Today’s Transportation Challenges

**Safety**
- 33,561 highway deaths in 2012
- 5,615,000 crashes in 2012
- Leading cause of death for ages 4, 11-27

**Mobility**
- 5.5 billion hours of travel delay
- $121 billion cost of urban congestion

**Environment**
- 2.9 billion gallons of wasted fuel
- 56 billion lbs. of additional CO₂
Connections (V2X): Vehicle to What?

V2V: Vehicle-to-Vehicle

V2I: Vehicle-to-Infrastructure
V2 – What else?

- Vehicle to Central Systems & Service Providers (V2X)
- Vehicle to “nomadic travelers” - Pedestrians, bicyclist, motorcyclists (V2X)
Why Connected Vehicles?

- Connected vehicles have the potential to address up to 81% of unimpaired crash scenarios.

  - Rear End Warning 28%
  - Lane Departure 23%
  - Intersection 25%
  - Lane Change 9%
  - Opposite Direction 2%
  - Backover 2%
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What's going on in the Connection?

"Here I Am" / Where's My Bus/Carpool?

latitude, longitude, time, heading angle, speed, lateral acceleration, longitudinal acceleration, yaw rate, throttle position, brake status, steering angle, headlight status, wiper status, external temperature, turn signal status, vehicle length, vehicle width, vehicle mass, bumper height

"Here I Am" / What is the Fastest Route to my Delivery Point

"Here I Am" / I am Full
Connected vs. Autonomous
Autonomous will be Connected

Connected Vehicles
FHWA Turner Fairbank Research Facility
Dedicated Short Range Communications

What is it?
- Special Wi-Fi radio (802.11p) adapted for high speed environment
  - Very short latency times – well suited for Safety Applications
  - Provides ad hoc communications
- NA Frequency 5.9GHz – EU/Asia 5.8GHz
  - Dedicated frequency set aside by FCC – local agency license
  - 75 MHz of dedicated Spectrum
- Relatively inexpensive in production quantities
V2I Intersection Architecture
ODOT’s Approach to CV

- Began internal investigation work in early 2015
- Created a high level position: Policy Advisor for Connected, Automated and Electric Vehicles
- Took advantage of Statewide ITS Architecture Update which was already underway to include CV
- Included CV elements in active procurement for new signal system
Where is ODOT’s I in the V2I

- 10% of road network and 40% of VMT are within 1000 feet of ODOT traffic devices

1955 Signals

805 ITS Equipment + 22 Weigh Stations

500 and 1000 ft diameter buffers
## Connected Vehicle Application Research: ODOT’s Approach

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What Apps Suit Oregon?

**V2I Safety**
- Signal Phase & Timing (SPAT)
- Curve Speed Warning
- Spot Weather Impact Warning
- Railroad Crossing Warning
- Disabled/Oversized Vehicle Warning

**Environment**
- AFV Charging/Fueling Information
- Eco-ICM Decision Support System

Advanced Traveler Information System (EnableATIS)
Intelligent Network Flow Optimization (INFLO)
Dynamic Speed Harmonization (SPD-HARM)
Queue Warning (Q-WARN)
Next Generation Ramp Metering (RAMP)
Response, Incident, Emergency (RESCUME)
Incident Guidance Emergency Response (RESP-STG)
Incident Scene Work Zone Alerts (INC-ZONE)
Emergency Communications/Evacuation (EVAC)
Freight Advanced Traveler Information (FRATIS)
Freight Dynamic Travel Planning & Performance

**V2V Safety**

**Road Weather**
- Motorist Advisories & Warnings (MAW)
- Enhanced Maintenance Decision Support

**Agency Data**
- Probe-based Pavement Maintenance
- Probe-enabled Traffic Monitoring
- CV-enabled Performance Measures
- Work Zone Traveler Information

**Fee Payment**
- Tolling
- High Occupancy Toll Lanes
- Congestion Pricing

- Wireless Inspection
- Smart Truck Parking
Where are we now?

- Finished ITS Architecture Update and Operational Concept
- Developed Connected Vehicle Project List (some examples to follow)
- Testing new Signal System with ATC
Preliminary

Use Case 1: Curve Speed Warning

A curve speed warning uses recent data to determine the appropriate advisory speed for a geometric curve based on current weather conditions. This advisory speed is calculated using local data from Agency environmental sensor stations (ESS) and from on-board equipment that monitors and reports the speed and traction control system status of vehicles that have recently traversed the curve. Speed advice can be provided to drivers as general advisory messages or as targeted warnings to those vehicles exceeding the recommended speed.

Stakeholders
- Drivers
- Freight operators
- Agency winter maintenance
- Agency ITS maintenance
- Agency operations staff

Expected Benefits
- Reduced crashes
- Reduced post-crash congestion
- Probe vehicle data augmentation of Agency ESS, helping prioritize winter maintenance activities

Improvement Metrics
- Crash rate
- Travel time and delay
- Time from detection of dangerous conditions to maintenance action
**Preliminary**

**Use Case 2: Rural Freeway Weather Incident**

A rural freeway weather incident reporting system uses connected vehicle data to collect and analyze road weather data for the purpose of facilitating maintenance activities and informing travelers. Early warnings can be distributed to road users when a road is expected to close due to worsening weather conditions. With these warnings, drivers can adjust their route choice and travel plans accordingly. In rural areas, freight carriers often may not have alternate routes nearby. In the example depicted above, a weather incident reporting system works in tandem with a Smart Parking application. Truck drivers are informed of downstream inclement weather in time to access parking facilities that are not filled to capacity. This avoids the return trips required if parking availability can only be assessed after arriving at the full lot, saving time and frustration.

**Stakeholders**
- Drivers
- Freight operators
- Agency winter maintenance and ITS maintenance staff
- Agency operations staff

**Expected Benefits**
- Reduced crashes
- Reduced post-crash congestion
- Reduced unnecessary rerouting
- Reduced staff required to direct traffic

**Improvement Metrics**
- Crash rate
- Travel time and delay
- VMT, trucker satisfaction
- Staff-hours available for other work
Preliminary

Use Case 3: Freeway Active Traffic Management

An active traffic management system on the freeway combines many applications to facilitate better traffic operations, inform travelers, and improve system efficiency. Traveler information can be distributed to road users about expected travel times, congestion, and roadway incidents. Drivers can prepare for unusual conditions and not be surprised and anxious by sudden congestion. Operationally, eco-ramp metering and speed harmonization applications can be used to optimize traffic flow for reduced emissions or to decrease traffic speed differentials.

Stakeholders
- Drivers
- Freight operators
- Agency operations staff

Expected Benefits
- Increased safety
- Decreased emissions
- More reliable travel times

Improvement Metrics
- Crash rate and severity
- Roadside air quality
- Travel time reliability
Preliminary

Use Case 4: Traffic Signal Timing and Operations Distribution

Connected traffic signals can provide information on the current phasing and timing to drivers and allow support other operational applications. As a vehicle approaches a traffic signal, the signal phase and timing can notify the driver if the light will turn yellow or red before they arrive, allowing the driver to slow down and travel in the coordinated green band. This same technology can also support preemption events from emergency vehicles and priority requests from transit vehicles and heavy freight vehicles.

Stakeholders
- Drivers
- Freight operators
- Transit
- First Responders

Expected Benefits
- Improve intersection efficiency
- Improve safety
- Improve fuel economy
- Improve driver happiness

Improvement Metrics
- Intersection delay
- Percent vehicles arrival on green
- Crash rate
- Crash severity
- Roadside air quality
Portland Metro Next Generation Transit Signal Priority

**Existing IR**

**Phase 1 IR + V2C**

**Phase 2 IR + V2C + CV**

**Abbreviations and Legends**:
- IR: Infrared
- IR Receiver
- TOC: Transit Operations Center
- TMC: Transit Management Center
- MAR: Mobile Access Router
- AVL: Automated Vehicle Location
- PRS: Priority Request Server
- PRG: Priority Request Generator
- GPS: Global Positioning System
- CV: Connected Vehicle
- V2C: Vehicle to Center
- V2I: Vehicle to Infrastructure
- Signal Communications
- CV to Cabinet
- TMC to Cabinet
- Existing Cell Connection
- New Connection for V2C
- New Connection for C2C
Applications of Connected Vehicles Considered in Signal System Procurement

**Multimodal Intelligent Traffic Signal System (MMITSS)**

- Intelligent Traffic Signal System (ISIG)
- Transit Signal Priority (TSP)
- Mobile Accessible Pedestrian Signal System (PED-SIG)
- Emergency Vehicle Preemption (PREEMPT)
- Freight Signal Priority (FSP)
ODOT RFP for new Signal Provider
Intelight: MaxConnect and MaxConnect Server

- ATC Controller
  - MaxTime
  - MaxConnect
  - DSRC Radio
  - SAEJ2735

- Central
  - MaxView
  - MaxConnect Server
  - NTCIP
  - HTTP/WS

- 3rd Party
  - External CV Application Server
  - HTTP
What is the Role of the Signalized Intersection?

CONNECTED VEHICLE CONTROLLER SERVES AS:

• Data Collection Hub
  • Host V2I Protocols for DSRC
  • Host V2I Protocols over Internet/Wireless

• Platform for Connected Vehicle Applications

• Standards based data provider to Vehicles and Services
  • Signal Phase and Timing - SPaT
  • Geometry Data Message - MAP
  • Traveler Information Message - TIM
  • Signal Request / Signal Status Message - SRM/SSM
INTERSECTION CONTROLLERS OF THE PAST

- Single purpose box
- Proprietary hardware/software
- No ability to add additional applications
- No interoperability
Meeting the Needs of a Connected Vehicle World

**Modern ATC Intersection Controller**

- ATC 5201 Advanced Transportation Controller (ATC)
  - Standards-based
  - Linux-based Operating System
  - Faster Processors
- ATC 5401 Application Programming Interface (API)
  - Support to run multiple applications
  - Provide access to shared controller resources
Positioning for the Future

ATC 5201 v06.22 – Advanced Traffic Signal Controller

- More flexible hardware requirements
- Requires vendors to provide SDK and hardware libraries
- Allows for more cost effective manufacturing
- Encourages compatible components
- Linux kernel
- Multi-processing
ATC 5401 v02.17 – Application Programming Interface (API)

- Consistent application interface between software and:
  - Front Panel Display
  - Keypad
  - Controller clock and Time Sync utilities
- Better management when running multiple apps
- Consistent hardware solution for 3rd party apps
MaxConnect – Embedded Connected Vehicle Applications

**MaxConnect Firmware**

- Runs on the same ATC Intersection Controller as MaxTime
- Uses ATC API specification for shared interface
- Full web browser with rich status and configuration view
- Web based configuration on MAP data—shared across MaxTime and MaxView
- Broadcast SPaT, MAP, SRM/SSM to connected DSRC or web service
- Connect with a broad set of DSRC radio or external services vehicle services
MaxConnect

**MaxConnect Server**

- Central based connected vehicle data aggregator
- Direct real time communication with MaxConnect over HTTP/Websocket for fast exchange
- Log and analyze incoming SPaT, MAP, SRM/SSM messages
- Provides third Party real-time access to aggregated Spat, MAP, etc. data with <1 sec latency
In 1997 the FCC allocated the frequency spectrum of 5.9GHz specifically to transportation applications.

Two bills are now before Congress that propose opening up the 5.9GHz band for unlicensed WiFi use. This potentially poses a threat to the use of DSRC for safety applications.

ITS America and others have petitioned the FCC to delay any action by the FCC until testing can show the DSRC for Connected Vehicles will not be impacted by opening the 5.9 GHz spectrum space to unlicensed use.
Active Safety Latency Requirements (sec)

- Traffic Signal Violation Warning: 0.1 sec
- Curve Speed Warning: 1.0 sec
- Emergency Electronic Brake Lights: 0.1 sec
- Pre-Crash Sensing: 0.02 sec
- Cooperative Forward Collision Warning: 0.1 sec
- Left Turn Assistant: 0.1 sec
- Lane Change Warning: 0.1 sec
- Stop Sign Movement Assistance: 0.1 sec

Note: y-axis not to scale for illustration purposes

Data source: Vehicle Safety Communications Project – Final Report