Nevada DOT

Dedicated Short Range Communications (DSRC) Radio for Rural ITS

Yreka, CA

Thursday, June 23, 2016
Acronyms

- **DSRC**: Dedicated Short Range Communication
- **IMO**: Integrated Mobile Observations
- **MDSS**: Maintenance Decision Support System
- **MMS**: Material Management System
- **mESS**: Mobile Environmental Sensor Station
- **NCAR**: National Center for Atmospheric Research
- **NDEX**: Nevada Data Exchange
- **NIMO**: Nevada Integrated Mobile Observation
- **OBU**: On-Board Unit
- **RSU**: Road Side Unit
- **TMDD**: Traffic Management Data Dictionary
- **UNR**: University of Nevada - Reno
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>C2C</td>
<td>Center to Center</td>
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<tr>
<td>WSDL</td>
<td>Web Services Description Language</td>
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<tr>
<td>XSD</td>
<td>XML Schema Definition</td>
</tr>
<tr>
<td>XML</td>
<td>Extensible Markup Language</td>
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<tr>
<td>TMS</td>
<td>Traffic Management System</td>
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<tr>
<td>NNG 511</td>
<td>Nevada Next Generation 511</td>
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<tr>
<td>EDACS</td>
<td>Enhanced Digital Access Communications System</td>
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<tr>
<td>JSON</td>
<td>JavaScript Object Notation</td>
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</table>
DSRC Radio for Rural ITS

Nevada DOT
Traffic Operations ITS, Signals, and Lighting
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Nevada DOT
Traffic Operations Technology Section
• Jim Whalen
• ITS Technology Manager
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Joint collaboration to leverage existing NIMO resources and expertise in the state and develop a pilot test corridor for Connected Vehicles using multimodal communication methods.
DSRC Project Outline

1. Background Review
2. NIMO DSRC Hardware Implementation
3. DSRC Pilot Corridor RSU Site Plan
4. DSRC Installations
5. Application Development & Implementation
6. Sustainability Planning
7. Lessons Learned
DSRC Challenges in Nevada

1. Past experiences: road weather forecasts have historically not been of adequate quality for NDOT.

2. Microclimates: many local areas (especially in mountainous areas) make forecasting more challenging, especially without “enough data”.

3. Data Telemetry: cellular telemetry is the standard (nationwide), but not currently workable in most of Nevada.
DSRC Challenges in Nevada

4. Pilot Demonstration: need to show that a viable approach can be implemented in Nevada for MDSS, MMS and other services.

5. Previous NIMO Phases: focus was on developing general understanding of how to gather data. Use of that data was not adequately explored and evaluated.
Applications

Nevada
Integrated
Mobile
Observations

Material Management System

Enhanced Maintenance Decision Support System

Additional Information for
- Freight Carriers
- Emergency Responders
- DMS, 511 Motorist Advisories
- Variable Speed Limits

7/5/2016
NIMO System Framework

**In-Vehicle Equipment**
- Weather sensors
- Vehicle sensors (OBU, CANBus)
- Equipment sensors (spreader)
- Location sensor (GPS)
- Radio(s)

**Applications**
- Current conditions
- Weather data environment
- Forecasts
- Material usage tracking
- Road maintenance recommendations

**Multi-Mode Receiving Station**
- Receives data from mobile vehicles
- Archives and forwards data
- Currently UNR moving to NDOT

**Cellular**

**DSRC**
NIMO System Framework

Cellular

In-Vehicle Equipment
- Weather sensors
- Vehicle sensors (OBU, CANBus)
- Equipment sensors (spreader)
- Location sensor (GPS)
- Radio(s)

DSRC

Multi-Mode Receiving Station
- Receives data from mobile vehicles
- Archives and forwards data

Applications
- Current conditions
- Weather data environment
- Forecasts
- Material usage tracking
- Road maintenance recommendations
NIMO 3 Vehicles

- 9 Snow plows with instrumented spreader motors and 1 freeway service patrol vehicle
  - 5 in Reno
  - 3 in Carson City
  - 2 in Lake Tahoe

### District II IMO Inventory

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<td>AWD</td>
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<td>R1</td>
<td>2012</td>
<td>FORD</td>
<td>E240</td>
<td>FREEWAY SERVICE PATROL VAN/PU</td>
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</table>
NIMO 3 Vehicles

- 4 OBUs are gathering data
- 1 installation approximately 3 days
- Lessons learned
  - Coordination efforts are essential
  - Different plow interiors having to redesign backplane
On Board Units (OBU, ~$3,500 ea.)

**Arada Locomate**
- $1,200

**Comet T7511 Ethernet**
- Weather Sensor Head
  - Barometric Pressure
  - Air Temperature
  - Humidity
  - $600

**Technologic Systems CPU (Main Computer)**
- $400

**Roadwatch**
- (not included in costs)
  - Air Temperature
  - Surface Temperature

**Cradlepoint IBR1100**
- Cellular Modem, GPS
- $800

**Custom Sensors**
- Windshield Wiper Sensor
- Spreader Rate Sensor
- Spreader Material Sensor

**Adam 6051**
- Ethernet DIO/counter
- $200
Connectivity Diagram (OBU)

Geo-fencing: Cradlepoint vs. DSRC RSU
Multimodal Communications Testing

Multi-Mode Receiving Station
• Receives data from mobile vehicles
• Currently UNR (Moving to NDOT)
“IMO 3” Sensor Package
Example Snow Plow Installation

Use of COTS components. Only software is “custom” (no custom electronics)
• Pilot will have 10 vehicles
• Retrofits of IMO phases 1 & 2 installs to follow
• Typical mount on back wall of passenger cabin behind seats
• Transmission frequencies vary with the telemetry mode, ranging from ~10 seconds to 5 minutes
• No driver interface/display
• No imagery/video

GPS Antenna
DSRC Antenna
Road Temperature Sensor
Air Sensor
Spreader Sensor
Plow On-Board Hardware
FSP Van On-Board Hardware

Sensor Package
Dataset

- Wave Short Message Protocol (WSMP)
- Same “payload” over DSRC and cellular

- Date
- Time
- Location (lat., long.)
- Speed
- Altitude
- Air Temp
- Barometric Pressure
- Humidity
- Dew Point
- Road Temp
- Wiper Status
- Spread Rate
Status – NIMO 3 Vehicle Hardware

• All sensor components selected & tested

• Interface via on-board Ethernet LAN that can link to WAN (internet) via cellular modem

• 12V vehicle power bus designed and tested, individually fused per device, ~50 watts
Status – NIMO 3 Vehicle Hardware (cont.)

- Enclosure prototype designed & field tested
- All enclosures (cases) are 90% manufactured
- Ruggedized sensor/network/processing units (-20 to 60 degrees C) and vibration
Status – NIMO 3 Vehicle Hardware

- Software to sample all sensors completed
  - Comet WX: air temperature, humidity, dew point
  - Roadwatch SS: air temperature, surface temperature
  - Adam DIO 32-bit Counter/frequency: spreader, windshield wiper
  - Cradlepoint COR Modem/Router: NMEA GPS, WAN access
Status – NIMO 3 Vehicle Hardware

• Modular architecture will allow same system to support vehicles not operating in the DSRC areas

• Main processing unit (Technologic TS-7250-V2) is separate from OBU (Arada Locomate)
Status – NIMO 3 Vehicle Hardware

- Multi-modal capability partially implemented – geo-fenced RSU database drives switch between cell and DSRC mode, but confirmations are under development. Handoffs need to be fine-tuned.

- Data snapshots taken every 10 seconds, synchronized to GPS time.
Status – NIMO 3 Vehicle Hardware

- Cell and DSRC packets received by same development server, which detects transmission mode, and associates data with a plate ID

- Currently using same compressed CSV format for both cell and DSRC modes as with phase 2 NIMO, will have also the ability to have transmission over low-bandwidth trunked radio if/where necessary
Status – NIMO 3 Vehicle Hardware

• Application on the server will interface with the Nevada Data Exchange (NDEX)

• Current focus is implementation of NTCIP compliance (through the NDEX), and ACK confirmations from RSU’s (or TCP/IP over DSRC) to support DSRC retransmission/error-checking, and to fine-tune hand-offs with other modes
DSRC Site Locations

18 Locations
Vehicle Routes

- 18 DSRC Locations
- 32 Miles DSRC
- 54 Miles Cellular
DSRC Multimodal Data Tests

Preliminary Tests:
- Multimodal functionality is good
- Message transmissions confirmed
- Geo-fencing behavior needs decreased latency for sharper transitions
FSP Van, 2/8/16 Data

Prior to full DSRC Radio Install

- Cellular
- DSRC
I580/US395 Test Corridor with SR341/US50 UNR test vehicle, 6/20/16
Data

Number of waypoints was condensed from 2396 to 480.

Cellular

DSRC
I580/US395 Test Corridor with SR341/US50 UNR test vehicle, 6/20/16 Data

Cellular

DSRC
I580/US395 Test Corridor with SR341/US50 UNR test vehicle, 6/20/16 Data
DSRC Installations

18 sites completed
• First two done under single quote contract
  • Completed November 2015
• Remaining 16 done under three quote contract
  • Completed February 2016
UNR IMO Portal
https://134.197.27.248:8001/

IMO1
- Logged Data
- Most Recent Table (includes IMO2 vehicles)
- NCAR
- Transmitted Data
- Vehicle Map

IMO2
- Transmitted Data
- Android / EDACS Map
- EDACS-only Map (includes IMO1 vehicles)
- Spreader Map
- App Versions
Nevada Data Exchange (NDEX)  
Integrated Mobile Observations (IMO)  
Integration  
mobile ESS (MESS)
Nevada TMDD Data Exchange

- Nevada DOT’s C2C
  - Central Data Exchange
  - Data Warehouse
- Web Services Implementation: WSDL, XSD and XML
- Traffic Management Data Dictionary Standard (TMDD)
- Restricts access based on authentication
- Three-Tier Security Implementation
- NDOT’s Needs Requirements Traceability Matrix (NRTM)
User Needs

1. Need to authenticate access
2. Need to support request-response
3. Need to support error handling
4. Need to share IMO vehicle inventory
5. Need to share IMO sensor inventory from any vendor-specific sensor
6. Need to share IMO observations
NDEX Architecture

Only the owning center may control field devices.

Field Devices  --> control status  --> TMS District 2 (Owner Center)
NDEX Architecture

Field Devices  
control  
status

TMS  
District 2  
(Owner Center)

publish  
subscribe

NDEX receives data from the owning center
NDEX Architecture

Field Devices control status

TMS District 2 (Owner Center)

subscribe publish

NDEX shares data with external centers

NNG 511 (External Center)
NDEX works with multiple data centers
External centers require security authentication to access NDEX.
NDEX Architecture

Field Devices → TMS District 2 (Owner Center) → Enhanced Security

Nevada DOT Active Directory ↔ NDEX

subscribe → NNG 511 (External Center) x.509

NDEX provides data summary reporting capability
Concept of Operations

Phase 1
- Instrumented Maintenance Vehicles
  - EDACS Radio
  - 3G/4G
  - DSRC

  IMO Server (UNR)

  CSV File

  NCAR
  National Center for Atmospheric Research

Phase 2
- Mobile ESS (mESS) Database

Phase 3
- NCAR
  National Center for Atmospheric Research

NDEX

7/5/2016
Concept of Operations

Instrumented Maintenance Vehicles

Owning Center
- EDACS Radio
- 3G/4G
- DSRC

IMO Server

External Centers
- NCAR
  National Center for Atmospheric Research
- WxDE
  Weather Data Exchange

NDEX
Mobile ESS (mESS) Database
### NDEX Organizations and Centers

<table>
<thead>
<tr>
<th>Organization Id</th>
<th>Organization Name</th>
<th>Center Id</th>
<th>Center Name</th>
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</thead>
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<tr>
<td>its.nv.gov</td>
<td>NVDOT ITS</td>
<td>D1</td>
<td>District 1</td>
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<tr>
<td>its.nv.gov</td>
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<td>D2</td>
<td>District 2</td>
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<td>NVDOT ITS</td>
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<td>its.nv.gov</td>
<td>NNG511</td>
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<td>nhp.nv.gov</td>
<td>NHP</td>
<td>NHP</td>
<td>Nevada Highway Patrol</td>
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</table>

NDEX integrates data from various centers using Organization and Center Ids.
# mESS Organizations and Centers

<table>
<thead>
<tr>
<th>Organization Id</th>
<th>Organization Name</th>
<th>Center Id</th>
<th>Center Name</th>
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<td>IMO</td>
<td>IMO UNR</td>
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<td>ncar.ucar.edu</td>
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<td>wxde.fhwa.dot.gov</td>
<td>Weather Data Environment</td>
<td>WXDE</td>
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</table>
NDEX Messages

Device Types:
- Detector Station
- CCTV
- Dynamic Message Sign (DMS)
- Environmental Sensors (ESS)
- Mobile Environmental Sensors (mESS)
- Highway Advisory Radio (HAR)
- Incidents/Events
- Ramp Meter
- Node, Link, Traffic Network

NDEX messages include inventory and device status
TMDD Web Service Endpoint

- [http://coloNDEXsrv.its.nv.gov/tmddws/TmddWS.svc](http://coloNDEXsrv.its.nv.gov/tmddws/TmddWS.svc)
- Web Services Implementation: WSDL, XSD and XML

- [https://coloNDEXsrv.its.nv.gov/imows/](https://coloNDEXsrv.its.nv.gov/imows/)
- REST API Endpoint Implementation: JSON
- Requires JSON plugin
IMO References

- DSRC SAE J2735 DSRC Message Set Dictionary
- NTCIP 1204 ESS Interface Protocol
- https://wxde.fhwa.dot.gov/
- https://www.its-rde.net/home
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<tr>
<th>SensorId</th>
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<th>Source Unit of Measure</th>
<th>Target Observation Type</th>
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<td>Airmar</td>
<td>Temperature Celsius</td>
<td>NTCIP 1204 ESS Air Temperature</td>
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<td>RTRoadwatch</td>
<td>Roadwatch</td>
<td>Temperature Celsius</td>
<td>NTCIP 1204 ESS Surface Temperature</td>
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<tr>
<td>PRAirmar</td>
<td>Airmar</td>
<td>Atmospheric Pressure Bar</td>
<td>NTCIP 1204 ESS Atmospheric Pressure</td>
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<td>PROmega</td>
<td>Omega</td>
<td>Atmospheric Pressure kPa (kilopascal)</td>
<td>NTCIP 1204 ESS Atmospheric Pressure</td>
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<td>GPGGA</td>
<td>Cradle Point</td>
<td>NMEA 0183 Sentence GPGGA</td>
<td>NMEA 0183 Sentence GPGGA</td>
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<td>ATAirmar(°C)</td>
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<td>ATCanbus(°C)</td>
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<td>ATOmega(°C)</td>
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Owning Center Dialog Messages

* Authentication Token will be recycled after 20 minutes of inactivity
External Center Dialog Messages

* Authentication Token will be recycled after 20 minutes of inactivity
<table>
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<tr>
<th></th>
<th>Need to share IMO vehicle inventory</th>
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<tr>
<td>4.1</td>
<td>Contents of the vehicle inventory</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>(See Table 5 – Fundamental Data Element Definitions)</td>
<td></td>
</tr>
<tr>
<td>4.1.1</td>
<td>Vehicle identifier</td>
<td>M</td>
</tr>
<tr>
<td>4.1.2</td>
<td>Organization identifier</td>
<td>M</td>
</tr>
<tr>
<td>4.1.3</td>
<td>Center identifier</td>
<td>M</td>
</tr>
<tr>
<td>4.1.4</td>
<td>Vehicle description</td>
<td>O</td>
</tr>
<tr>
<td>4.1.5</td>
<td>Vehicle primary purpose</td>
<td>O</td>
</tr>
<tr>
<td>4.1.6</td>
<td>Vehicle year</td>
<td>O</td>
</tr>
<tr>
<td>4.1.7</td>
<td>Vehicle make</td>
<td>O</td>
</tr>
<tr>
<td>4.1.8</td>
<td>Vehicle model</td>
<td>O</td>
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<tr>
<td>4.1.9</td>
<td>SAEJ2735_DE_VehicleType</td>
<td>M</td>
</tr>
</tbody>
</table>
Sample Observation Report Message

```json
{
  "ObservationReportMsg": {
    "RequestID": "123",
    "OrganizationID": "imo.unr.edu",
    "CenterID": "IMO",
    "ObservationReports": [
      {
        "VehicleID": "D2-0423",
        "DateTime": "2015-09-17T00:19Z",
        "Latitude": 39527500,
        "Longitude": -119792500,
        "Bearing": 46,
        "Elevation": 333,
        "Speed": 46,
        "Observations": [
          {
            "SensorID": "ATRoadwatch",
            "SourceValue": "17.1"
          },
          {
            "SensorID": "ATWxSensor",
            "SourceValue": "18.3"
          },
          {
            "SensorID": "RHwxSensor",
            "SourceValue": "24.6"
          },
          {
            "SensorID": "PRWxSensor",
            "SourceValue": "86.1"
          },
          {
            "SensorID": "RTRoadwatch",
            "SourceValue": "22.8"
          },
          {
            "SensorID": "SpGPS",
            "SourceValue": "12.7986"
          },
          {
            "SensorID": "Spreader",
            "SourceValue": "0"
          },
          {
            "SensorID": "WiperCount",
            "SourceValue": "0"
          }
        ]
      },
      {
        "VehicleID": "0423",
        "DateTime": "2015-09-17T00:19Z",
        "Latitude": 39527500,
        "Longitude": -119792500,
        "Bearing": 46,
        "Elevation": 333,
        "Speed": 46,
        "Observations": [
          {
            "SensorID": "ATRoadwatch",
            "SourceValue": "17.1"
          },
          {
            "SensorID": "ATWxSensor",
            "SourceValue": "18.3"
          },
          {
            "SensorID": "RHwxSensor",
            "SourceValue": "24.6"
          },
          {
            "SensorID": "PRWxSensor",
            "SourceValue": "86.1"
          },
          {
            "SensorID": "RTRoadwatch",
            "SourceValue": "22.8"
          },
          {
            "SensorID": "SpGPS",
            "SourceValue": "12.7986"
          },
          {
            "SensorID": "Spreader",
            "SourceValue": "0"
          },
          {
            "SensorID": "WiperCount",
            "SourceValue": "0"
          }
        ]
      }
    ]
  }
}
```