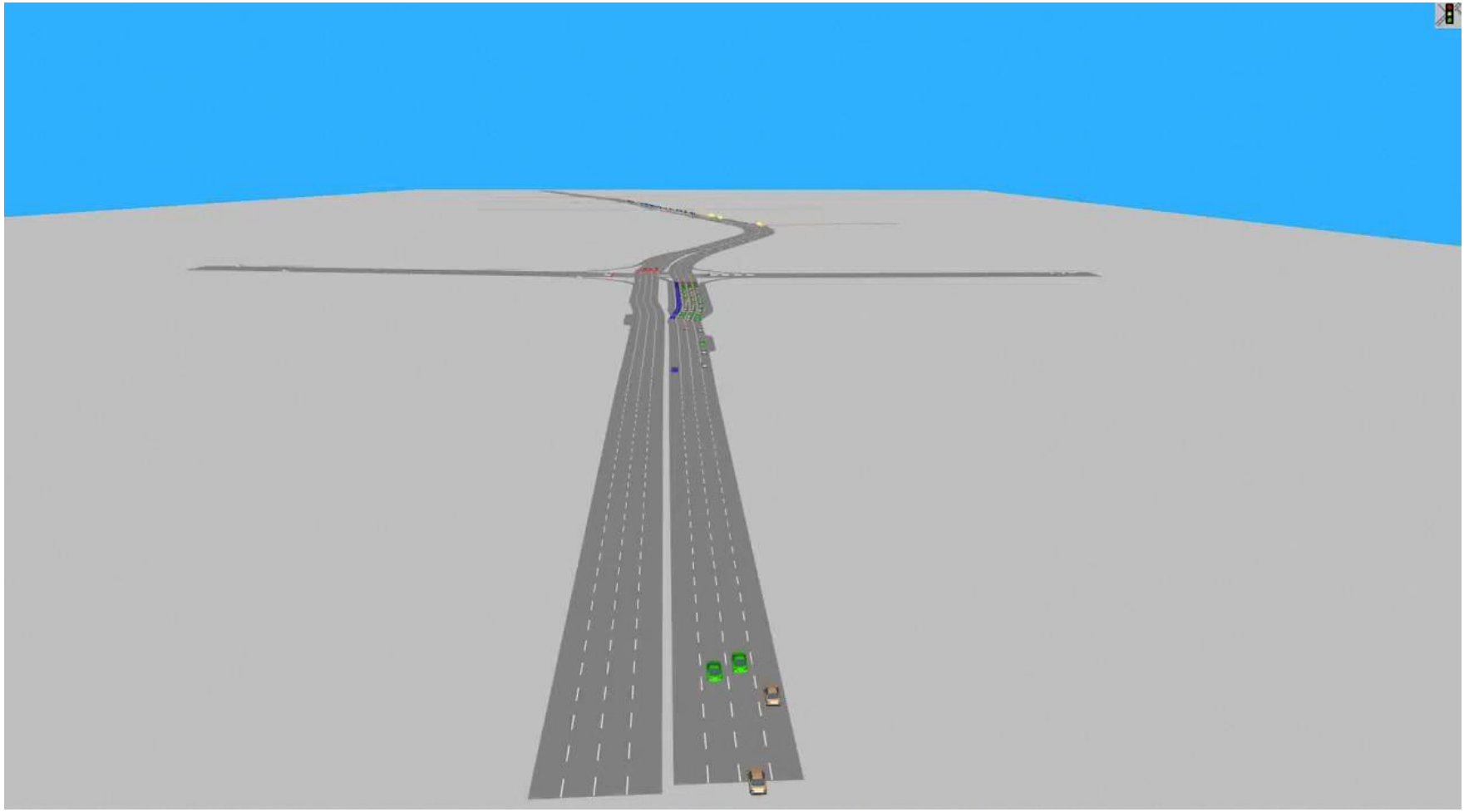
BLIP: Bus Lanes with Intermittent Priority

- VISSIM Simulation Connected Vehicle (CV) Demonstration



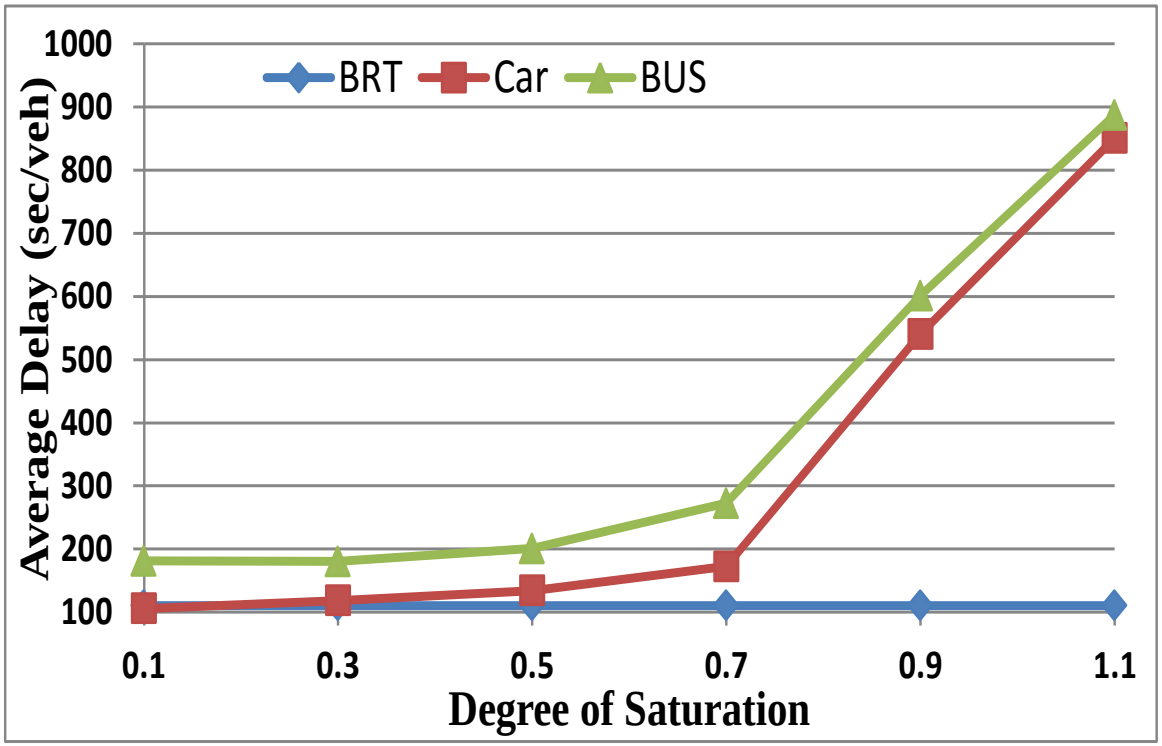
- Red Bus: BRT(Bus Rapid Transit)
- Yellow Bus: regular bus
- Yellow Cars: regular cars, can not enter the BRT lane
- Green Cars: CVs
- Red Cars: CVs that are required to get out of the BRT lane
- Blue Cars: CVs allowed use of the BRT lane

VISSIM Visualization of BLIP



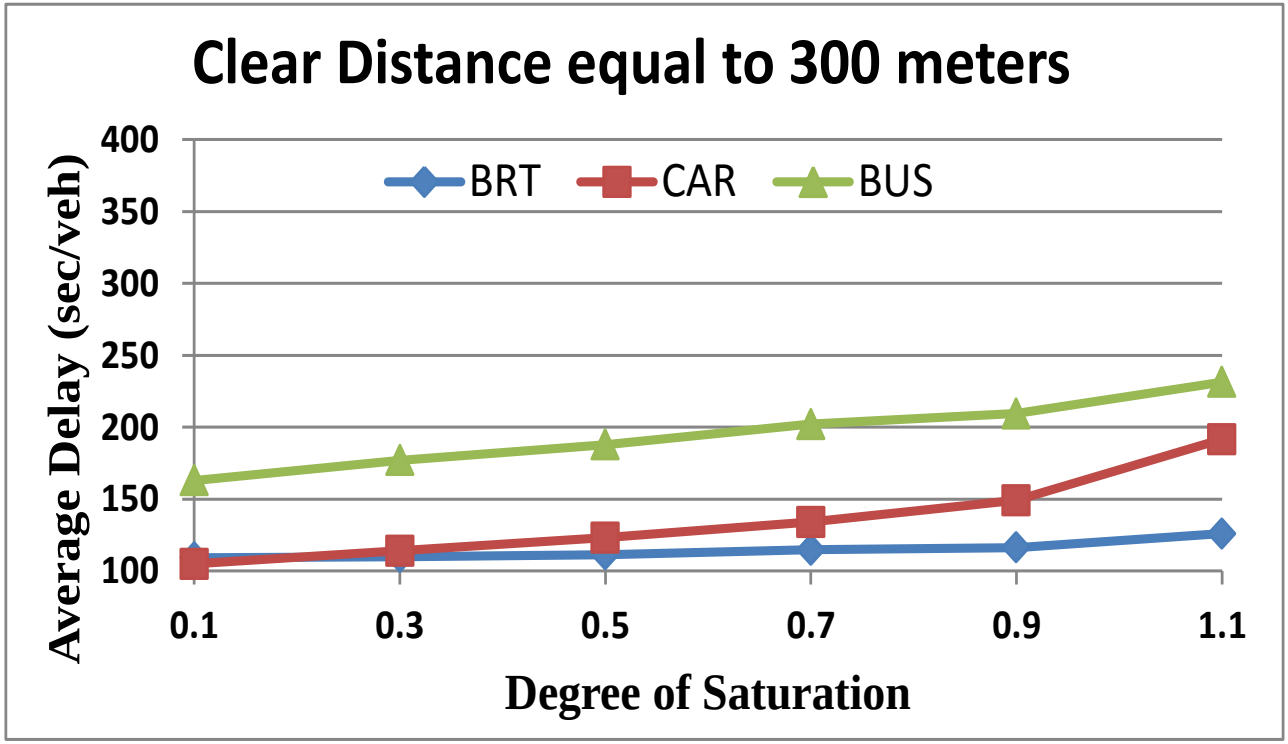
BLIP: Bus (Truck) Lanes with Intermittent Priority

- Some performance observations
  - Basic Behavior with Exclusive Lane



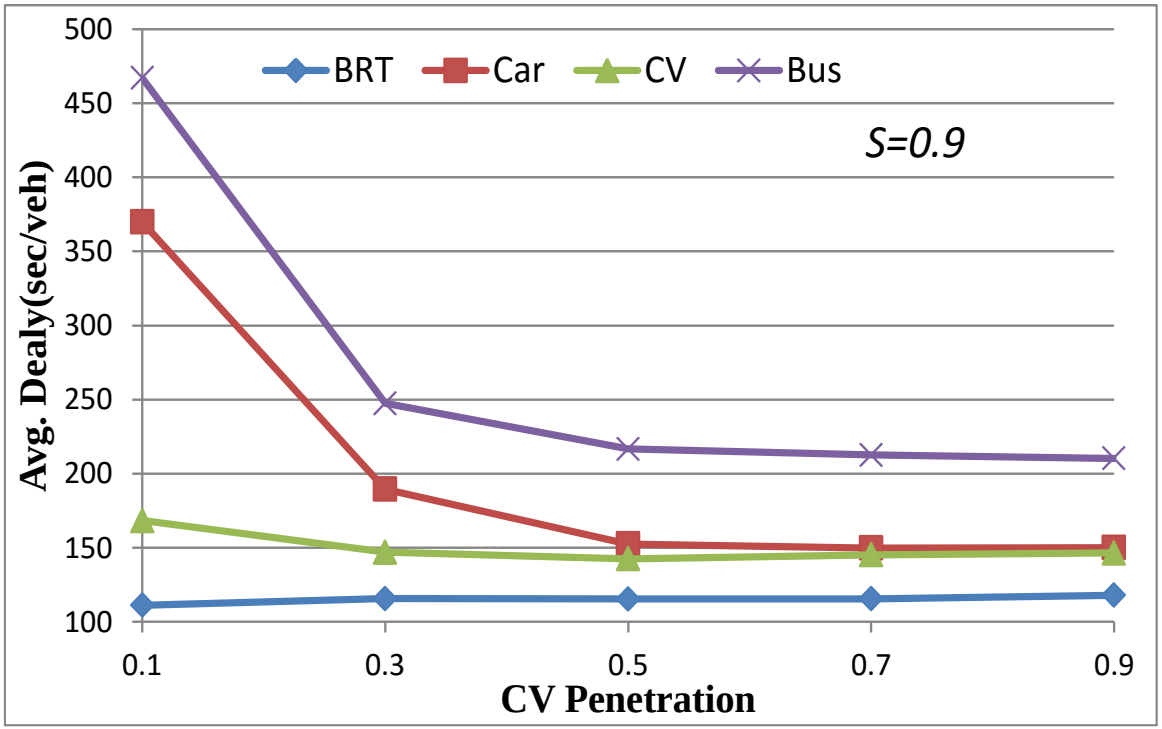
BLIP: Bus (Truck) Lanes with Intermittent Priority

- 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



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

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