Enabling Deployment of Connected Work Zones

In-Person Meeting: Madison, WI

April 29, 2024

Today's Agenda

Key Topics:

- Task 3: Arizona Pilot Summary and Discussion (20 minutes)
- Task 6: Review Plan for Guidance Materials (15 minutes)
- Task 2: Coordination with National Standards Efforts (45 minutes)

Other Activities & Next Steps: (10 minutes)

- Caltrans Update
- MCDOT Update

Project Tasks

- Task 1: Project Management
- Task 2: Coordination with National Standards
- Task 3: ADOT Smart Work Zone Project
- Task 4: Provide Technical Support for CA Connected Work Zone Project
- Task 5: Conduct Assessment of Interoperability
- Task 6: Develop Guidance Materials

Task 3: Arizona Connected Work Zone Pilot Summary and Discussion

Goal of the ADOT Summary Document

- We've shared & discussed details of the project in webinars
- Insights from ADOT are already benefitting MCDOT and Caltrans efforts
- This summary report:
  - Assembles all the documentation in one document (e.g., ADOT approach, Verizon MEC overview, BSM data types & frequency, etc.)
  - Not intended to be a formal document, but a succinct summary of content with images, drawings, and graphics to help inform readers

ADOT Summary Report Structure and Content

Organizational Structure:

- List of Acronyms
- Explanation of ADOT system components
- Summary of referenced standards
- ADOT process
- Additional deployment considerations shared by ADOT
- Glossary of key terms

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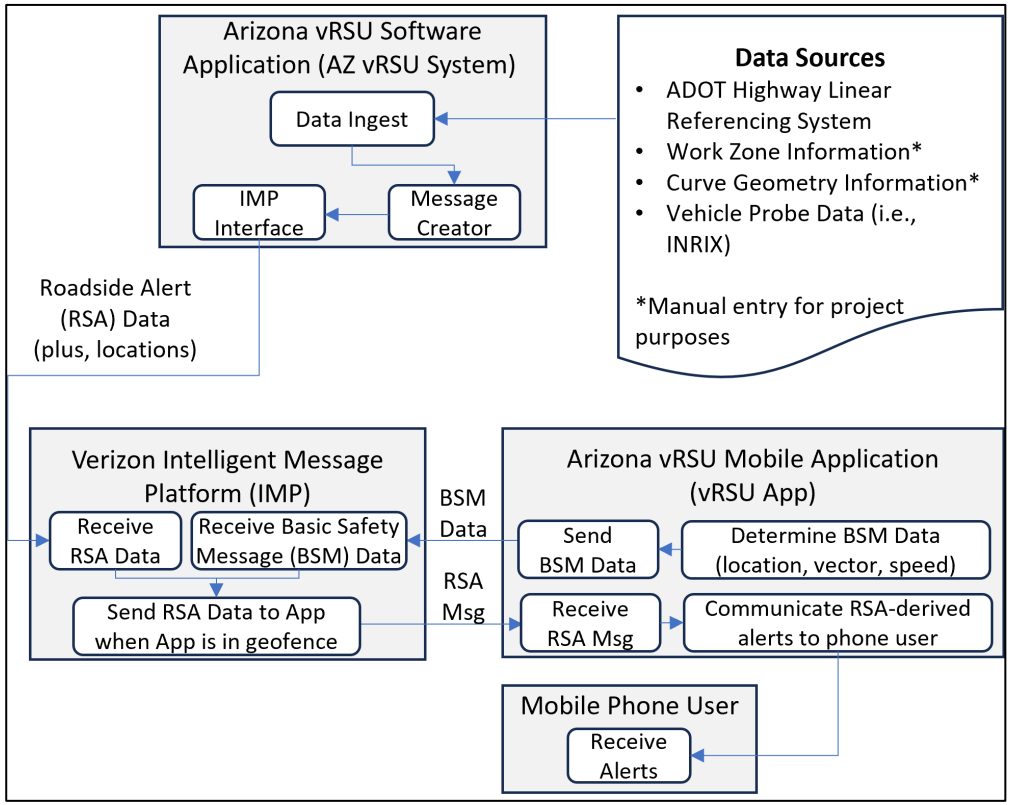

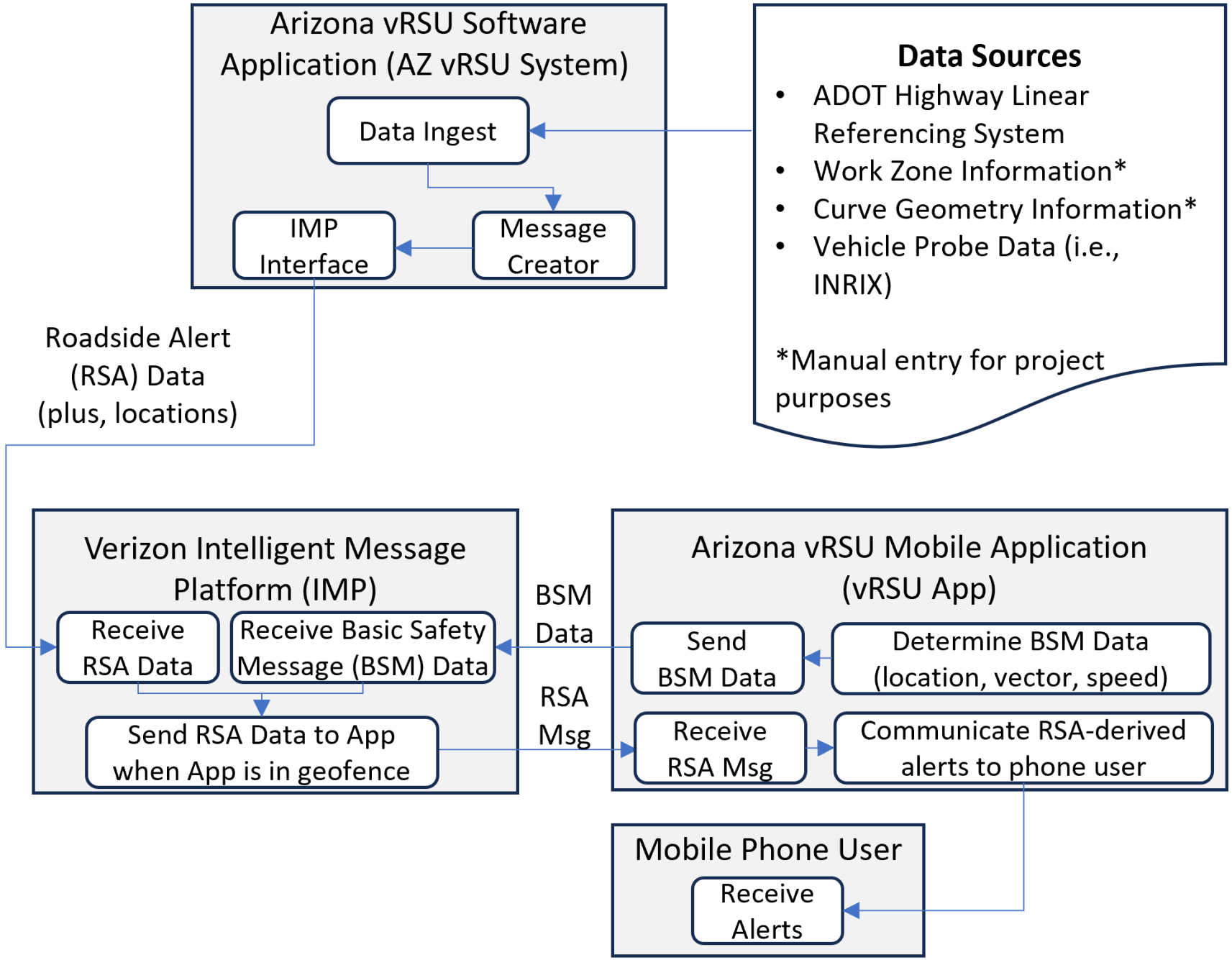
Arizona vRSU Software Application (AZ vRSU System)
Data Ingest
IMP Interface
Message Creator
Data Sources
ADOT Highway Linear Referencing System
Work Zone Information*
Curve Geometry Information*
Vehicle Probe Data (i.e., INRIX)
*Manual entry for project purposes
Roadside Alert (RSA) Data (plus, locations)
Verizon Intelligent Message Platform (IMP)
Receive RSA Data
Receive Basic Safety Message (BSM) Data
Send RSA Data to App when App is in geofence
BSM Data
RSA Msg
Arizona vRSU Mobile Application (vRSU App)
Send BSM Data
Determine BSM Data (location, vector, speed)
Receive RSA Msg
Communicate RSA-derived alerts to phone user
Mobile Phone User
Receive Alerts

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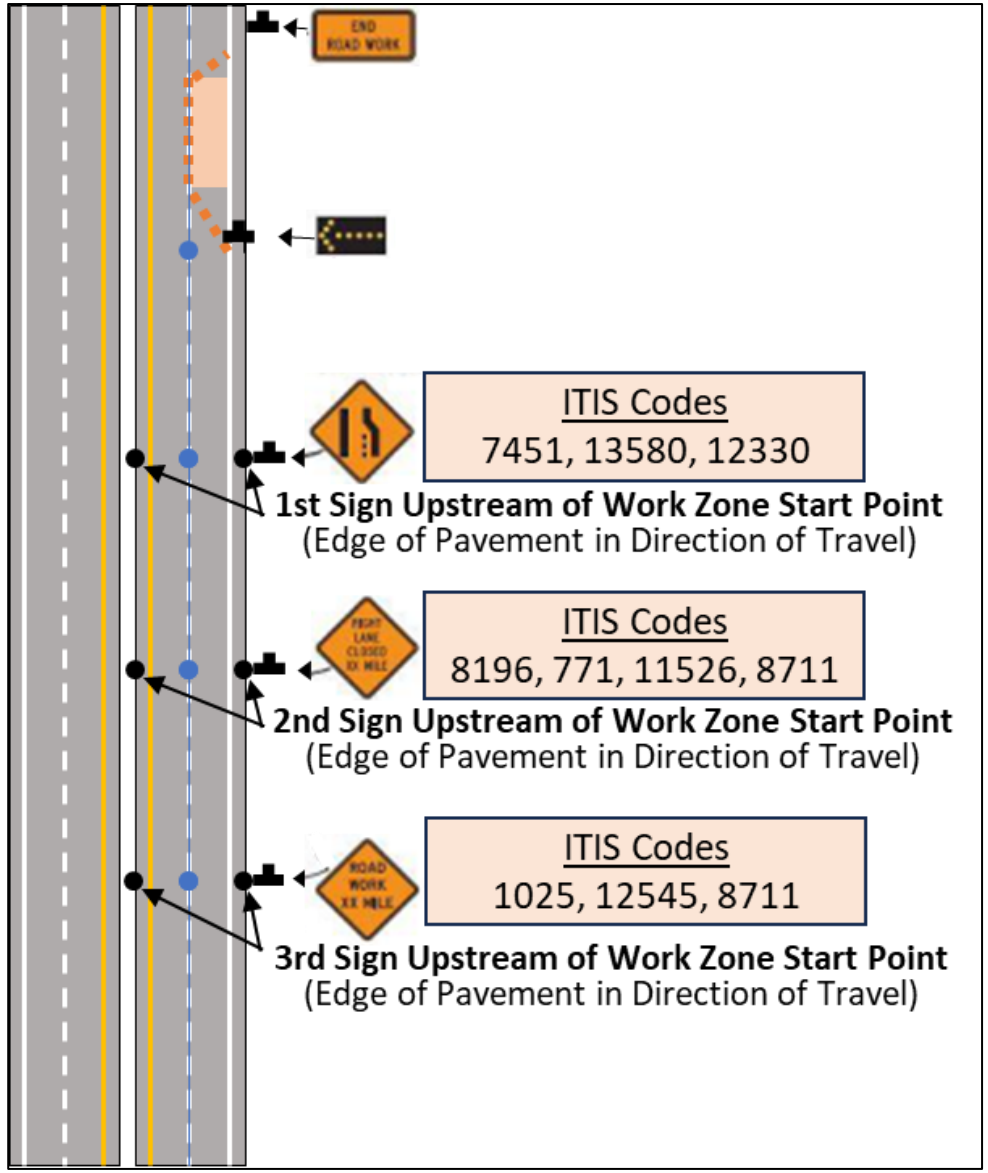
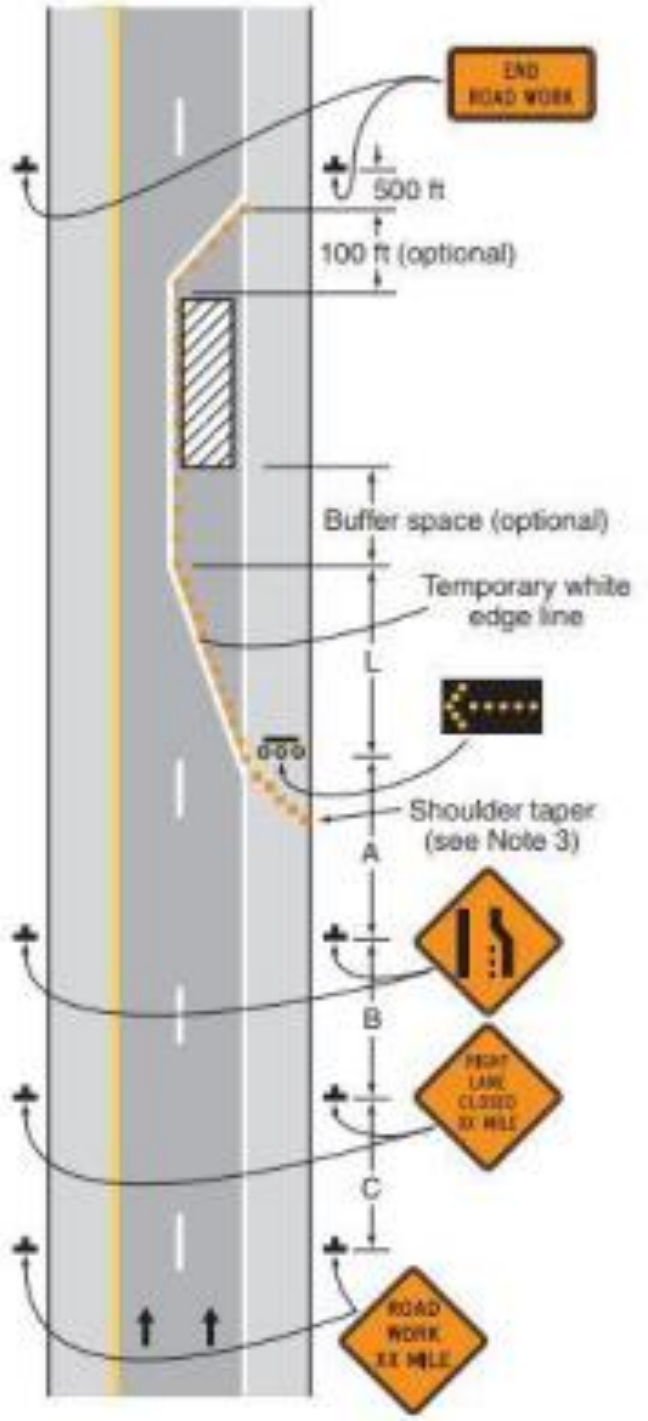


MUTCD Temporary Traffic Control for Work Zones

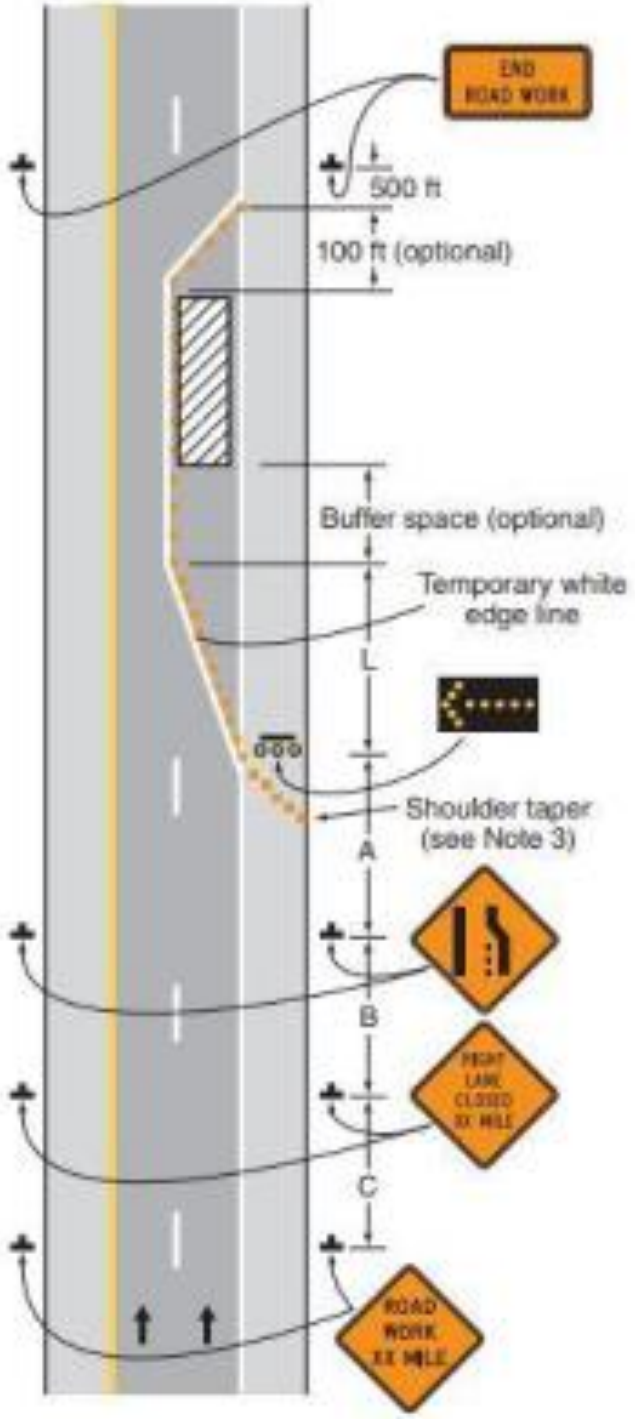
- MUTCD used by Arizona as a basis for generating data to broadcast in-vehicle connected work zone messages
- Message information corresponded to the MUTCD-recommended static signing in advance of the work zone
- Messages provided at distances that correspond to MUTCD-recommended distances for static signing



MUTCD for In-Vehicle Signing

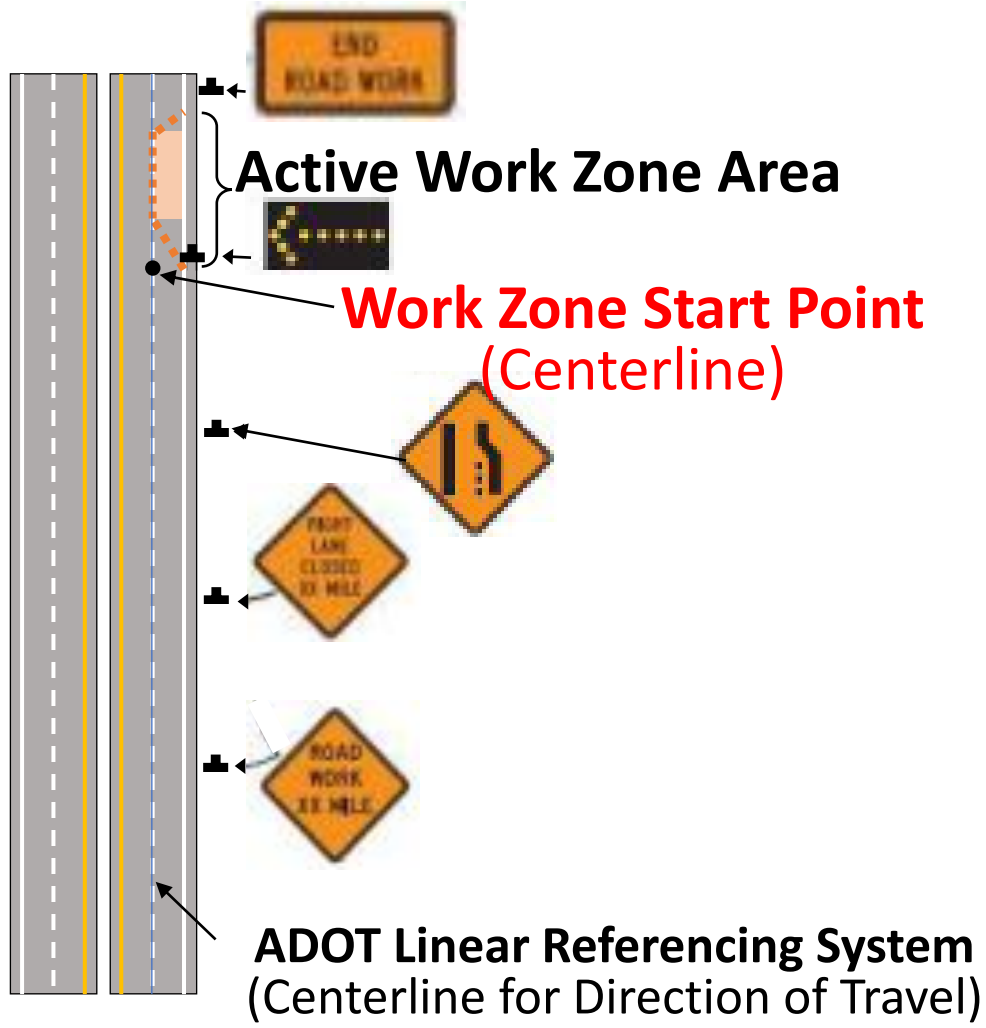
- The Arizona approach is consistent with others (like the Ohio DOT V2X Guidelines)
- Our Guidance will build on this approach with some adjustments
  - e.g., to consider additional distance for driver to view the sign
- However, additional functions are also possible for V2X in-vehicle signing:

  Should our Guidance consider or recommend additional "alerts" beyond the MUTCD?



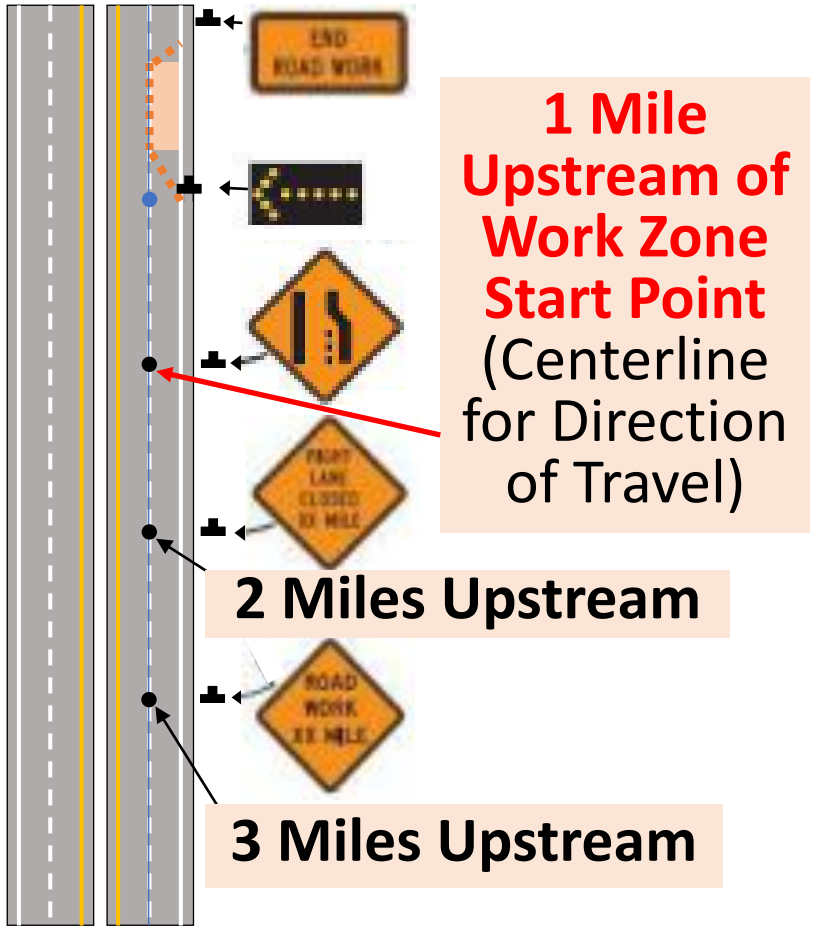
Arizona Connected Work Zone: Step 1

- Start of Work Zone:
  - A lat/long manually Selected
  - Beginning of active work zone
  - beginning of the taper –if lane closure
- As defined by MUTCD



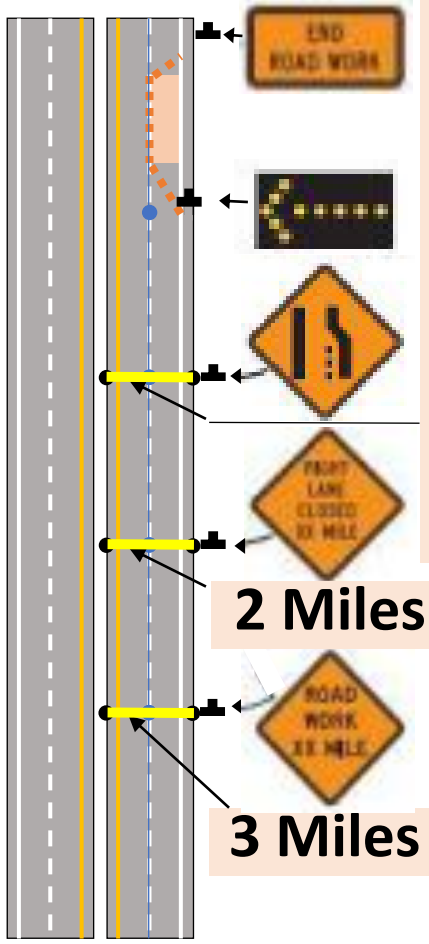
Arizona Connected Work Zone: Step 2

- Manually use ADOT linear referencing system identify lat/long points upstream of work zone start.
- Points based on MUTCD guidance for advanced warning signing upstream for corresponding in-vehicle messages.



Arizona Connected Work Zone: Step 3

- Linear referencing system used to calculate two lat/long for each point from step 2:
  - Number of lanes
  - Lane width
  - Shoulder widths
  - Direction of travel
- These are on the edge of pavement for impacted travel direction.
- When connected, these two points are a line perpendicular to the travel direction.
  - Only across lanes for the correct direction
  - **App designed to provide messages to devices crossing this line.**



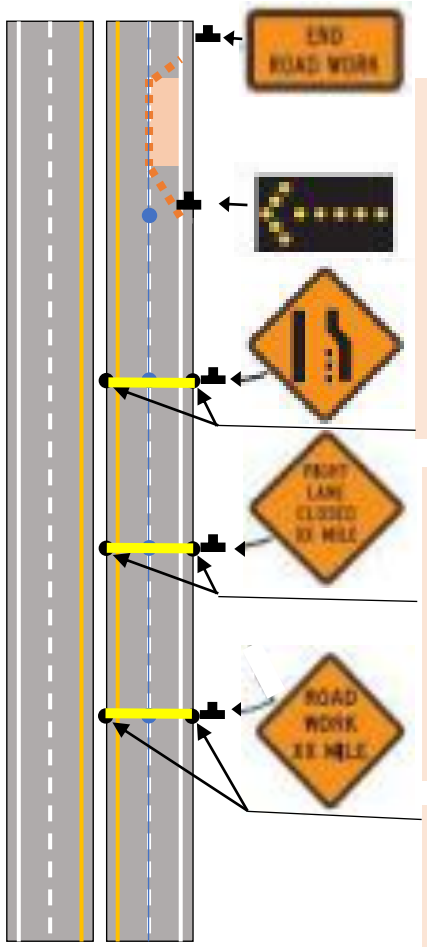
1 Mile Upstream of Work Zone Start Point (Line Between 2 Pavement Edge lat/long Points in Direction of Travel)

2 Miles Upstream

3 Miles Upstream

Arizona Connected Work Zone: Step 4

- ADOT assembled additional data for each point:
  - SAE J2540 ITIS Code of sign:
    - Road work, one mile
    - Right lane closed ahead, ½ mile
    - Merge left with caution
  - Textual description
  - Road identifier
  - Active timer period



1 Mile Upstream of Work Zone Start Point

ITIS Codes

7451, 13580, 12330

2 Miles Upstream

ITIS Codes

8196, 771, 11526, 8711

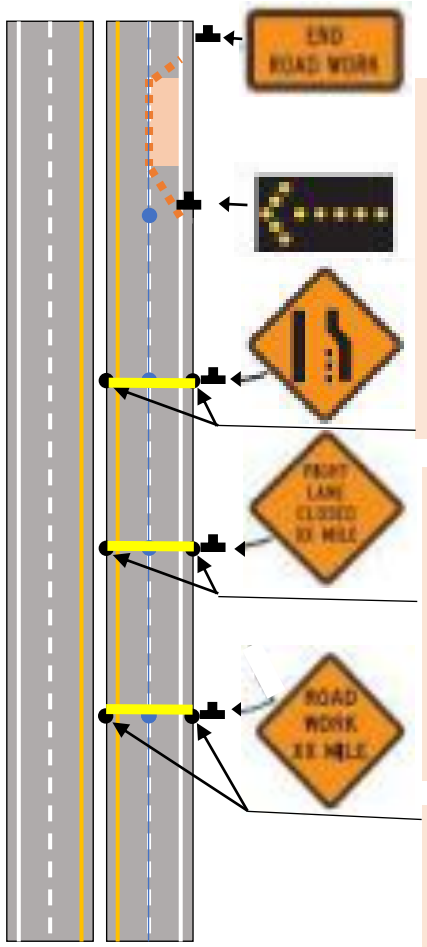
3 Miles Upstream

ITIS Codes

1025, 12545, 8711

Arizona Connected Work Zone: Step 5

- ADOT creates Roadside Alert (RSA) message for each set of points using data from Step 4
  - ***Lat/long of points sent as buffer to RSA***
- RSAs sent to Verizon Mobile Edge Computing via MQTT API.
  - MQTT requires specific code for ADOT access.
  - MQTT is a mass text distribution portal that facilitates sending many messages in low-bandwidth environments.



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Arizona Connected Work Zone: Step 6

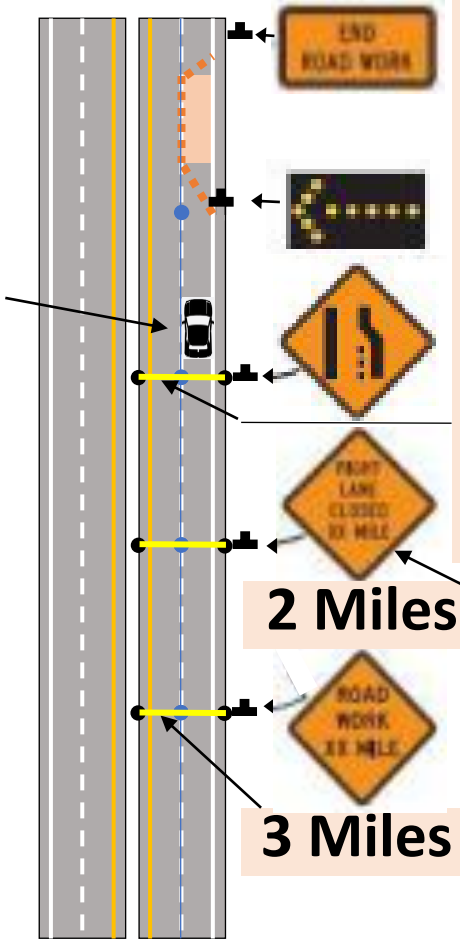
- In-vehicle Applications send Basic Safety Message (BSM) data from Android devices to the vRSU in the cloud.
  - Location
  - Heading
  - Speed

  Transmission Rate: 1/second

  Sample Representative BSM from Verizon:
  - Lat/Long & time in Protocol Buffer **and** core message
- The vRSU in the cloud (i.e., MEC) uses received app data to determine when the device crossed the line between points in the ADOT RSA buffer.

Arizona Connected Work Zone: Step 6

- When a device crosses a line, the appropriate RSA message is sent to the Android device via 4G/5G cellular for the app to process data and provide an in-vehicle message and audio alert via the app user interface.
  - Two bars of 4G/5G service required for this to occur.



1 Mile Upstream of Work Zone Start Point (Line Between 2 Pavement Edge lat/long Points in Direction of Travel)

2 Miles Upstream

3 Miles Upstream

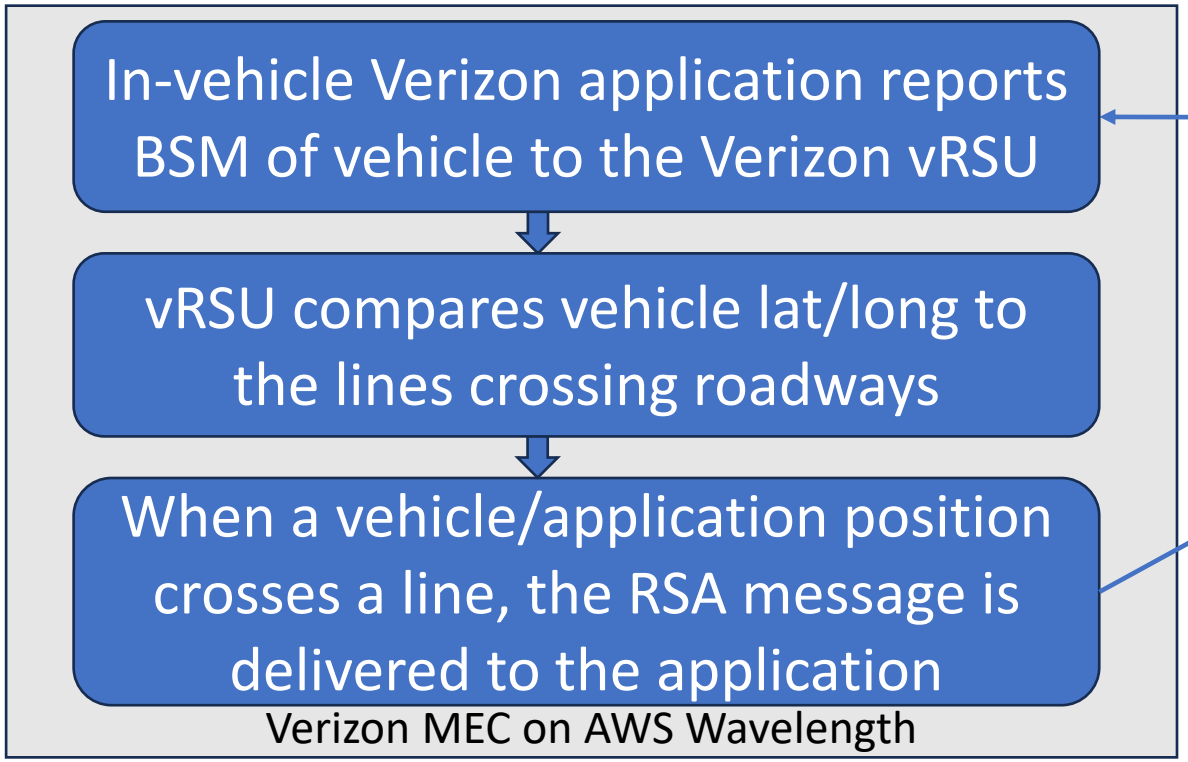
Arizona Connected Work Zone: Step 6

Example RSA message from Verizon MEC to in-vehicle App:


```
{
    "MessageFrame":{
        "messageId":"27",
            "value":{
             "RoadSideAlert":{
                "msgCnt":"0",
                "timeStamp":"0",
                "typeEvent":1025,
                "description":{
                    "ITIScodes": ["1025", "12545", "8711"]
                }
```

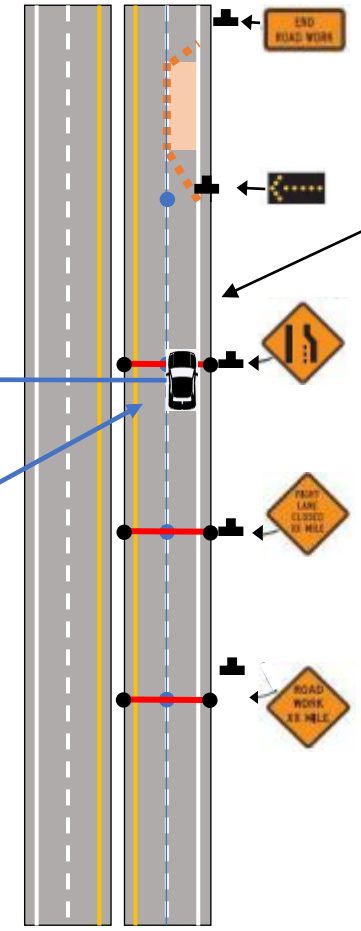

Arizona Connected Work Zone: Step 6

- The Verizon virtual roadside unit (vRSU) uses the 4G/5G cellular network to receive Basic Safety Messages (BSMs) from Android devices in vehicles that are using a specific application.



BSM w/location

RSA Message



- **Questions? Discussions?**

Task 6: Review Plan for Guidance Materials

Connected Work Zone Guidance Plan/Strategy

- **Guidance Document**: Comprehensive step-by-step resource for practitioners *(described on following slides)*
- Other proposed resources for discussion:
  - **Fact Sheet(s)**: One or more 2-3 page standalone resources.
    1. Executive Summary of Connected Work Zones and Guidance, for agency leadership and decision makers.
    2. Introduction to standards that support Connected Work Zones
  - **Presentation, Webinar, and Recording**: overview presentation & recorded webinar (similar to prior CV PFS Guidance efforts).
    - Introduce Connected Work Zones, associated benefits and deployment considerations, and an overview of the Guidance and how to use it.
  - **Others?**

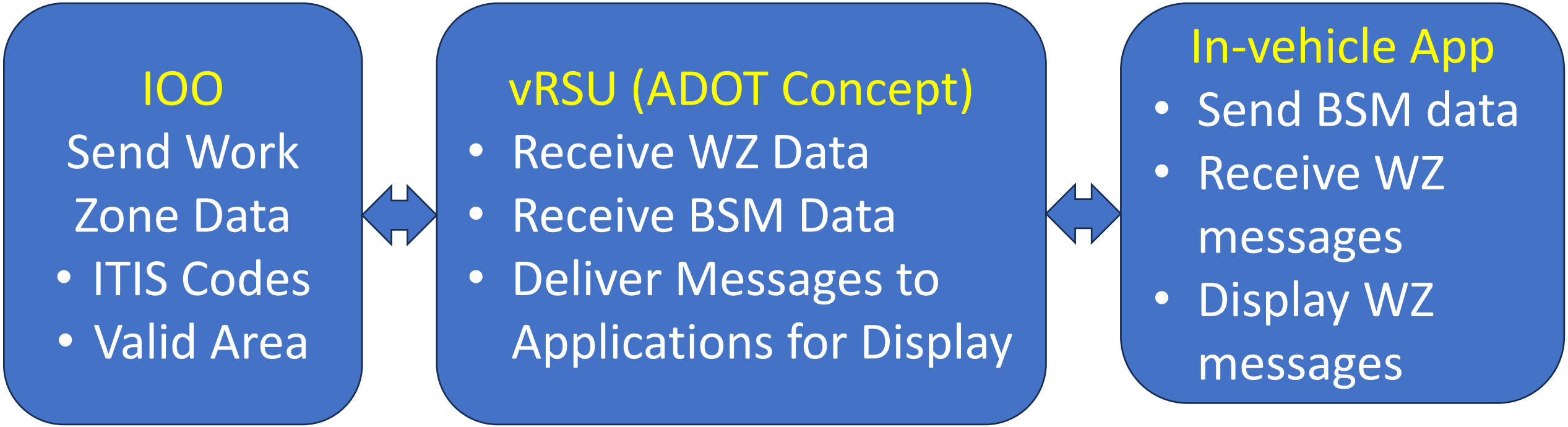
High Level Discussions / Decisions Needed
(Not to be decided today, but on future panel webinars)

1. **Is "Virtual RSU" the appropriate term?**
   - Included in the ADOT Summary Report as it was the project term used
   - Other "cloud" delivery of Work Zone systems do not use the term "vRSU"
   - Is "vRSU" associated with Verizon?

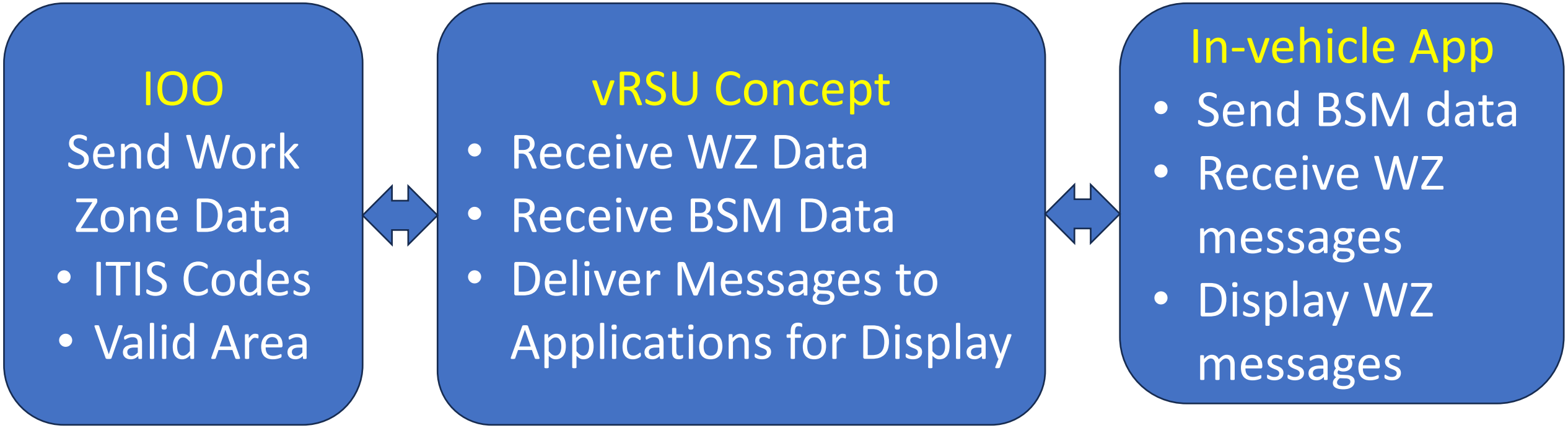
2. **Relationship to Physical RSUs?**
   - Suggested goal is that IOOs generate one set of messages to be disseminated both from Physical RSUs as well as vRSUs/Cloud Delivery
   - Is this appropriate? Critical?

3. **Should the ADOT Pilot Approach Be Specified in the Guidance?**
   - E.g., Delivery of RSA/TIM Message at the time the App crosses into valid area
   - Should the delivery approach be vendor specific, and Interoperability be key?
   - Should Applications "display when received"? Or "Display in valid region"?

The Overall Concept



The ADOT Pilot

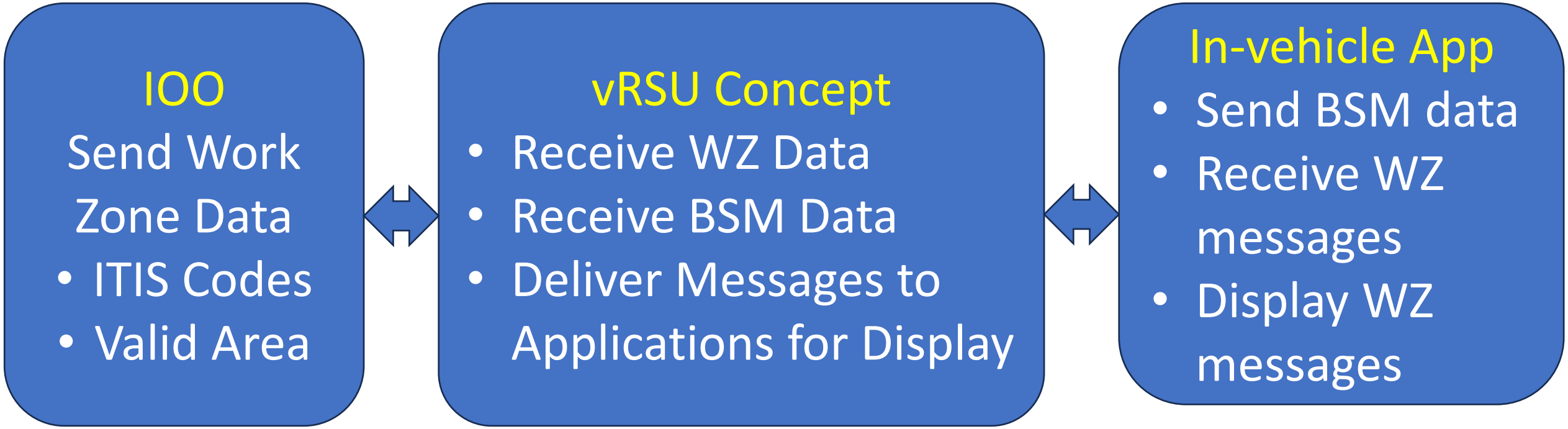


ADOT

Verizon
(contracted service)

Verizon
(contracted service)

MCDOT & Caltrans “Pilots”

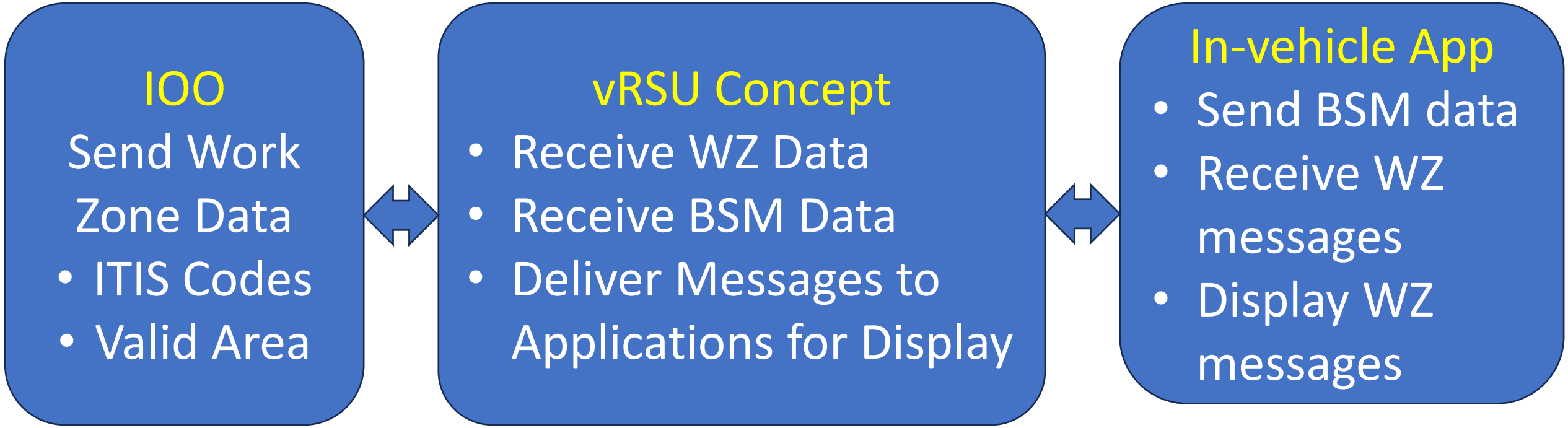


MCDOT / Caltrans

Verizon (contracted service)

MCDOT / Caltrans Apps

Future “Implementations” (not pilots)

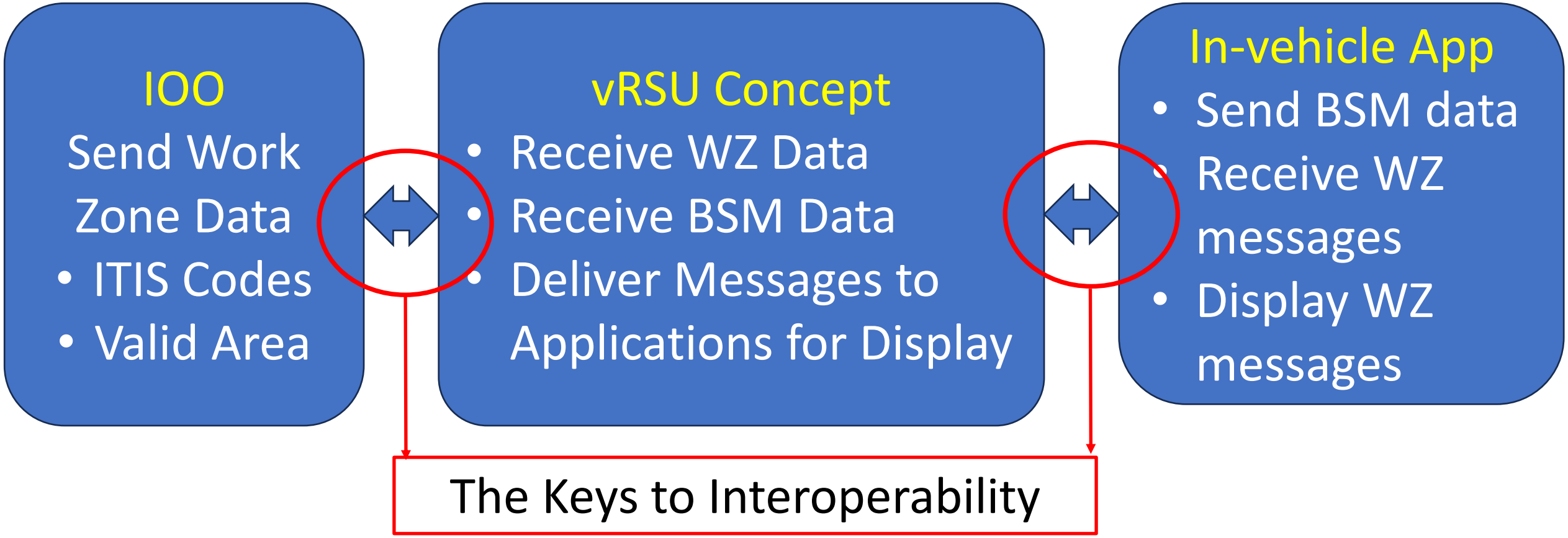


IOOs

Should the details of this be specified? (vs. just the outcomes)

IOOs or Private Apps

Future “Implementations” (not pilots)



The Business Model is Still TBD. Will IOOs contract for the “vRSU Concept” or will private products emerge?

Future “Implementations” (not pilots)

At This Time….

Is the best approach to write Guidance for how the next round of IOOs could create pilots or deployments that:

1. Procure services of a “vRSU Concept” to deliver messages to applications (as was done by ADOT)?
2. Develop IOO software and systems to interface with the procured services?
3. Develop in-house or procure services for applications to display information to drivers?

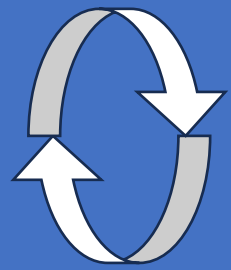
Guidance Document Structure

Initial, one-time process

Establish the vRSU Environment

- IOO Software
- Communication to Network
- In-vehicle Application

Cyclical, ongoing process



Each Work Zone

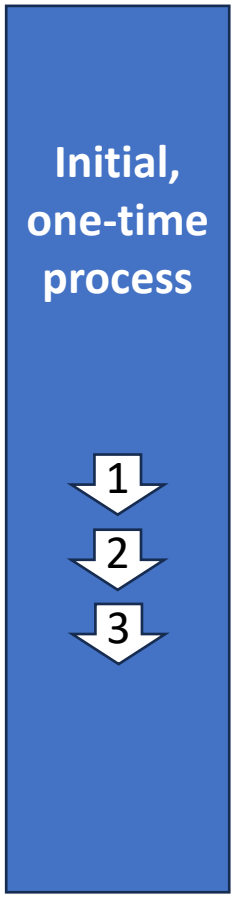
- Create Messages
- Exchange messages with Network

Guidance Document Structure

- Two key parts:
  1. Initiation of Connected Work Zones Using Virtual RSUs:
     - Software development, vendor procurement, and data sources
     - Eventually, IOOs might publish a REST API and allow competing services deliver messages to applications
  2. Ongoing Operations:
     1. Work zone selection
     2. Initiation of a CWZ for vRSU Sharing
     3. Data management
     4. Wrap-up / Removal of the vRSU Connected Work Zone

Guidance Document Structure – Initial One-time Process

- Two key parts:



1. **Initiation: software development, vendor procurement, and data sources**
   - *Work zone data and standards:* ensure work zone data is available and interoperable; assist in interpreting current and emerging standards for data and communications.
   - *Communications to/from vehicles:* overall interoperable communication of work zone data with CVs via cellular network(s) (and potentially physical RSUs).
     - Testing and validation activities.
   - *Driver interface:* guidance for IOO implementation as well as for working with in-vehicle application or OBU providers.
     - Who creates and owns the App?

Guidance Document Structure – Ongoing processes

- Two key parts:
  1. Software development, vendor procurement, and data sources
  2. **Ongoing operations, including work zone selection and data management**
     - *Work zone selection and connectivity:* steps to follow when assessing which work zones (e.g., duration, impact on lane access, traffic volumes impacted) are most suited for connectivity.
       - Selection of messages to share with vehicles.
     - *Data management:* process to ensure work zone data is timely, accurate, and reliable; considerations for receiving vehicle data for agency use; understanding data storage and archiving; and security considerations.

Cyclical, ongoing process

Guidance Document Structure

1. Initiation, with Guidance to describe:

   1.1 Familiarizing and selecting standards for interoperability (RSA/TIM/RSM, ITIS codes, WZDx)

   1.2 Assessment of agency data sources (ensure availability, accuracy, quality, and format)

   1.3 Driver interface approach (what messages to provide, when, how – e.g., one-time audio-only message “work zone 1 mile ahead, reduce speed”)

   1.4 Staffing and vendor support considerations (to develop software; quality control and data generation)

   1.5 Software development (agency system to generate messages; possible upgrades to agency apps)

   1.6 Data governance, liability, and security policies and considerations

   1.7 Private sector engagement (outreach to promote availability of information)

   1.8 Additional considerations: other message types (weather, congestion), provision via other means (physical RSUs)

Guidance Document Structure

2. Ongoing operations, with Guidance to describe:

   2.1 Develop and implement approach for work zone selection (duration, impact on lane access, traffic volumes impacted, data availability, Interstate routes, smart work zone devices for verification)

   2.2 Quality control (timely, accurate, and reliable data)

   2.3 Data security, storage, and archival on agency systems

   2.4 Monitoring and evaluation (assess impact and effectiveness, possible expansion to more work zones or providers

   2.5 Additional considerations: receiving vehicle data for agency use

Task 2 Coordination with National Standards Efforts

Task 2: Coordination with National Standards

Today:

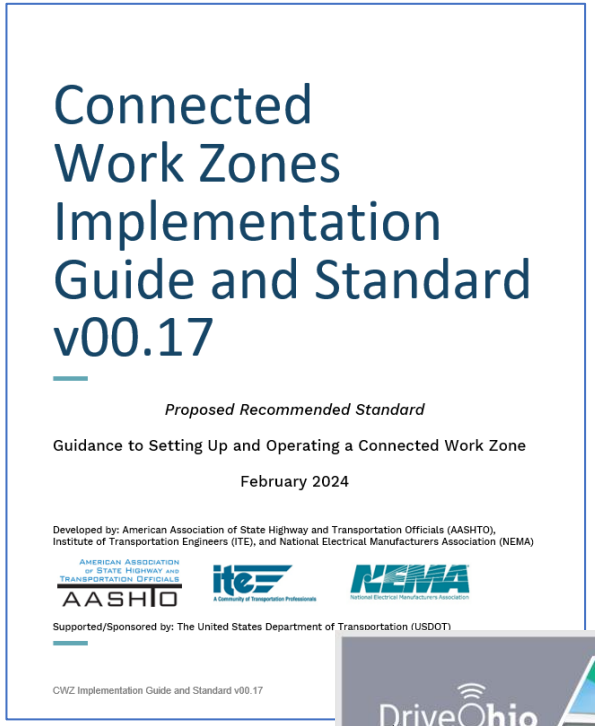
- Describe the RSA, TIM, and RSM standards from SAE
- Hear how CV PFS participants are using these messages
  - Ohio about their current/planned use of RSM
  - Utah (with Wyoming and Colorado) use of TIM
  - Work in California to develop TIM Guidance
  - DRIVE AZ Team's opinion about TIM vs. RSM
  - Discuss preferred approach for the Guidance

Supplemental Webinar:

- May 6–24 time period (?)

Possible Standards

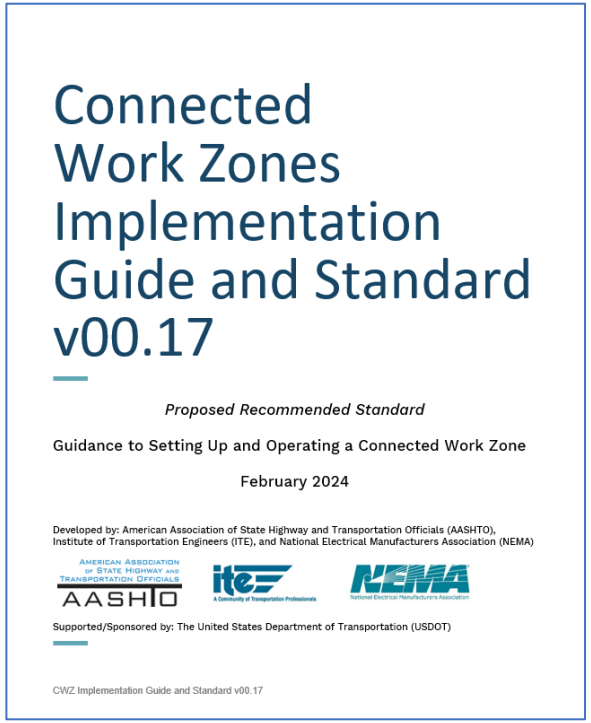
- Connected Work Zones Implementation Guide and Standard (draft)
  - Work Zone Data Exchange (WZDx) Specification is the core of this
- SAE J2735
  - Traveler Information Message (TIM)
  - Roadside Alerts (RSA)
- SAE J2945/4 Road Safety Applications (RSA)
  - Road Safety Message (RSM) supplements TIM
- Drive Ohio Connected Vehicle Applications: Standard Operating Principles
  - Utilizes the SAE J2945/4 RSM messages



Standards Updates

- Connected Work Zones Implementation Guide and Standard (draft)
  - Work Zone Data Exchange (WZDx) Specification is the core of this
  - Met March 28-29 to review comments received on the Proposed Recommended Standard

Envisioned to be a supporting data source in this effort, but not a standard for communicating work zone data to in-vehicle applications


Connected Work Zones Implementation Guide and Standard v00.17

Proposed Recommended Standard

Guidance to Setting Up and Operating a Connected Work Zone

February 2024

Developed by: American Association of State Highway and Transportation Officials (AASHTO), Institute of Transportation Engineers (ITE), and National Electrical Manufacturers Association (NEMA)

Supported/Sponsored by: The United States Department of Transportation (USDOT)

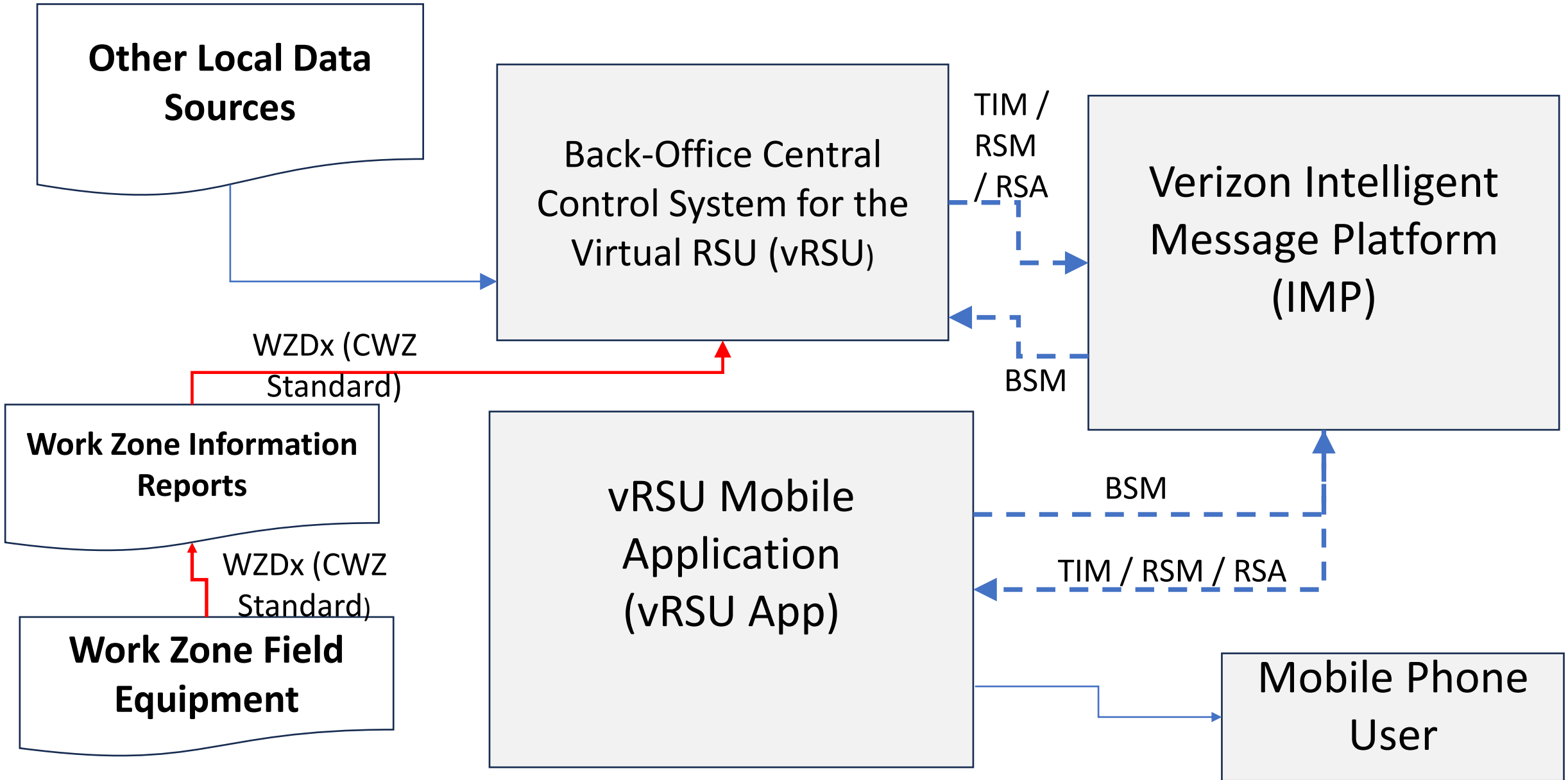
CWZ Implementation Guide and Standard v00.17

Recap of Project Goals for the Guidance:

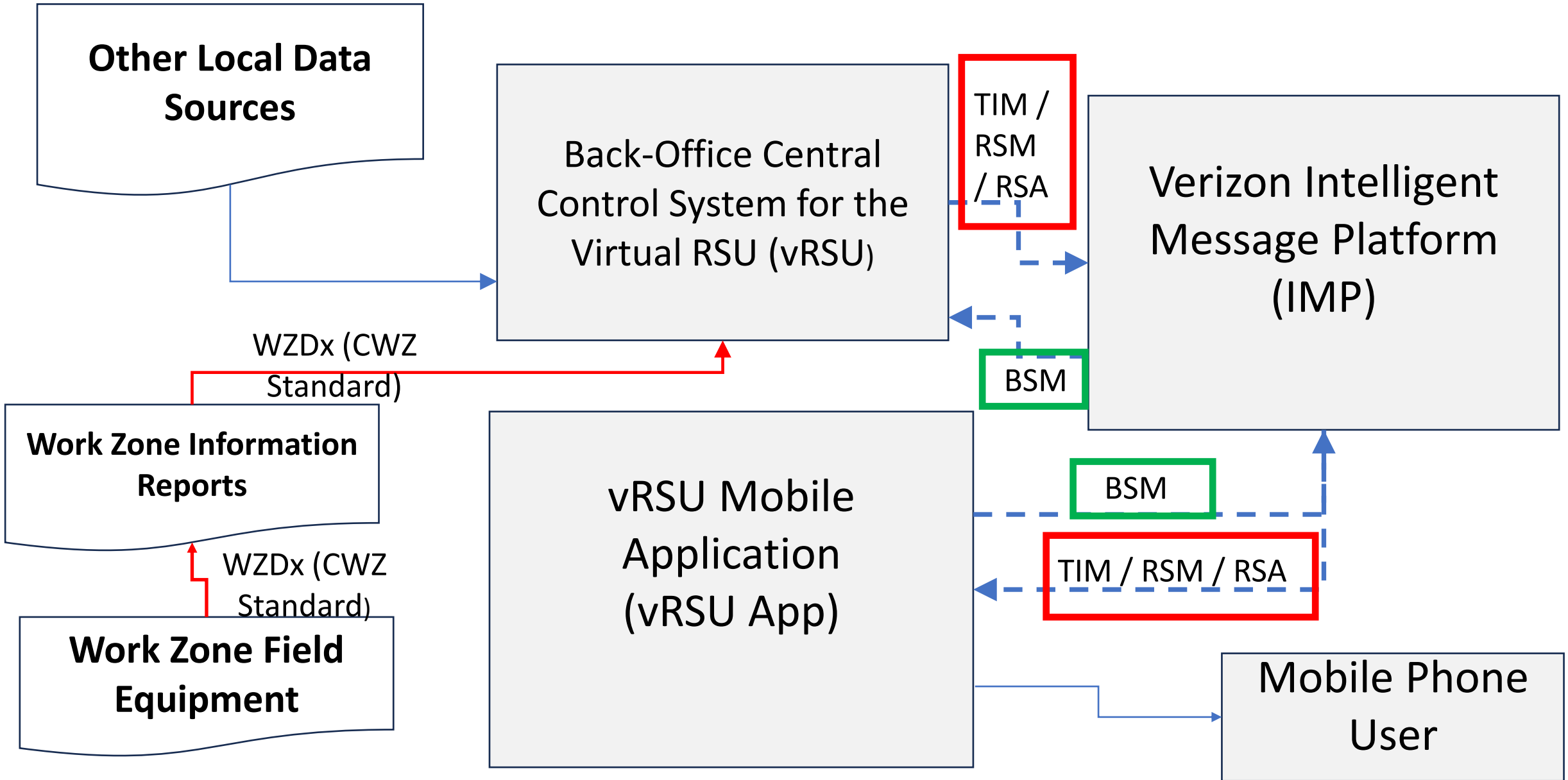
- Our goal (as we understand it) is that the Guidance will define:
  - What standard(s) to use when sending messages to vRSUs
  - What standards to expect when receiving alerts in the mobile apps

- Ideally the selected approach:
  - Is acceptable to Verizon (and other vRSU operators) for vRSU communications
  - Can be used by DOTs when using Physical RSUs
  - Can be used by DOTs sharing with data exchanges (e.g., Situational Data Exchange)
  - Can be used in future Connected and Automated Vehicle Systems

vRSU Connected Work Zones – Message Delivery



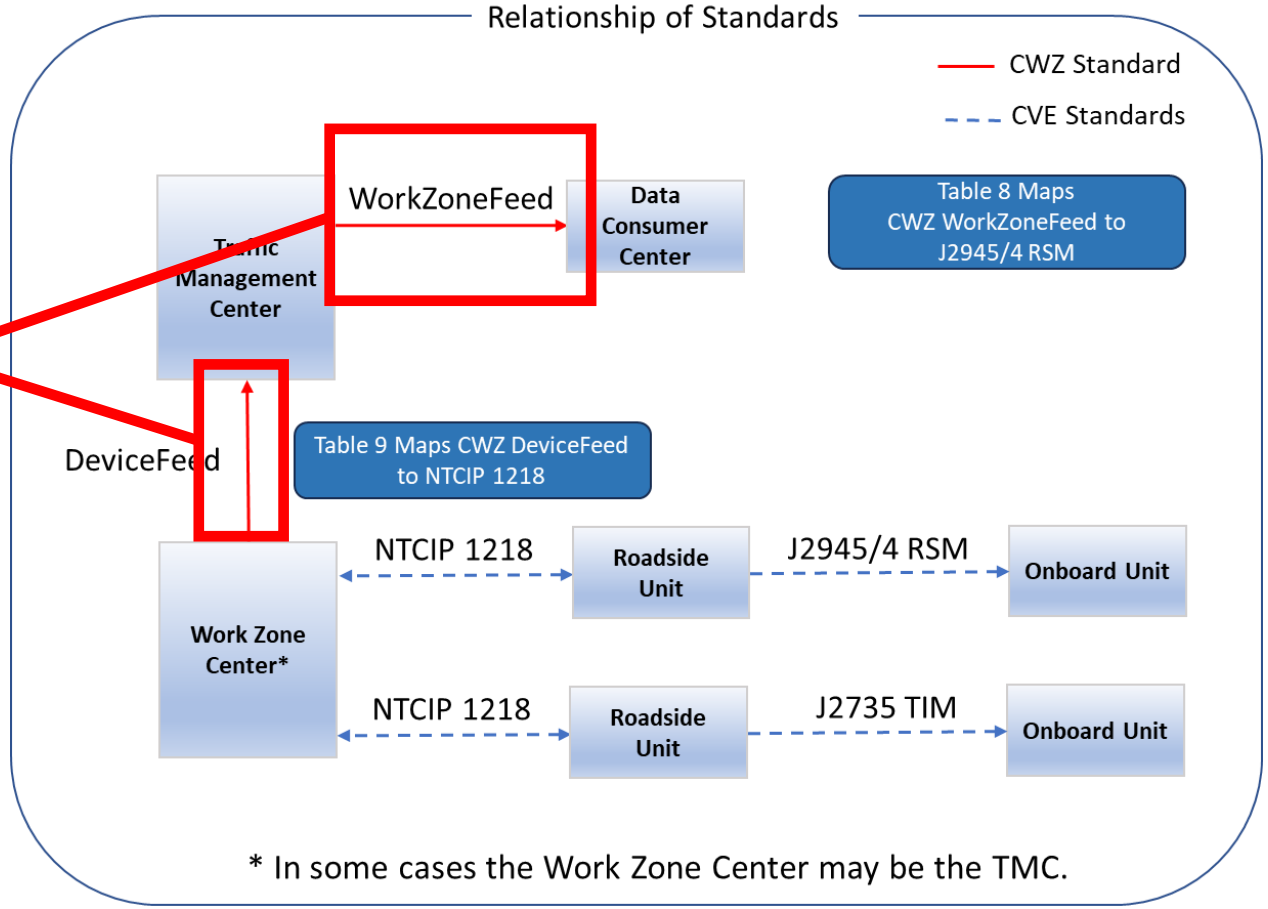
vRSU Connected Work Zones – Message Delivery

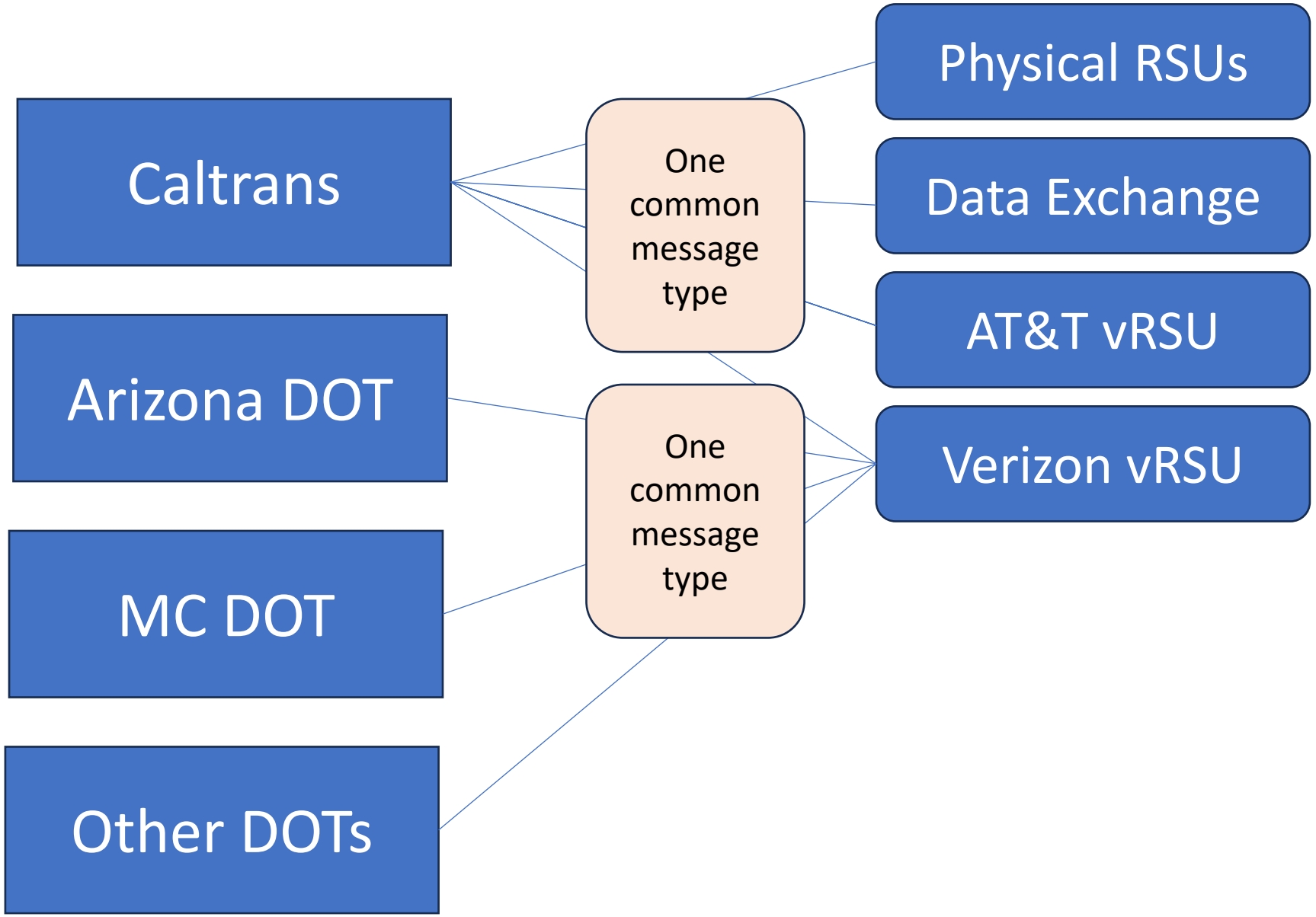


Excerpt from Connected Work Zone Standard

Connected Work Zone Standard – WZDx Specifically

Identified as between the TMC and Data Consumer Center




Caltrans
Arizona DOT
MC DOT
Other DOTs
One common message type
One common message type
Physical RSUs
Data Exchange
AT&T vRSU
Verizon vRSU

Let's Look at RSA, TIMs & RSM

RoadSide Alert (RSA)

- Message in SAE J2735
- "Message is to send alerts for nearby hazards to travelers"
- Does not include location references "this message likely applies to the receiver by the very fact that it is received"
- Examples: "Bridge icing ahead" "Train coming"
- Typically transmitted as V2X

Traveler Information Message (TIM)

- Message in SAE J2735 Support a Variety of Events
- Define the Valid Area of the Message & Viewing Angle
- Similar to "In-vehicle Signing"

Road Safety Message (RSM)

- Defined in SAE J2945/4
- Three levels of Areas:
- Low Level Fidelity:
  - Areas (e.g., evacuation area)
- Medium Level Fidelity:
  - Road Segment (Valid Area)
- High Level Fidelity:
  - Lane Level Details
- Can support OBU specific "warnings"

RSA Structure

- Message Count
- Timestamp (optional)
- TypeEvent (ITIS Codes)
- Description (additional optional ITIS codes)
- Position (optional)
  - Lat, Lon, Ele, Heading, etc.

TIM Structure

- Start Date/Time
- End Date/Time
- View Angle of TIM
- Valid Area of TIM
  - Polygon – Node Points & Width
  - Circle – Center Point and Radius
- ITIS Codes Defining the Message

RSM Structure

- Start Date/Time
- End Date/Time
- Lane Reports:
  - Lane 1: Nodes, Lane Width,
  - Lane 2: Nodes, Lane Width
- Valid Area of RSM
  - Polygon – Node Points & Width
  - Circle – Center Point and Radius
- ITIS Codes Defining the Message

RSA Use in the ADOT Pilot

RSA Message with a Protocol Buffer (protobuffer)

- The buffer outside the RSA contains the lat/lon coordinates defining when to deliver message to the application

Example RSA message from Verizon MEC to in-vehicle App:


```
{
    "MessageFrame":{
        "messageId":"27",
          "value":{
           "RoadSideAlert":{
              "msgCnt":"0",
              "timeStamp":"0",
              "typeEvent":1025,
              "description":{
                 "ITIScodes": ["1025", "12545", "8711"]
              }
```

TIM Illustration

Message(s) would be available to Travelers in the “valid area”

Road Construction Ahead; Right two lanes closed

TIM Illustration

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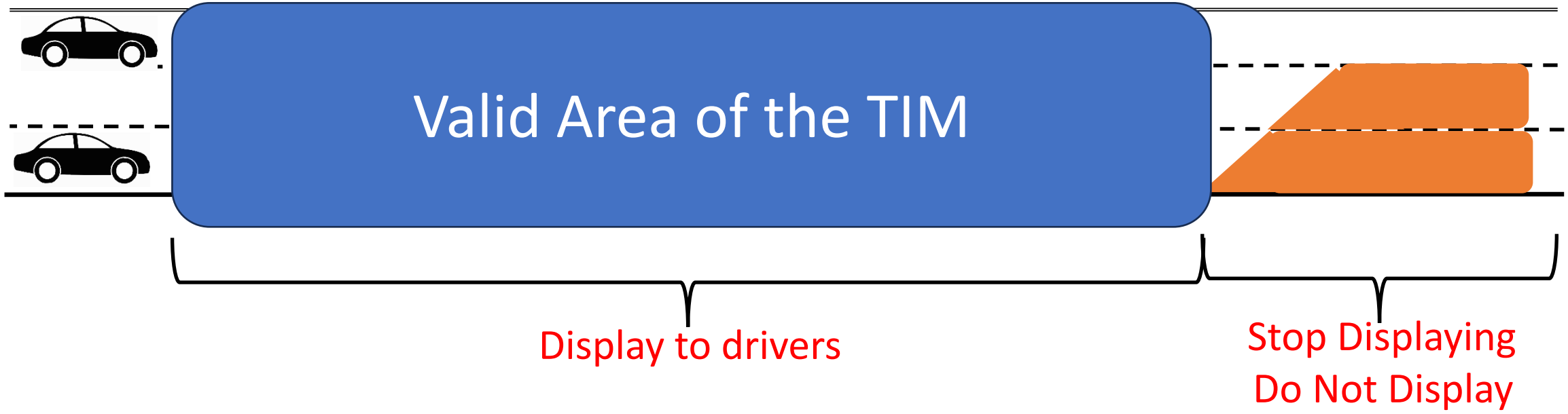
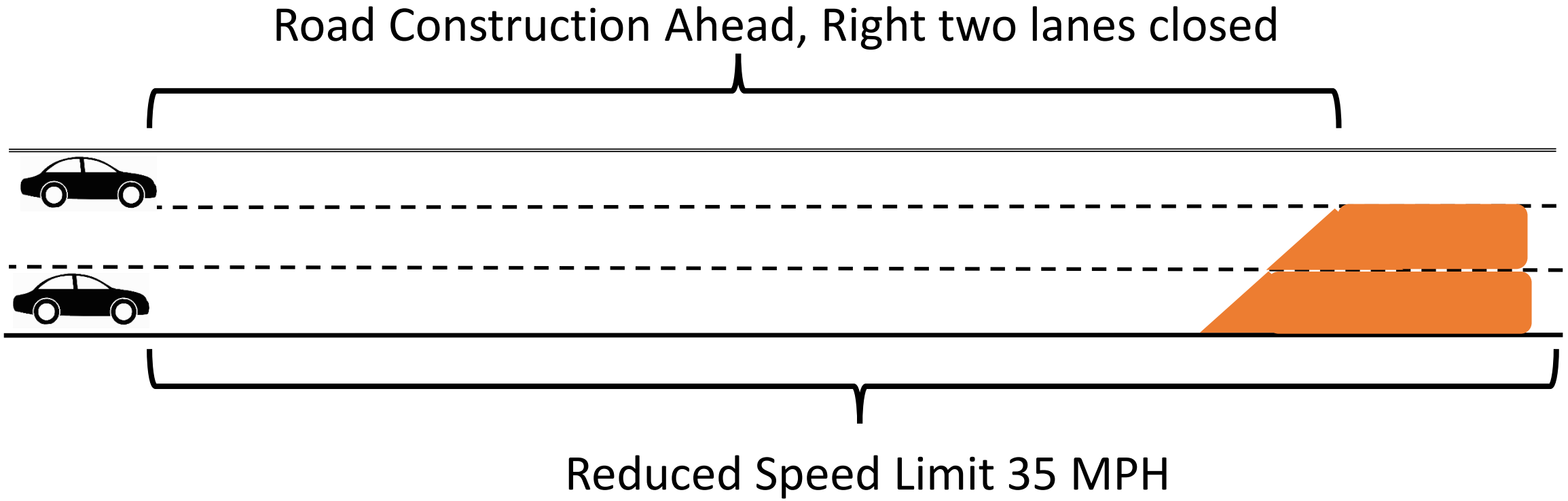


Road Construction Ahead; Right two lanes closed

TIM Illustration

Message(s) would be available to Travelers in the “valid area”

Valid Area for TIM

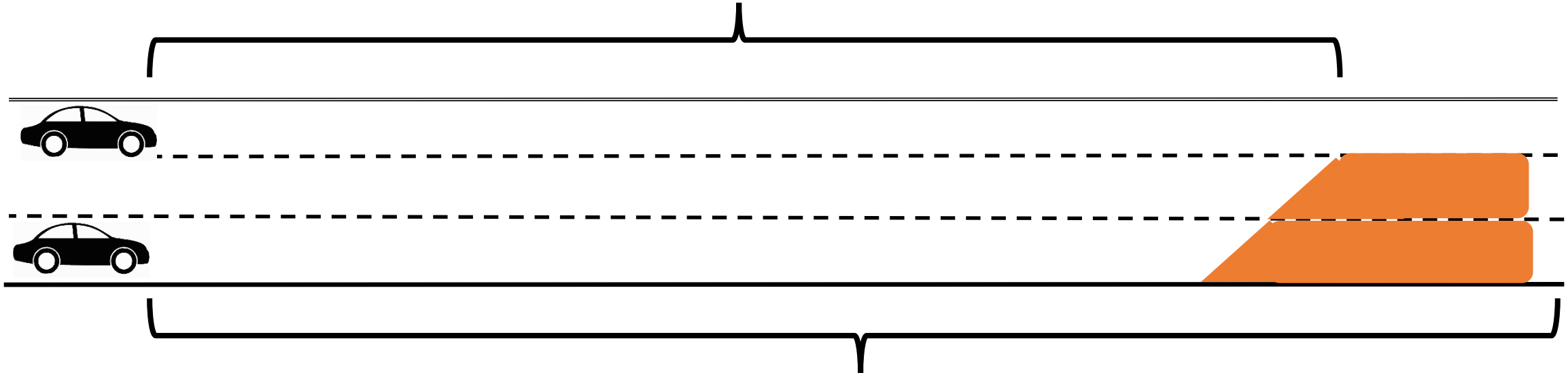


TIM Illustration

Message(s) would be available to Travelers in the “valid area”

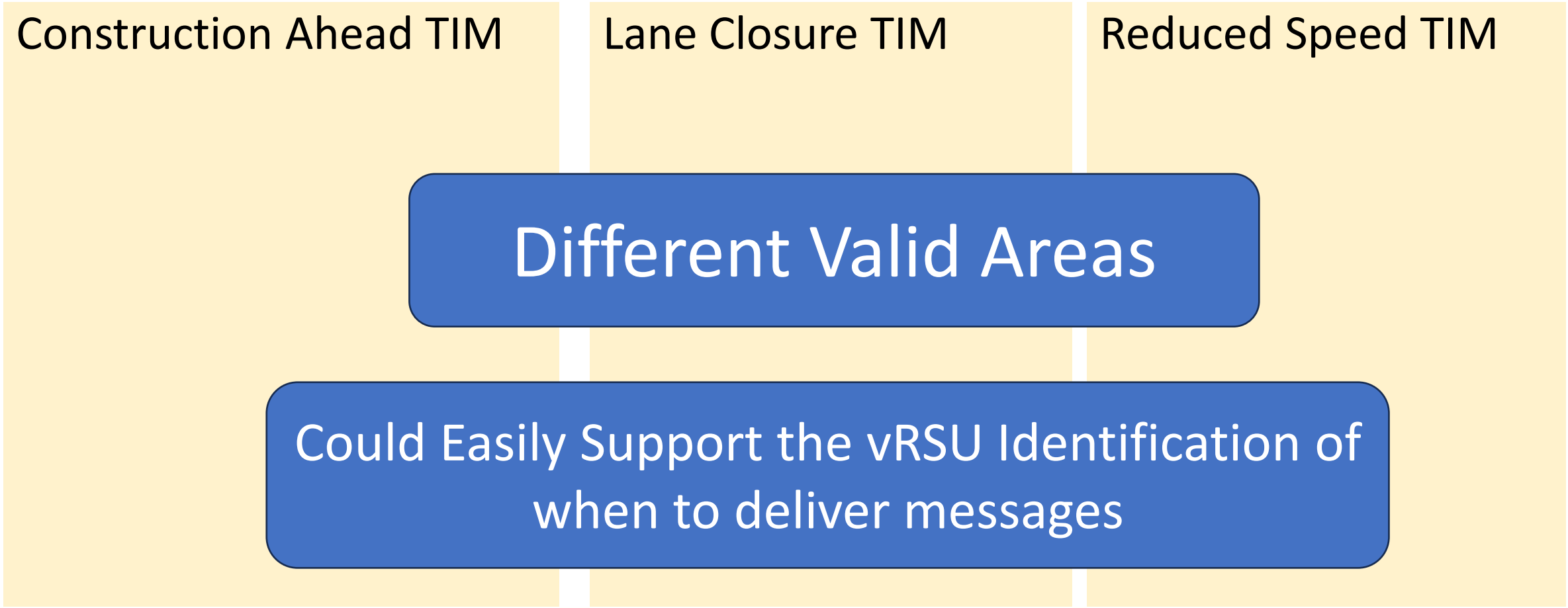
Valid Area for TIM

Road Construction Ahead, Right two lanes closed



Reduced Speed Limit 35 MPH

Multiple TIMs for Each Event



TIM Illustration

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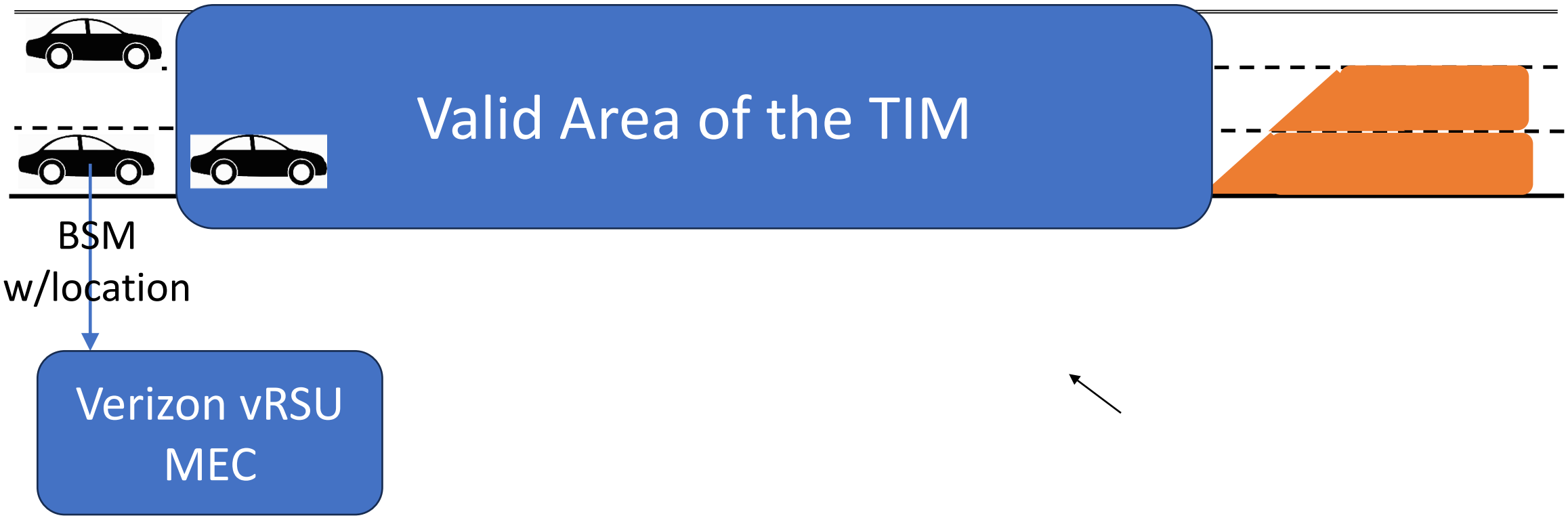

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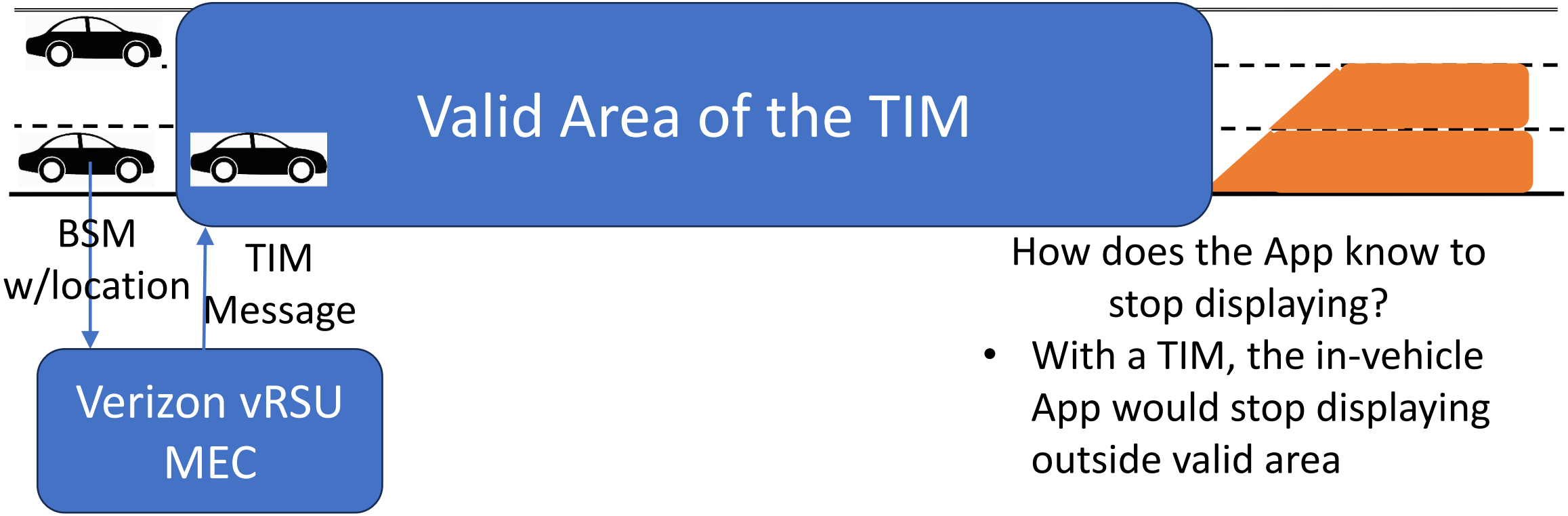
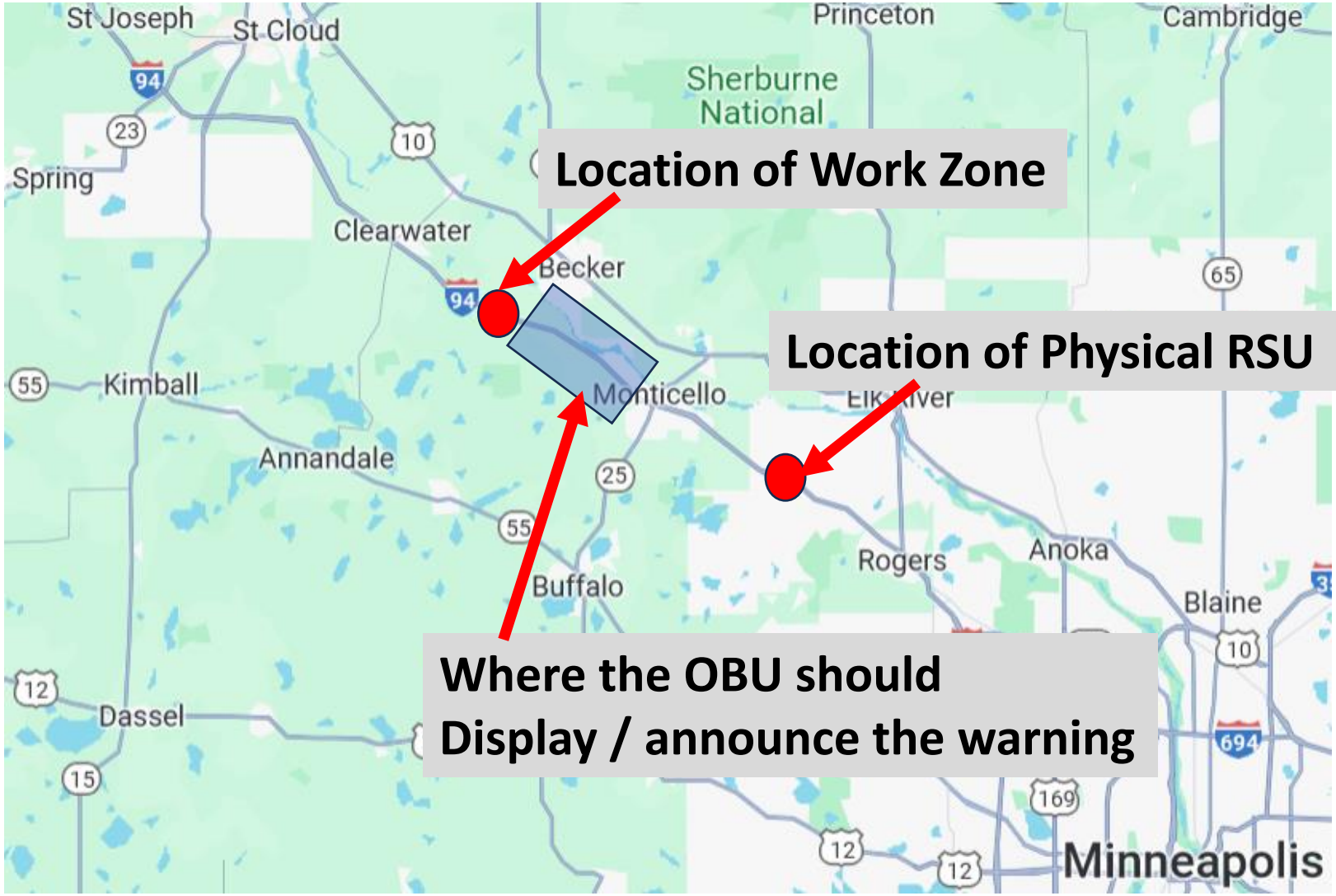


How does the App know to stop displaying?

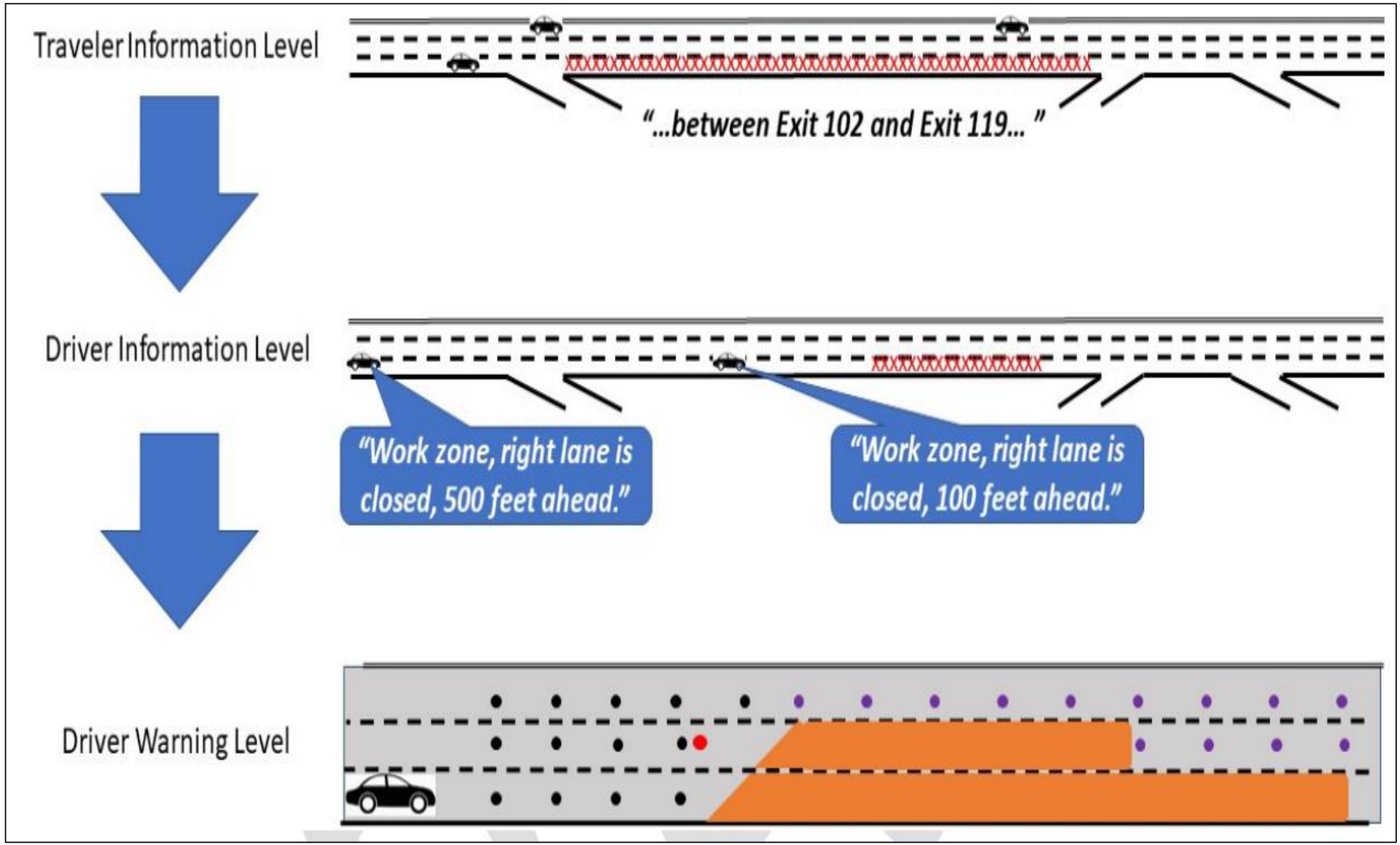
- With a TIM, the in-vehicle App would stop displaying outside valid area



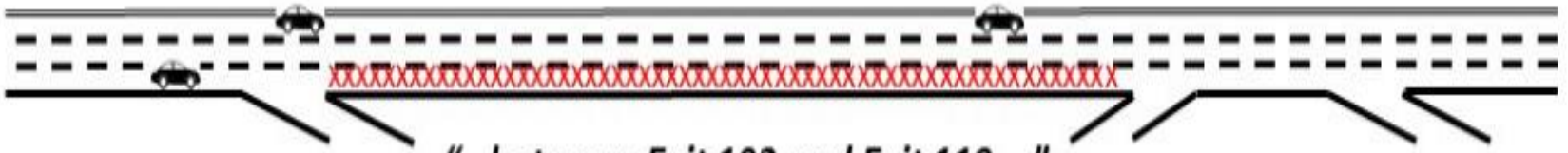
TIM
"Valid" Area Polygon

- Allows for upstream RSUs to broadcast messages
- OBUs could hold the message until vehicle is in the "valid" area
- Also would support Virtual RSU Deployments

RSMs – How are They Different?


Traveler Information Level
"...between Exit 102 and Exit 119... "
Driver Information Level
"Work zone, right lane is closed, 500 feet ahead."
"Work zone, right lane is closed, 100 feet ahead."
Driver Warning Level

Traveler Information Level

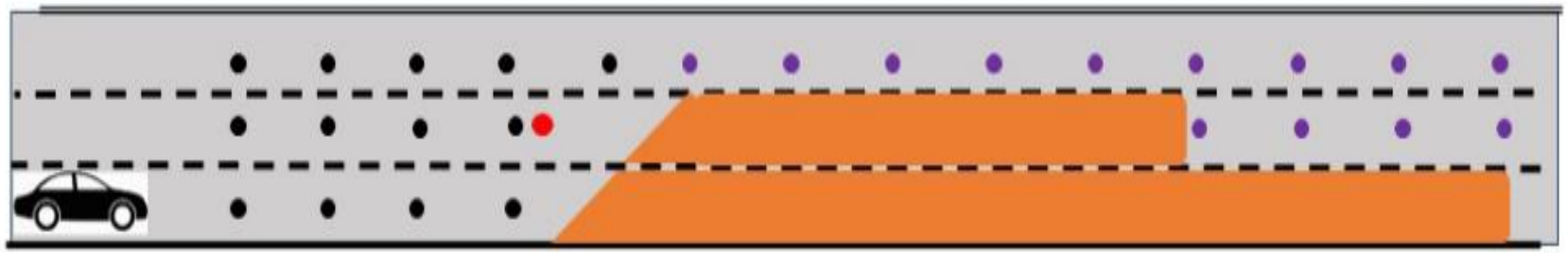


Driver Information Lev

The Concept of Driver Warnings:

- Only vehicles in lanes that are closing receive a warning
- Only vehicles exceeding the reduced speed receive a warning
- Eventually AVs could be navigated through the WZ

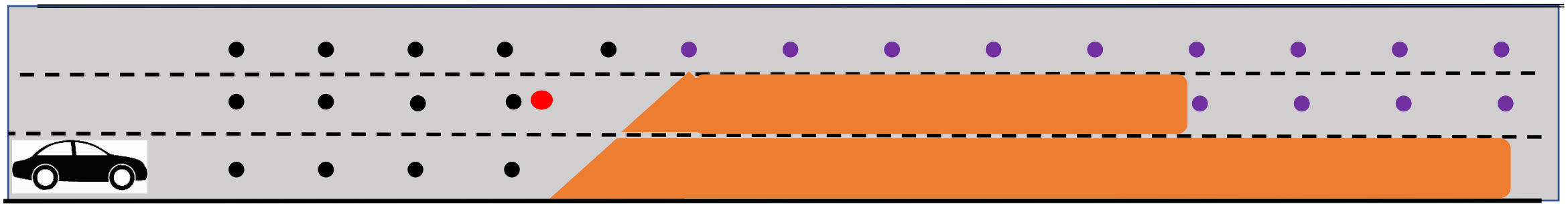
Driver Warning Level



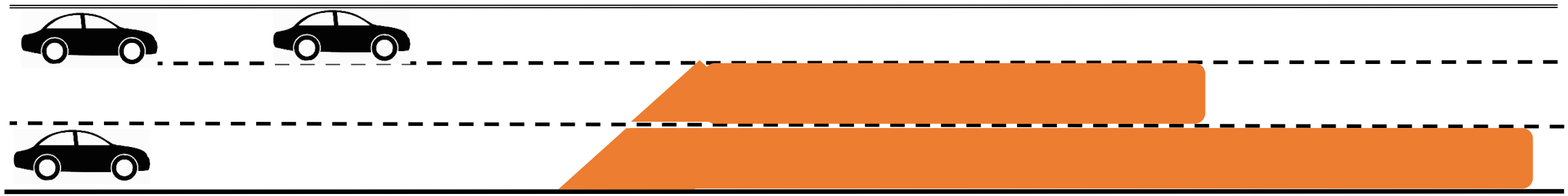
RSM for Work Zones

Work Zone Description:

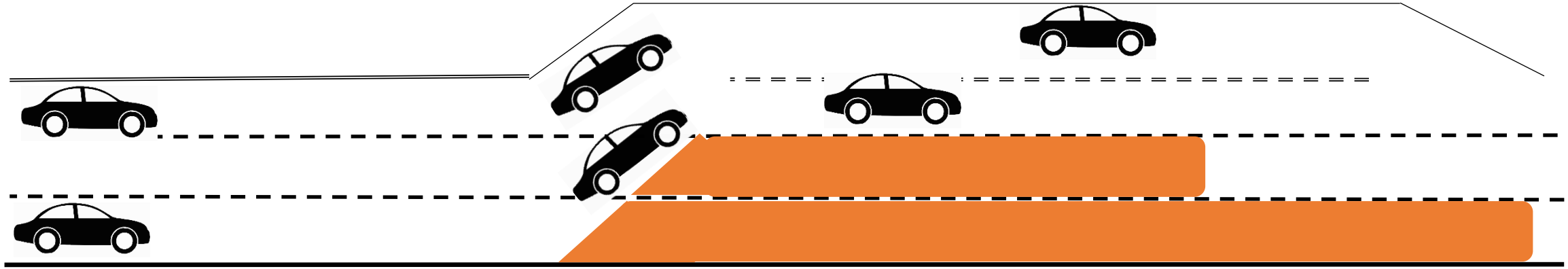
- Reference Point – Work Zone start
- Approach Nodes
- Work Zone Nodes



Temporary Lane Adjustments



Temporary Lane Adjustments (additional lane added temporarily)



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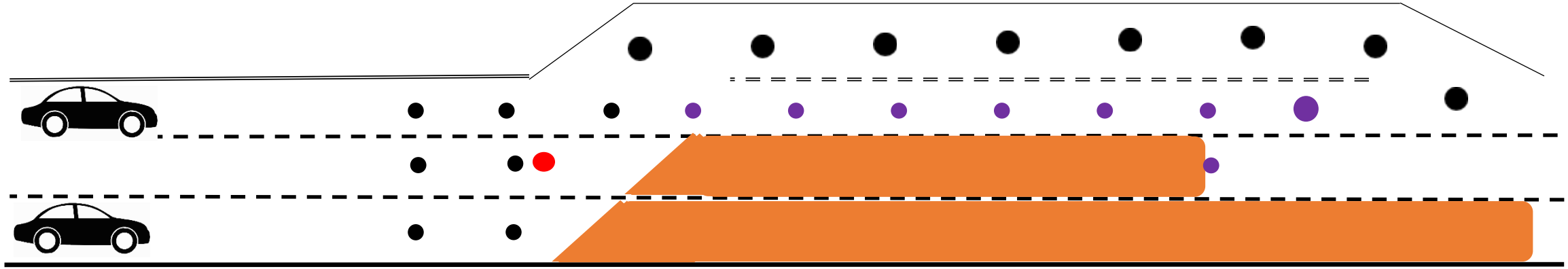


Drive Ohio CV Applications Standard Operating Principles

- Describes the use of RSMs
- Contains “optional” and “mandatory” fields
  - No documented guidelines (e.g., CTIC document for Connected Intersections
  - No detailed definition of how to code work zone locations (e.g., polygon vs. point location)
- A lot of very useful clarifications in the Drive Ohio Report
  - “Connected Vehicle Applications: Standard Operating Principles

Very Active vRSU Developments re: Connected Work Zones

vRSU Connected Work Zones:

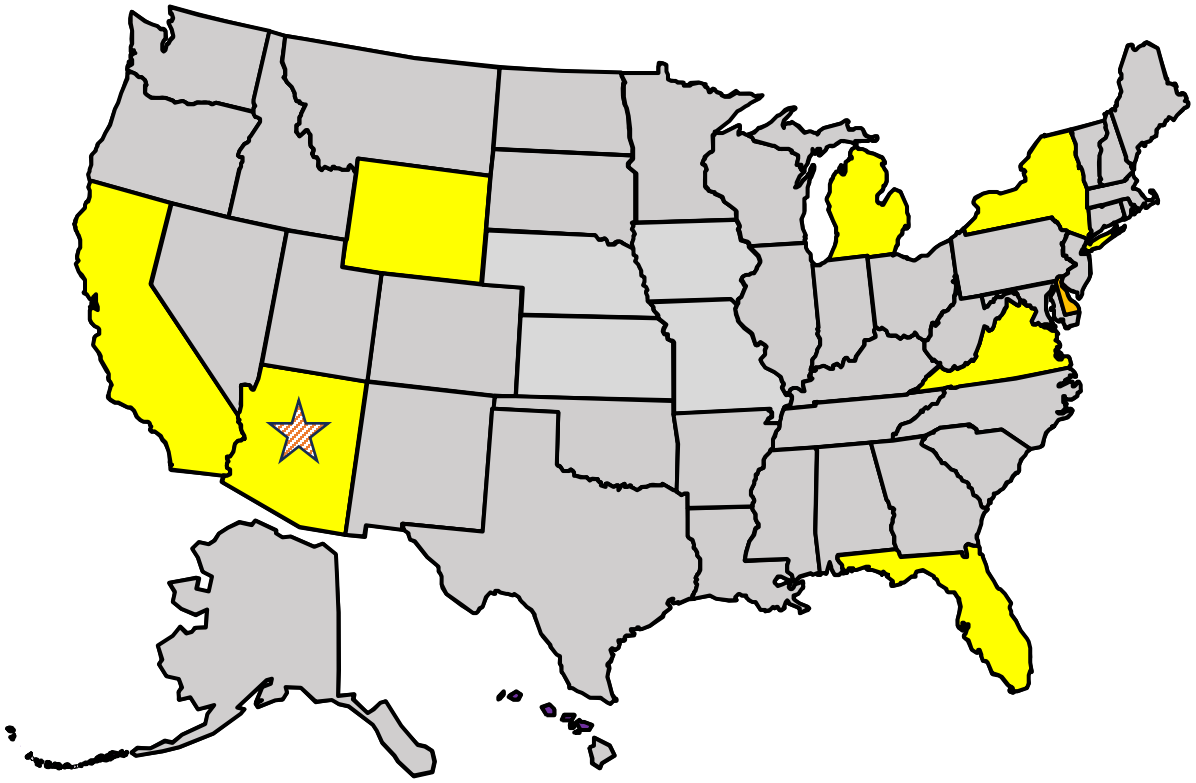
- Arizona DOT
- California
- Maricopa County

Other vRSU (non Work Zones):

- Delaware
- M-City (Michigan)

Physical RSU Connected Work Zones:

- MCDOT (MC85) (4-5 years ago)
- MCDOT & ADOT (current)
- Virginia (VTTI)
- CV Model Deployments (WY, FL, NY)
- Utah RSUs



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The timing of this project seems ideal to:

- Learn from current & past deployments (physical and virtual RSUs)
- Collaborate with current projects
- Develop guidance for consistent RSA/TIM/RSM message creation
- Facilitate better interoperability with Verizon and other partners

Discussion

Our preliminary thoughts:

- **RSA**: not equipped to support Connected Work Zones
  - e.g., lat/long information must be added as a buffer

- **TIM**: sufficient for current deployments, perhaps not robust enough for future deployments & complex work zones; industry experience with RSUs/OBUs communicating TIMs **Use Today**

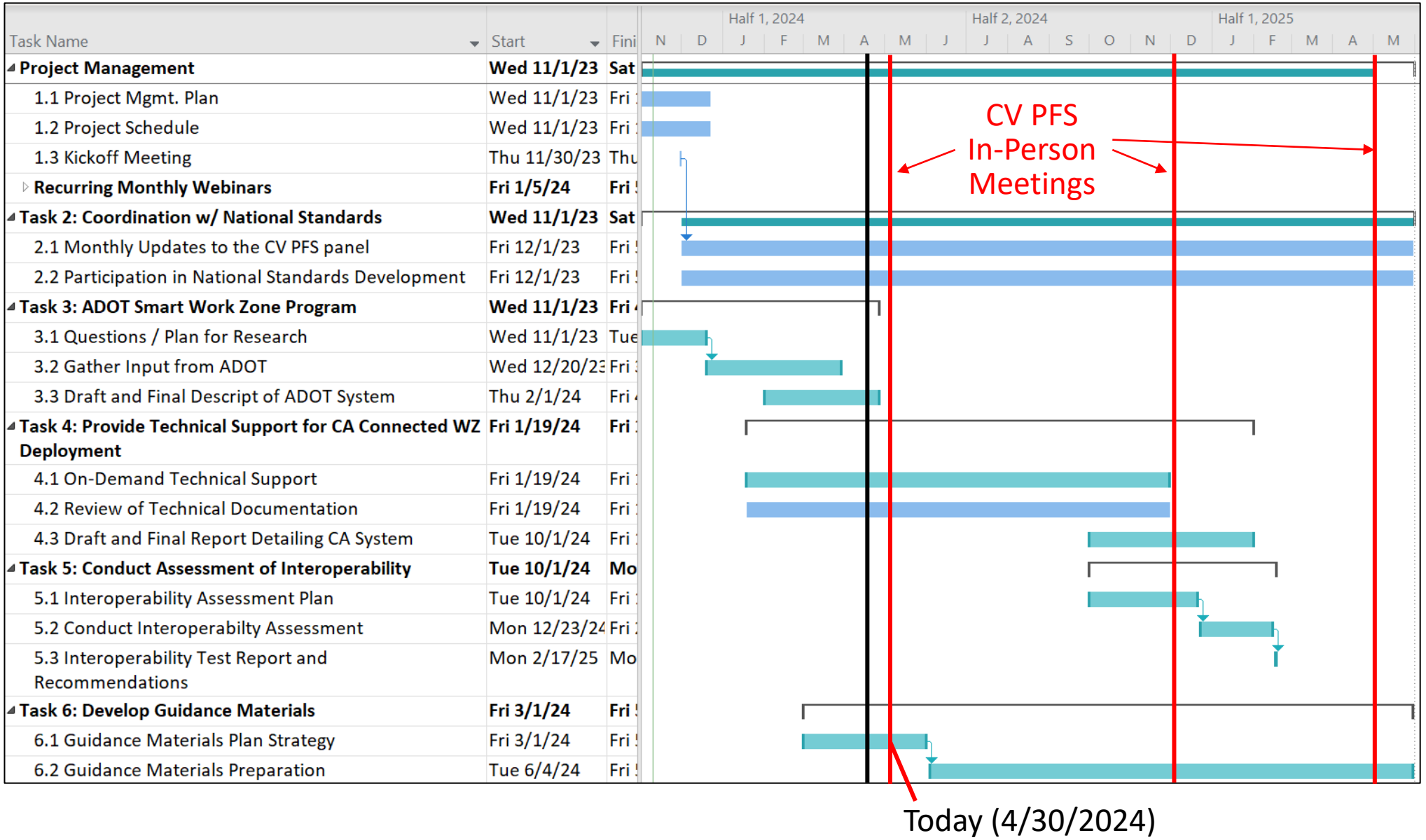
- **RSM**: sufficient for current deployments and future needs, possibly higher level of effort for current needs; no industry experience deploying or OBUs decoding messages **Planned Transition**

Caltrans Connected Work Zone Project Update

Nathan Loebs, Caltrans

MCDOT Project Status

David Lucas, MCDOT


Task Name
Start
Fini
Half 1, 2024
Half 2, 2024
Half 1, 2025
N D J F M A M J J A S O N D J F M A M
Project Management Wed 11/1/23 Sat
1.1 Project Mgmt. Plan Wed 11/1/23 Fri
1.2 Project Schedule Wed 11/1/23 Fri
1.3 Kickoff Meeting Thu 11/30/23 Thu
Recurring Monthly Webinars Fri 1/5/24 Fri
Task 2: Coordination w/ National Standards Wed 11/1/23 Sat
2.1 Monthly Updates to the CV PFS panel Fri 12/1/23 Fri
2.2 Participation in National Standards Development Fri 12/1/23 Fri
Task 3: ADOT Smart Work Zone Program Wed 11/1/23 Fri
3.1 Questions / Plan for Research Wed 11/1/23 Tue
3.2 Gather Input from ADOT Wed 12/20/23 Fri
3.3 Draft and Final Descript of ADOT System Thu 2/1/24 Fri
Task 4: Provide Technical Support for CA Connected WZ Deployment Fri 1/19/24 Fri
4.1 On-Demand Technical Support Fri 1/19/24 Fri
4.2 Review of Technical Documentation Fri 1/19/24 Fri
4.3 Draft and Final Report Detailing CA System Tue 10/1/24 Fri
Task 5: Conduct Assessment of Interoperability Tue 10/1/24 Mo
5.1 Interoperability Assessment Plan Tue 10/1/24 Fri
5.2 Conduct Interoperabilty Assessment Mon 12/23/24 Fri
5.3 Interoperability Test Report and Recommendations Mon 2/17/25 Mo
Task 6: Develop Guidance Materials Fri 3/1/24 Fri
6.1 Guidance Materials Plan Strategy Fri 3/1/24 Fri
6.2 Guidance Materials Preparation Tue 6/4/24 Fri
CV PFS In-Person Meetings
Today (4/30/2024)

Questions and Discussion