U.S. DOT AERIS Program:
Applications for the Environment: Real-Time Information Synthesis

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Objectives of AERIS

- Identify connected vehicle applications that could provide environmental impact reduction benefits via reduced fuel use, more efficient vehicles, and reduced emissions.
- Facilitate and incentivize “green choices” by transportation service consumers (i.e., system users, system operators, policy decision makers, etc.).
- Identify vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-grid (V2G) data (and other) exchanges via wireless technologies of various types.
- Model and analyze connected vehicle applications to estimate the potential environmental impact reduction benefits.
- Develop a prototype for one of the applications to test its efficacy and usefulness.
Operational Scenarios and Applications

**ECO-SIGNAL OPERATIONS**
- Eco-Approach and Departure at Signalized Intersections (similar to SPaT)
- Eco-Traffic Signal Timing (similar to adaptive traffic signal systems)
- Eco-Traffic Signal Priority (similar to traffic signal priority)
- Connected Eco-Driving (similar to eco-driving strategies)
- Wireless Inductive/Resonance Charging

**ECO-LANES**
- Eco-Lanes Management (similar to HOV Lanes)
- Eco-Speed Harmonization (similar to variable speed limits)
- Eco-Cooperative Adaptive Cruise Control (similar to adaptive cruise control)
- Eco-Ramp Metering (similar to ramp metering)
- Connected Eco-Driving (similar to eco-driving)
- Wireless Inductive/Resonance Charging
- Eco-Traveler Information Applications (similar to ATIS)

**ECO-TRAVELER INFORMATION**
- AFV Charging/Fueling Information (similar to navigation systems providing information on gas station locations)
- Eco-Smart Parking (similar to parking applications)
- Dynamic Eco-Routing (similar to navigation systems)
- Dynamic Eco-Transit Routing (similar to AVL routing)
- Dynamic Eco-Freight Routing (similar to AVL routing)
- Multi-Modal Traveler Information (similar to ATIS)
- Connected Eco-Driving (similar to eco-driving strategies)

**ECO-INTEGRATED CORRIDOR MANAGEMENT**
- Eco-ICM Decision Support System (similar to ICM)
- Eco-Signal Operations Applications
- Eco-Lanes Applications
- Low Emissions Zones Applications
- Eco-Traveler Information Applications
- Incident Management Applications

**LOW EMISSIONS ZONES**
- Low Emissions Zone Management (similar to Low Emissions Zones)
- Connected Eco-Driving (similar to eco-driving strategies)
- Eco-Traveler Information Applications (similar to ATIS)
Eco-Signal Operations Modeling Overview

Traffic Simulation Model Inputs
- Origin-Destination (OD) Data
- Roadway Geometry
- Traffic Signal Timing Plans
- Driver Behavior Parameters

Traffic Simulation Model Outputs
- Vehicle Type
- Vehicle Position
- Vehicle Speed
- Traffic Signal Data
- Traffic Conditions

Assumptions for Sensitivity Analysis
- Connected Vehicle Technology Penetration Rates
- On-Board Equipment (OBE)
- Roadside Equipment (RSE)
- Driver Compliance Rate
- Volume-to-Capacity (V/C) Ratio
- Vehicle Fleet Mix
  - Percentage of Alternative Fuel Vehicles
  - Percentage Trucks
  - Percentage Transit

AERIS Algorithm API Outputs
- Updates to Traffic Signal Timing
  - Cycle Lengths
  - Green Splits
  - Offsets
  - Green Extension or Truncation (for traffic signal priority)
- Recommended Speeds

AERIS Algorithm APIs
- Eco-Approach and Departure at Signalized Intersections
- Eco-Traffic Signal Timing
- Eco-Traffic Signal Priority
  - Eco-Transit Signal Priority
  - Eco-Freight Signal Priority
- Connected Eco-Driving

MOVES API

MOVES Emissions Model

MOVES Outputs
- Fuel Consumption
- Emissions
Eco-Approach and Departure (EAD) at Signalized Intersections

- Collects signal phase and timing (SPaT) and Geographic Information Description (GID) messages using vehicle-to-infrastructure (V2I) communications
- Collects basic safety messages (BSMs) from nearby vehicles using vehicle-to-vehicle (V2V) communications
- Receives V2I and V2V messages, the application performs calculations to determine the vehicle’s optimal speed to pass the next traffic signal on a green light or to decelerate to a stop in the most eco-friendly manner
- Provides speed recommendations to the driver using a human-machine interface or sent directly to the vehicle’s longitudinal control system to support partial automation
EAD applications for Fixed Time Signals

Summary of Preliminary Modeling Results
- **10-15%** fuel reduction benefit for an equipped vehicle;
- **5-10%** fuel reduction benefits for traffic along an uncoordinated corridor.
- Up to **13%** fuel reduction benefits for a coordinated corridor
  - 8% of the benefit is attributable to signal coordination
  - 5% attributable to the application

Key Findings and Takeaways
- The application is less effective with increased congestion
- Close spacing of intersections resulted in spillback at intersections. As a result, fuel reduction benefits were decreased somewhat dramatically
- Preliminary analysis indicates significant improvements with partial automation
- Results showed that non-equipped vehicles also receive a benefit – a vehicle can only travel as fast as the car in front of it

Opportunities for Additional Research
- Evaluate the benefits of enhancing the application with partial automation: GlidePath
EAD applications for Actuated Signals

- Estimate Green Window
- Historical Database
- Real Time SPaT
- Green Window Estimator
- Vehicle Trajectory Planning Algorithm (VTPA)
- State Machine to Turn on/off the Display of Target Speed
- Human-Machine Interface (HMI)
- Car-Following Speed Estimator
- Estimate Preceding Vehicle Related Parameters
- Activity Data of Preceding Vehicle from Radar
- Time-to-Collision Estimator
- Extract Subject Vehicle Dynamics
- Instantaneous Speed, RPM and MPG
- Activity Data of Subject Vehicle from OBD
- Instantaneous Speed and Acceleration
- Map Information
- Map Matching
- Vehicle Location from GPS
- Estimate Distance to Intersection
- Distance to Intersection
Field Testing on EAD applications

Test platform in Riverside, CA

Roadside and on-board components
Saves 5%-10% energy for high entry speed, and 7%-26% energy for low entry speed

Field Test in El Camino Real testbed and HMI interface
Eco-Traffic Signal Timing Application

- Similar to current traffic signal systems; however, the application’s objective is to optimize the performance of traffic signals for the environment.
- Collects data from vehicles, such as vehicle location, speed, vehicle type, and emissions data using connected vehicle technologies.
- Processes these data to develop signal timing strategies focused on reducing fuel consumption and overall emissions at the intersection, along a corridor, or for a region.
- Evaluates traffic and environmental parameters at each intersection in real-time and adapts the timing plans accordingly.
- 5% Energy Benefit
Eco-Traffic Signal Priority Application

- Allows either transit or freight vehicles approaching a signalized intersection to request signal priority
- Considers the vehicle’s location, speed, vehicle type (e.g., alternative fuel vehicles), and associated emissions to determine whether priority should be granted
- Information from vehicles approaching the intersection, such as a transit vehicle’s adherence to its schedule, the passenger number on the transit vehicle, or weight of a truck is also considered in granting priority
- If priority is granted, the traffic signal would hold the green on the approach until the transit or freight vehicle clears the intersection
- ~4% Energy Benefit for freight; ~6% for all vehicles
Eco-Speed Harmonization Application

- Collects traffic information and pollutant information using connected vehicle-to-infrastructure (V2I) communications.
- The application assists in maintaining flow, reducing unnecessary stops and starts, and maintaining consistent speeds near bottleneck and other disturbance areas.
- Receives V2I messages, the application calculates the optimal speed for the segment of freeway where the bottleneck, lane drop, or disturbance is occurring.
- The optimal “eco-speed” is broadcasted by V2I messages from roadside RSE equipment to all connected vehicles along the roadway.
- ~4.5% Energy Benefit.
Eco-Cooperative Adaptive Cruise Control (CACC) Application

- Eco-CACC includes longitudinal automated vehicle control while considering eco-driving strategies.
- Connected vehicle technologies can be used to collect the vehicle's speed, acceleration, and location and feed these data into the vehicle's ACC.
- Receives V2V messages between leading and following vehicles, the application performs calculations to determine how and if a platoon can be formed to improve environmental conditions.
- Provides speed and lane information of surrounding vehicles in order to efficiently and safely form or decouple platoons of vehicles.
- Up to 19% fuel savings on a real-world freeway corridor.
Cooperative Adaptive Cruise Control applied to Intersections

Baseline: typical queuing

Arterial CACC Baseline
High Volume (800 vphpl)

CACC: ~17% less energy & emissions

Arterial CACC
High Volume (800 vphpl)
Lessons Learned (Eco-Signal Operations)

Free Flow Traffic Conditions

- Eco-Approach & Departure
- Connected Eco-Driving
- Arterial Speed Harmonization (*partially modeled*)
- Eco-Traffic Signal Priority
- Eco-Traffic Signal Timing
- Wireless Inductive / Resonance Charging (*not modeled*)

Congested Traffic Conditions

When traffic conditions are severely congested, there are limited opportunities for Connected Vehicle Applications of all types to provide mobility or environmental benefits.
Lessons Learned (Eco-Lanes)

Free Flow Traffic Conditions

- Eco-Speed Harmonization
- Eco-Cooperative Adaptive Cruise Control
- Combined Application of ESH + Eco-CACC

Congested Traffic Conditions

When traffic conditions are severely congested, there are excellent opportunities for Eco-CACC to provide mobility & environmental benefits.
Thank you

Questions or Comments ?