Enabling Deployment of Connected Work Zones

Monthly Panel Meeting

December 3, 2024

Today's Agenda

- Project Recap and Overview
- White Paper: "Network Communications Technologies to Support Vehicle-to-Everything (V2X) Safety Applications"
- What This Project Can and Cannot Do
- Plans for the Guidance Document
- Deployer updates: Caltrans and Maricopa County
- TIM Examples

Project Recap and Overview

- 6 Tasks
- Supporting MCDOT and Caltrans Efforts
- Assessment of Interoperability between MCDOT and Caltrans projects
- Final Product will be Guidance Materials for IOO Deployment of Connected Work Zones

Task 1: Project Management

Task 2: Coordination with Relevant National Standards Efforts

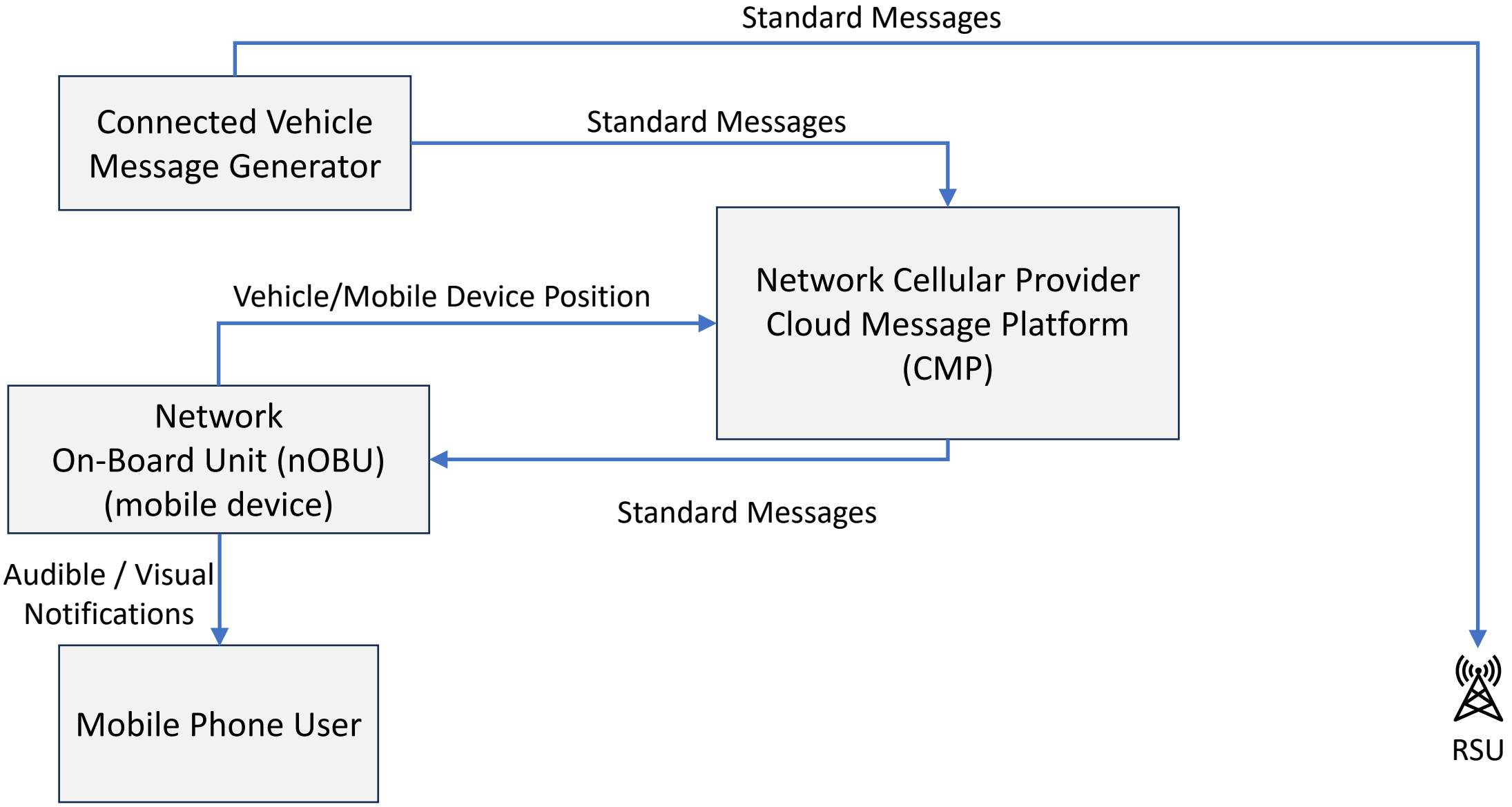
Task 3: Arizona DOT Smart Work Zone Program

Task 4: Provide Technical Support for California Connected Work Zone Program

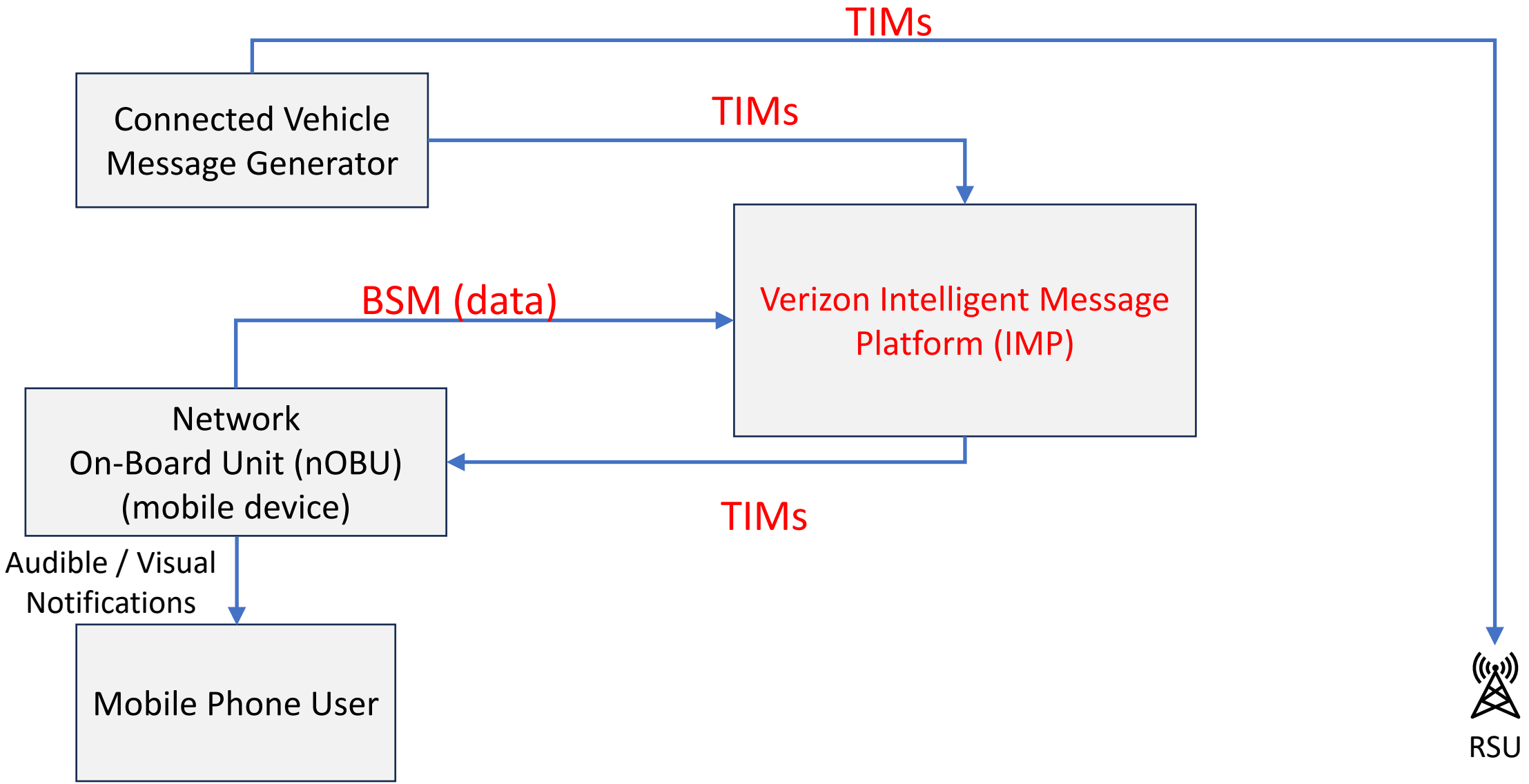
Task 5: Conduct Assessment of Interoperability of Arizona and California Deployments

Task 6: Develop Guidance Materials for IOO Deployment of Connected Work Zones

General Connected Work Zone Data Flow

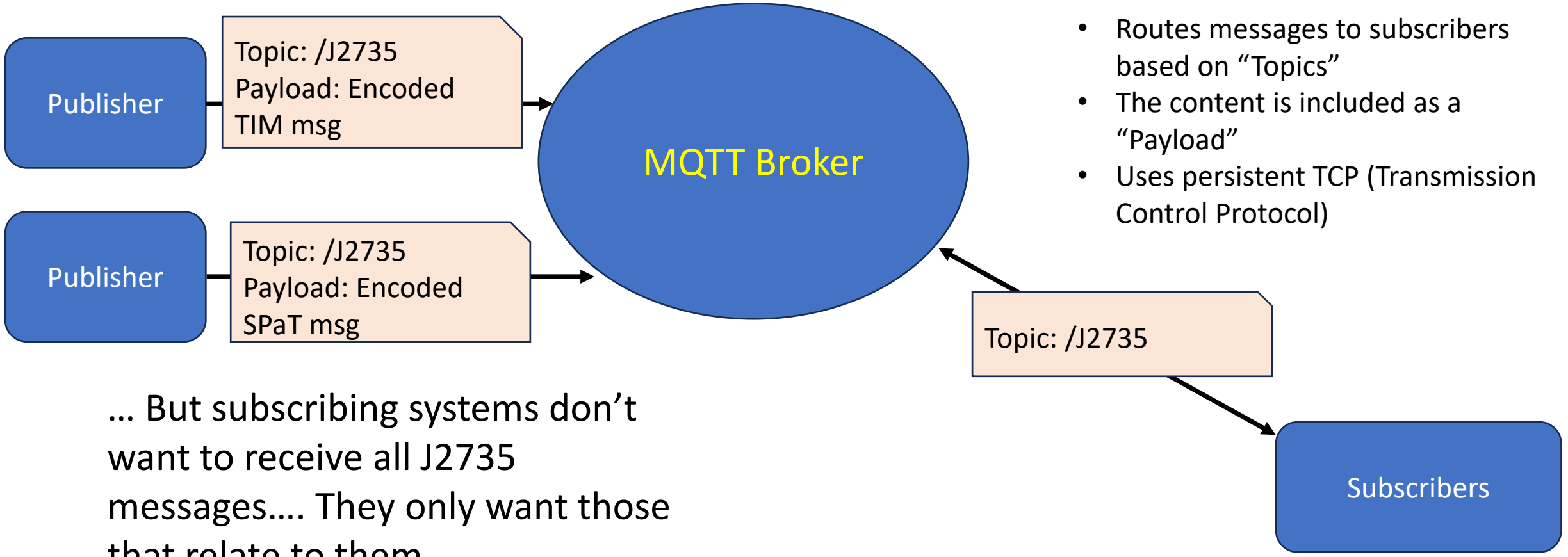


CV PFS Pilot Sites – Verizon IMP



Network Communications:
MQTT (Message Queuing Telemetry Transport)

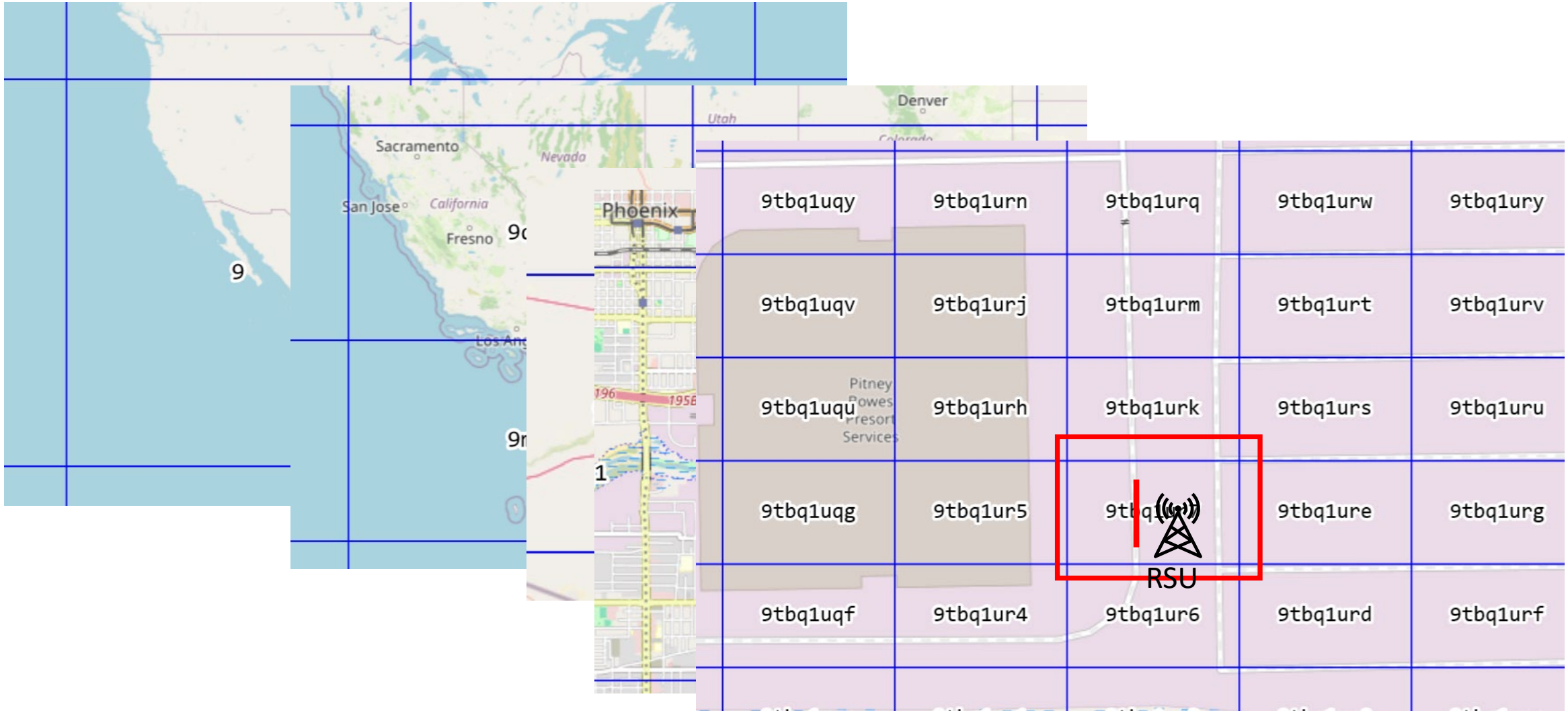
- Uses a Publish / Subscribe model



- Routes messages to subscribers based on “Topics”
- The content is included as a “Payload”
- Uses persistent TCP (Transmission Control Protocol)

… But subscribing systems don’t want to receive all J2735 messages…. They only want those that relate to them

GeoHash – Dividing the World into Rectangles



Source: https://chrishewett.com/blog/geohash-explorer/?xn775

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MQTT (Message Queuing Telemetry Transport)

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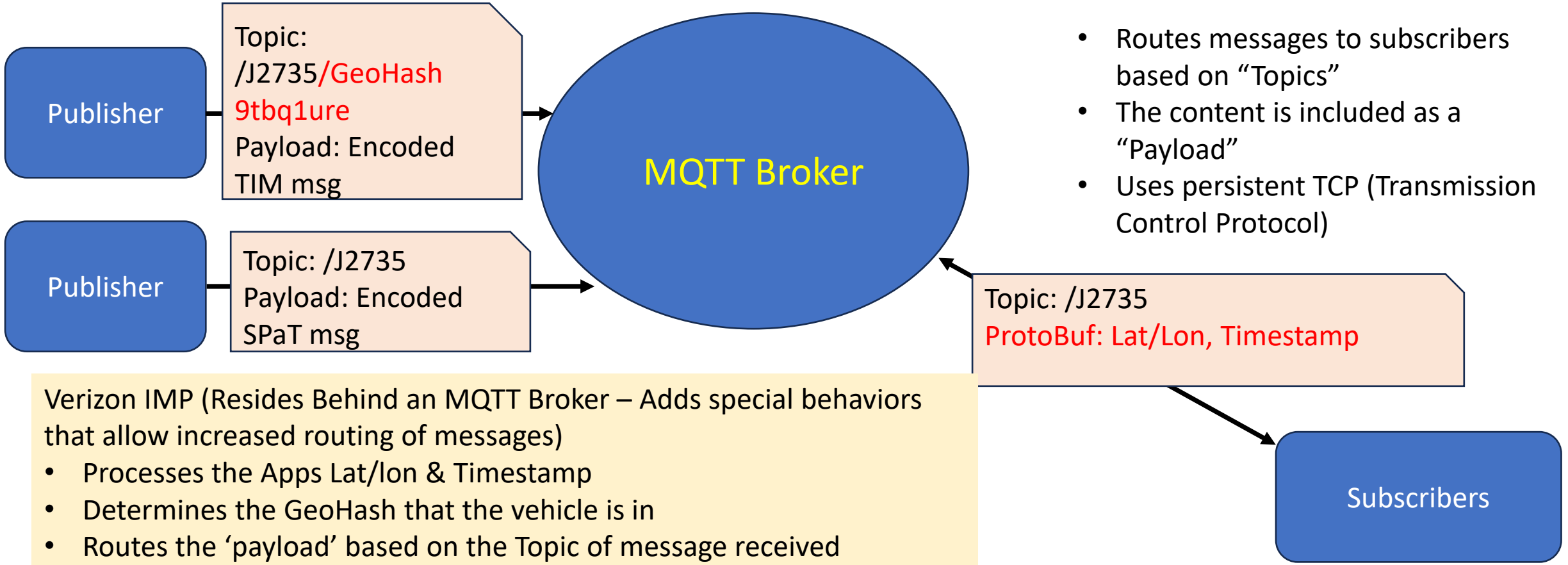


- Routes messages to subscribers based on “Topics”
- The content is included as a “Payload”
- Uses persistent TCP (Transmission Control Protocol)

Verizon IMP (Resides Behind an MQTT Broker – Adds special behaviors that allow increased routing of messages)

- Processes the Apps Lat/lon & Timestamp
- Determines the GeoHash that the vehicle is in
- Routes the ‘payload’ based on the Topic of message received
- Allows Apps to receive a TIM that is related to your current location

White Paper
“Network Communications Technologies to Support Vehicle-to-Everything (V2X) Safety Applications”

Network Communications Technologies to Support Vehicle-to-Everything (V2X) Safety Applications

October, 2024 DRAFT

In order to accomplish a vision of consistent connected work zone (CWZ) in-vehicle applications nationwide, the Connected Vehicle Pooled Fund Study (CV PFS) sponsored this project to develop clear and well documented guidance for infrastructure owner operators (IOOs) and private sector partners to follow as they approach connected work zone deployments that provide consistent work zone warnings via network cellular connected vehicle applications.

The purpose of this white paper is to document the flow of information from IOO systems to in-vehicle applications using network communications and supporting technologies.

Background: How Network Communications Differ from V2X Direct Communications

V2X Direct Communications

V2X direct communications operate in the 5.9 GHz spectrum, formerly reserved exclusively for dedicated short-range communications (DSRC) but being reallocated for use of Cellular-V2X (C-V2X) by the Federal Communications Commission (FCC). Direct communications use a physical roadside unit (RSU) to:

- Broadcast data for any on-board unit (OBU) receiver in range to receive (see Figure 1).
- No ‘handshaking’ is involved, such that there is no knowledge by the broadcaster of who receives the data.

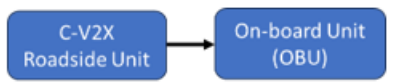


Figure 1. Illustration of V2X Direct Communications.

Network Communications

Cellular network communications typically follow a model in which the client (e.g., a web browser or mobile application) needs to initiate each interaction (see Figure 2). A request-response model often uses the hypertext transfer protocol (HTTP). For example, many IOOs publish an XML feed of road events that the IOO can update at any time; each time an application pulls the data, it receives the updated information. Alternatively, a publish-subscribe model may use Message Queuing Telemetry Transport (MQTT), which is described below.

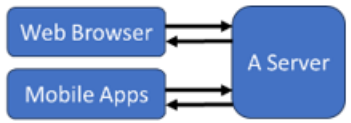


Figure 2. Illustration of Network Communications.

- Result of Webinar Discussions With:
  - Caltrans
  - MCDOT
  - U of A
  - Neaera
  - Verizon
  - TriHydro

White Paper
“Network Communications Technologies to Support Vehicle-to-Everything (V2X) Safety Applications”

High-Level Description of Message Queuing Telemetry Transport (MQTT) Interfaces

In general, MQTT is a generic protocol for a publish subscriber model to accomplish message transmission, using a “broker” approach, illustrated in Figure 3. In other words, the MQTT broker is a router and does not necessarily open received messages; it simply transfers the received messages, as described below.

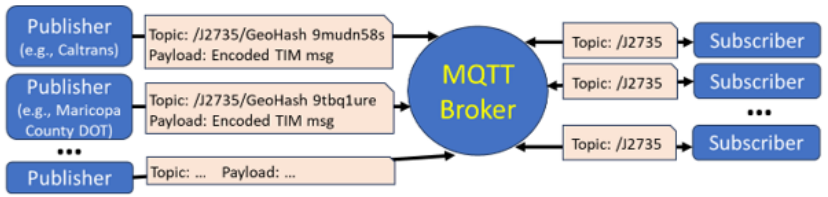


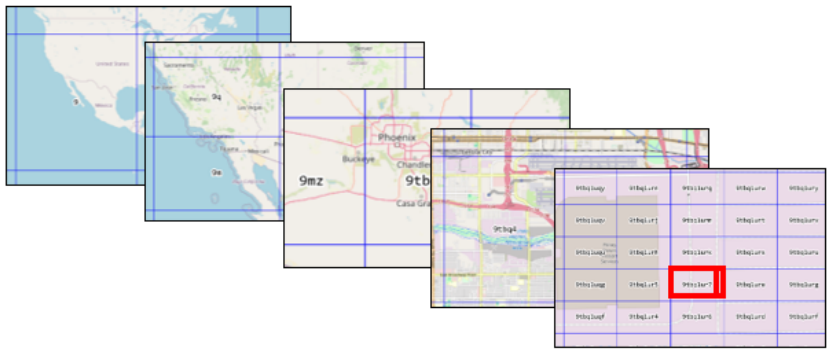
Figure 3. Illustration of message flows via the MQTT broker.

“Topics” as a method of organizing delivery of messages

Messages contributed by publishers identify one or more topics, the topics essentially identify the subject of the payload included in the message. Subscribers to the MQTT broker identify the topics they are interested in. This allows the broker to deliver appropriate messages of interest to each subscriber.

GeoHash as a method of routing messages by location

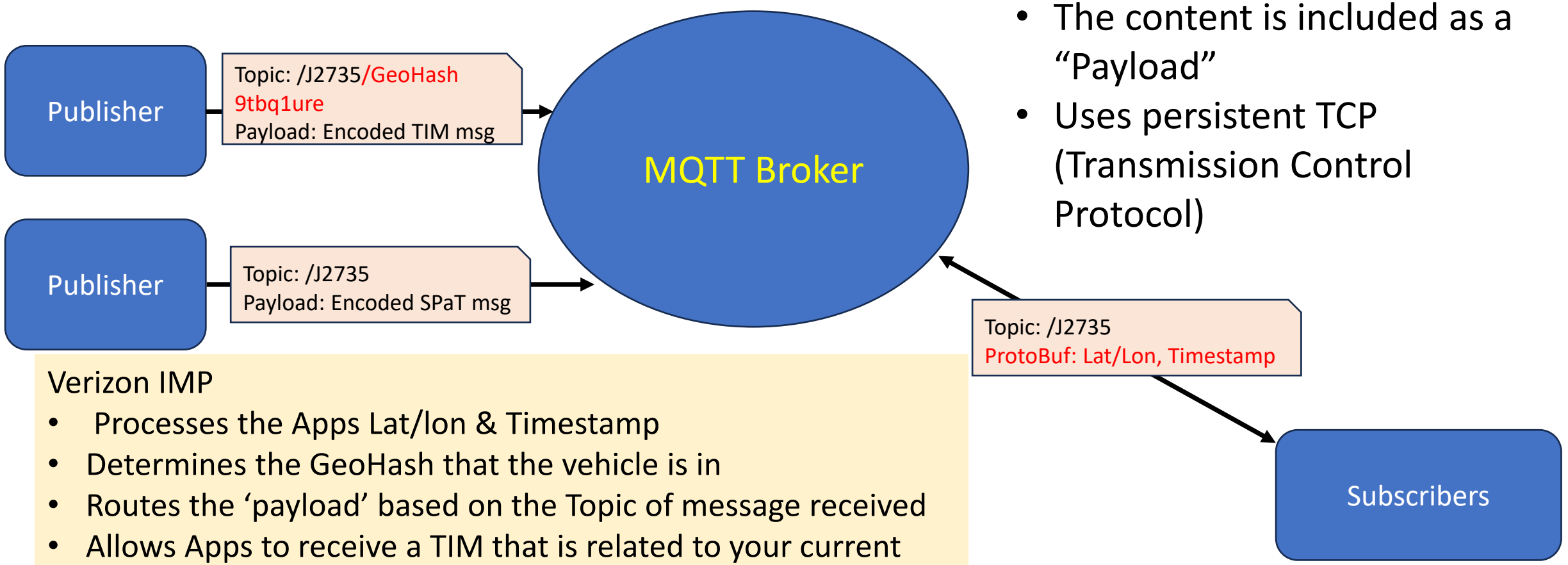
The concept of GeoHash divides the globe into rectangles, with increasing characters scaling the area covered by each rectangle until eventually the rectangle defines a small region. For more information about GeoHash https://bhaugen.com/blog/geohash-sizes/.



- **MQTT** as a generic protocol for a ‘Publisher – Subscriber’ model
- **“Topics”** as a method to organize delivery of messages
- **GeoHash** as a method of routing messages by location

This is the Model with the Verizon IMP

- Publish / Subscribe model

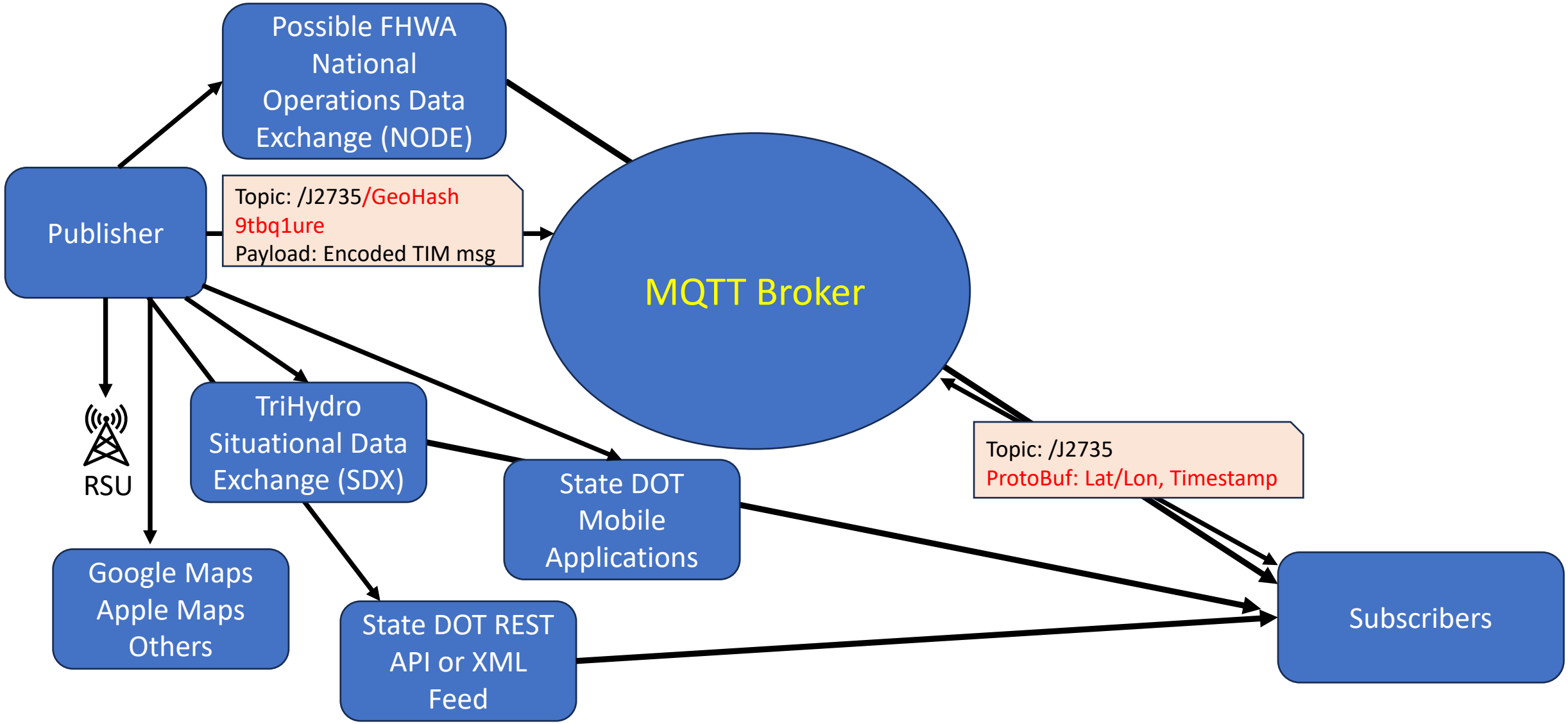


- Routes messages to subscribers based on “Topics”
- The content is included as a “Payload”
- Uses persistent TCP (Transmission Control Protocol)

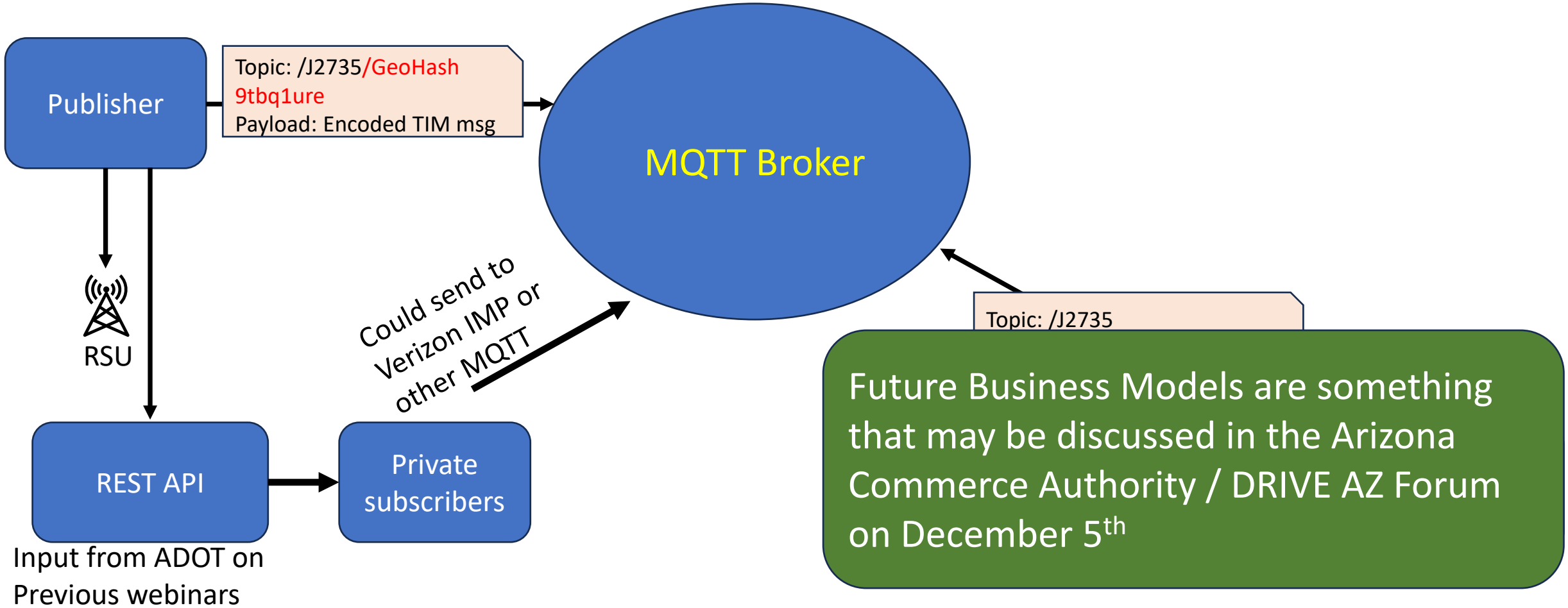
Verizon IMP

- Processes the Apps Lat/lon & Timestamp
- Determines the GeoHash that the vehicle is in
- Routes the ‘payload’ based on the Topic of message received
- Allows Apps to receive a TIM that is related to your current location

But… May Not be the only Model / Approach



But… May Not be the only Model / Approach



What We (This Project) Can and Cannot Do

- **We cannot predict the future private business models**
  - Best we can do is try to understand them and document what we learn publicly
- **We can document what is happening in MCDOT and Caltrans**
  - Use of UPER Encoded TIMs,
  - Common approaches to TIM generation (WY, UT, CO, AZ OH)
  - Common approaches to GeoHash calculations
  - Common use of MQTT (specifically Verizon IMP)
- **We can assess the interoperability of these two sites/systems**
  - Geographic Interoperability of Mobile Apps in AZ and CA
  - Cell Carrier Interoperability of Mobile Apps and Verizon IMP
- **We can develop guidance for future IOOs wanting to deploy Connected Work Zones**

Guidance Document

Guidance Document

Is the best approach to write Guidance for how the next round of IOOs could create pilots or are we focused on deployments?

Feedback on November webinar

Guidance will include steps to:

- Develop software and systems to generate the needed TIM messages for work zones (together with GeoHash or other routing)
- Procure services of a MQTT Service Provider to deliver messages to applications (as is done by Verizon), or services of another data router
- Develop in-house or procure services for IOO software and systems to interface with the procured services, as well as possible applications to display information to drivers

Proposed Guidance Document Structure

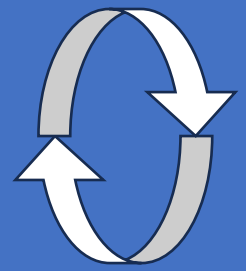
- Two key parts:

Initial, one-time process

Establish the CWZ Environment

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

Cyclical, ongoing process



Each Work Zone

- Create Messages
- Exchange messages with Network

Proposed Guidance Document Structure

- Two key parts:

Initial, one-time process

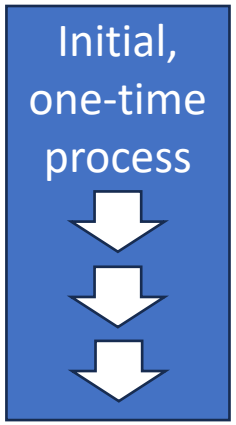
1. Initiation of Connected Work Zones Using Network Communications:
   - Data sources, CWZ scale, agency policies, software development, vendor procurement
   - Determine the overall approach to sharing WZ TIMs
     - Is it just network cellular? Is it RSUs? Will other competing approaches emerge?

Cyclical, ongoing process

2. Ongoing Operations:
   - Work zone inclusion
   - Initiation of a CWZ for TIM sharing to Cellular RSU (cRSU) and other mechanisms
   - Data management
   - Wrap-up / Removal of the CWZ TIM

Preliminary Guidance Steps: Initiating CWZs

- Currently Defined as Five Steps



Step 1: Identify & Define Data Sources

Step 2: Determine Scale of Deployment

Step 3: Define CWZ Plan

Step 4: System Development & Procurement

Step 5: CWZ System Testing

Preliminary Guidance Steps: Initiating CWZs

Initial, one-time process

1. Identify and define data sources
   - Assess available work zone data sources
     - e.g., WZDx, CWZ, etc.
   - Examine data elements, quality, accuracy, completeness
     - e.g., worker presence, planned vs. actual work zone data
   - Understand possible data gaps and possible solutions
     - Differences in data availability for different road classes or work zone types can inform scale of CWZ
     - Procure data or deploy more smart work zone devices

Step 1: Identify & Define Data Sources

Step 2: Determine Scale of Deployment

Step 3: Define CWZ Plan

Step 4: System Development & Procurement

Step 5: CWZ System Testing

Preliminary Guidance Steps: Initiating CWZs

Initial, one-time process

2. Determine scale of CWZ deployment

- Consider consumers of CWZ messages
  - e.g., agency staff, third-party providers, production vehicles
- Consider possible dissemination mechanisms of TIMs
  - Agency-owned feeds and traveler information websites and apps, cellular RSUs, infrastructure RSUs, third-party (e.g., Situational Data Exchange (SDX))
- Determine current feasible scale for deploying CWZs and consider goals for expansion. For example:
  - Number of pilot locations
  - All agency-managed work zones vs. all Interstate work zones
  - Any agency-managed work zone with smart work zone devices
  - Include short-duration maintenance work zones (e.g., <1 day)

Step 1: Identify & Define Data Sources

Step 2: Determine Scale of Deployment

Step 3: Define CWZ Plan

Step 4: System Development & Procurement

Step 5: CWZ System Testing

Preliminary Guidance Steps: Initiating CWZs

Initial, one-time process

3. Develop or understand policies to support CWZs

- CWZ selection
  - Use input from prior step to develop an agency policy that prioritizes work zones to include as a CWZ
    - This can help to "right-size" the approach for the agency and inform scale for procurement
    - e.g., a pilot will not necessarily include all work zones with available, quality data
  - May be based on road class, work zone duration, data quality and availability, worker presence
  - Consider including a vision and goals for expansion based on duration, impact on lane access, traffic volumes impacted, safety concerns
    - Vision may be that all lane closing/traffic impacting work zones will one day be connected; in the interim, IOOs may prioritize those where connectivity will benefit the most.

Step 1: Identify & Define Data Sources

Step 2: Determine Scale of Deployment

Step 3: Define CWZ Plan

Step 4: System Development & Procurement

Step 5: CWZ System Testing

Preliminary Guidance Steps: Initiating CWZs

Initial, one-time process

3. Develop or understand policies to support CWZs (continued)

- Agency data policies
  - Understand relevant data policies for disseminating work zone information
    - e.g., limitations or required terms of use
    - Automated generation of CWZ information vs. manual verification
  - Create data policies for archiving CWZ data to plan for evaluation
- Agency TIM policies
  - May vary based on data availability
  - e.g., general “work zone ahead” vs. more specific information about a reduced speed limit and/or lane closures

Step 1: Identify & Define Data Sources

Step 2: Determine Scale of Deployment

Step 3: Define CWZ Plan

Step 4: System Development & Procurement

Step 5: CWZ System Testing

Preliminary Guidance Steps: Initiating CWZs

Initial, one-time process

4. CWZ System Development and Procurement

- ***Understand relationship of CWZ to other applications that may be desired***
- Develop scope of work for software development to generate TIMs from agency systems
- Determine availability of internal resources to support software development
- If needed, issue procurement and select vendor to develop software or provide services
- Issue procurement and select vendor to provide network cellular services to support CWZs
  - Use input from prior steps to inform scale in RFP
  - Consider contract duration

Step 1: Identify & Define Data Sources

Step 2: Determine Scale of Deployment

Step 3: Define CWZ Plan

Step 4: System Development & Procurement

Step 5: CWZ System Testing

Preliminary Guidance Steps: Initiating CWZs

5. CWZ System Testing

Initial, one-time process

- Develop and execute test plan to ensure functionality of deployed CWZ system

Step 1: Identify & Define Data Sources

Step 2: Determine Scale of Deployment

Step 3: Define CWZ Plan

Step 4: System Development & Procurement

Step 5: CWZ System Testing

Preliminary Guidance Steps: Ongoing Operations

Cyclical, ongoing process

- Currently Defined as Five Steps

Step 6: Business Process for CWZ Inputs

Step 7: Initiate Work Zone TIM Generation

Step 8: Data Management

Step 9: Remove Work Zone TIM

Step 10: Data Analysis and Evaluation

Preliminary Guidance Steps: Ongoing Operations

Cyclical, ongoing process

6. Create, refine, and execute business processes for work zone inclusion in CWZ system
   - Use input from prior steps: identified data sources and CWZ selection
   - Confirm automated process vs. manual inputs or verification
   - Refine process over time, as necessary, based on evaluation and analysis, lessons learned, and as more quality data becomes available
7. Initiate a CWZ for TIM generation and sharing
   - Use input from prior steps to determine information to provide in TIMs for a given work zone
     - e.g., general “work zone ahead” vs. more specific information about a reduced speed limit and/or lane closures

Step 6: Business Process for CWZ Inputs

Step 7: Initiate Work Zone TIM Generation

Step 8: Data Management

Step 9: Remove Work Zone TIM

Step 10: Data Analysis and Evaluation

Preliminary Guidance Steps: Ongoing Operations

Cyclical, ongoing process

8. Data management

- Establish and execute processes to monitor data accuracy
- Establish and execute processes for updating information based on changing work zone conditions
- Establish and execute processes for disseminating TIMs via various mechanisms

9. Wrap-up / removal of the CWZ

- Establish and execute processes to remove TIMs from dissemination platforms in a timely manner
- Establish and execute processes to archive TIM and work zone data

Step 6: Business Process for CWZ Inputs

Step 7: Initiate Work Zone TIM Generation

Step 8: Data Management

Step 9: Remove Work Zone TIM

Step 10: Data Analysis and Evaluation

Preliminary Guidance Steps: Ongoing Operations

Cyclical, ongoing process

10. Data analysis and evaluation

- Establish and execute processes to periodically analyze data on an ongoing basis
- Establish and execute processes to evaluate impacts of CWZ program via different dissemination mechanisms

Step 6: Business Process for CWZ Inputs

Step 7: Initiate Work Zone TIM Generation

Step 8: Data Management

Step 9: Remove Work Zone TIM

Step 10: Data Analysis and Evaluation

Guidance Next Steps

- Begin drafting content for Guidance Steps
- Conduct walkthroughs of developed Guidance on monthly panel calls
- Opportunity to share with the overall CV PFS group

Deployer Updates

- **Maricopa County DOT**
- **Caltrans**

Common TIM Development Update

- **Rick Smith, TriHydro**

road-construction

TIM Prompt Conditions

- Work zones where construction activity may impede or restrict traffic flow
- Where a work zone includes safety barriers on or adjacent to roadway to isolate workers from traffic.
- When construction workers or equipment located on or adjacent to roadway

Extent of TIM Path:

- Start at beginning of defined work zone
- End at end of defined work zone

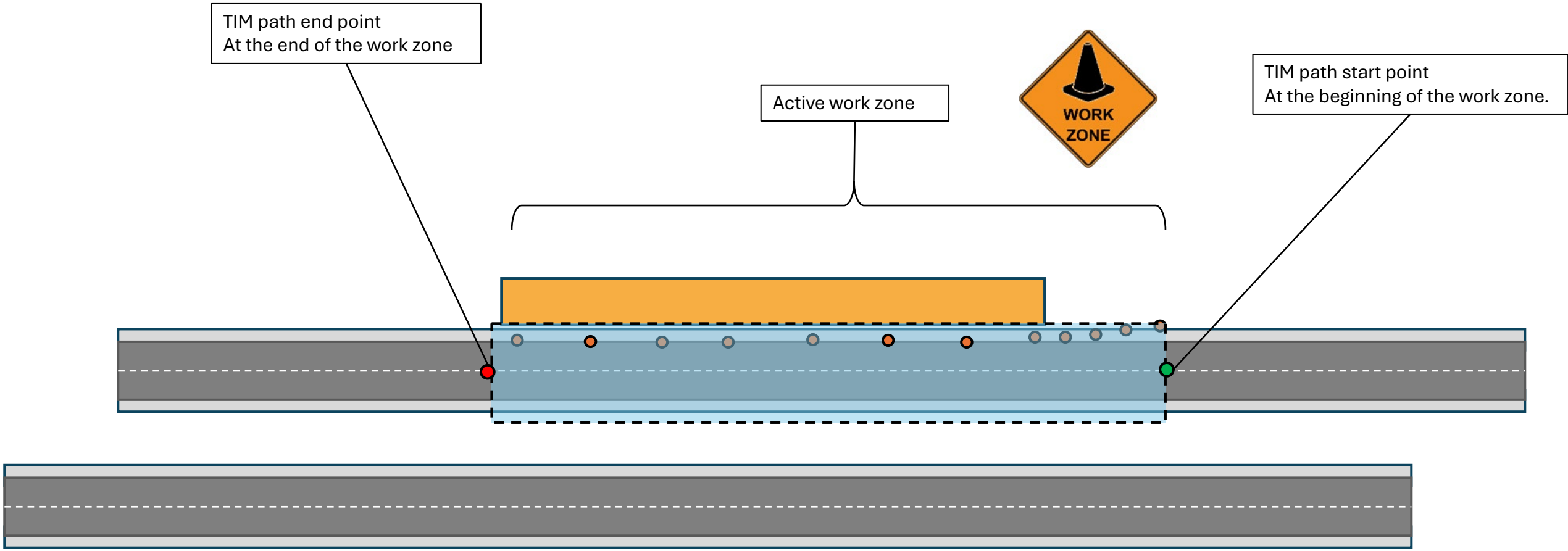
Messaging

Intent	Alert drivers that they are in a work zone and to be vigilant for construction activity.
ITIS Phrases	road-construction
ITIS Codes	1025
Suggested Display Icon	

TIM Timing:

- Start as soon as the work zone is emplaced.
- End when all construction activity has been cleared and work zone is removed

road-construction



look-out-for-workers

TIM Prompt Conditions

- Work zones where workers are present
- Workers may be in the open or operating equipment
- When construction workers and/or equipment working on or adjacent to roadway

Extent of TIM Path:

- Start at beginning of the defined work zone
- End at end of the defined work zone

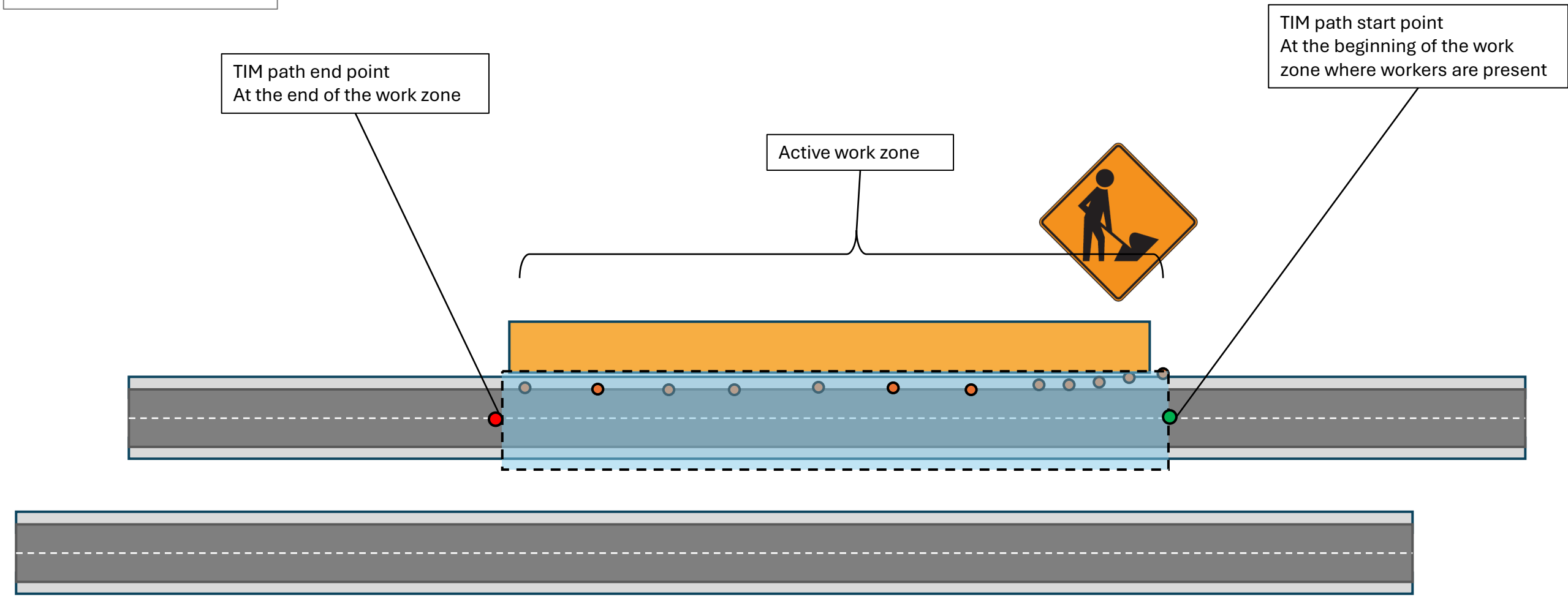
Messaging

Intent	Warn drivers/vehicle that workers **are** present near roadside.
ITIS Phrases	look-out-for-workers
ITIS Codes	6952
Suggested Display Icon	

TIM Timing

- Start when workers are present at work site
- End when workers no longer present at site (e.g. overnight)

look-out-for-workers

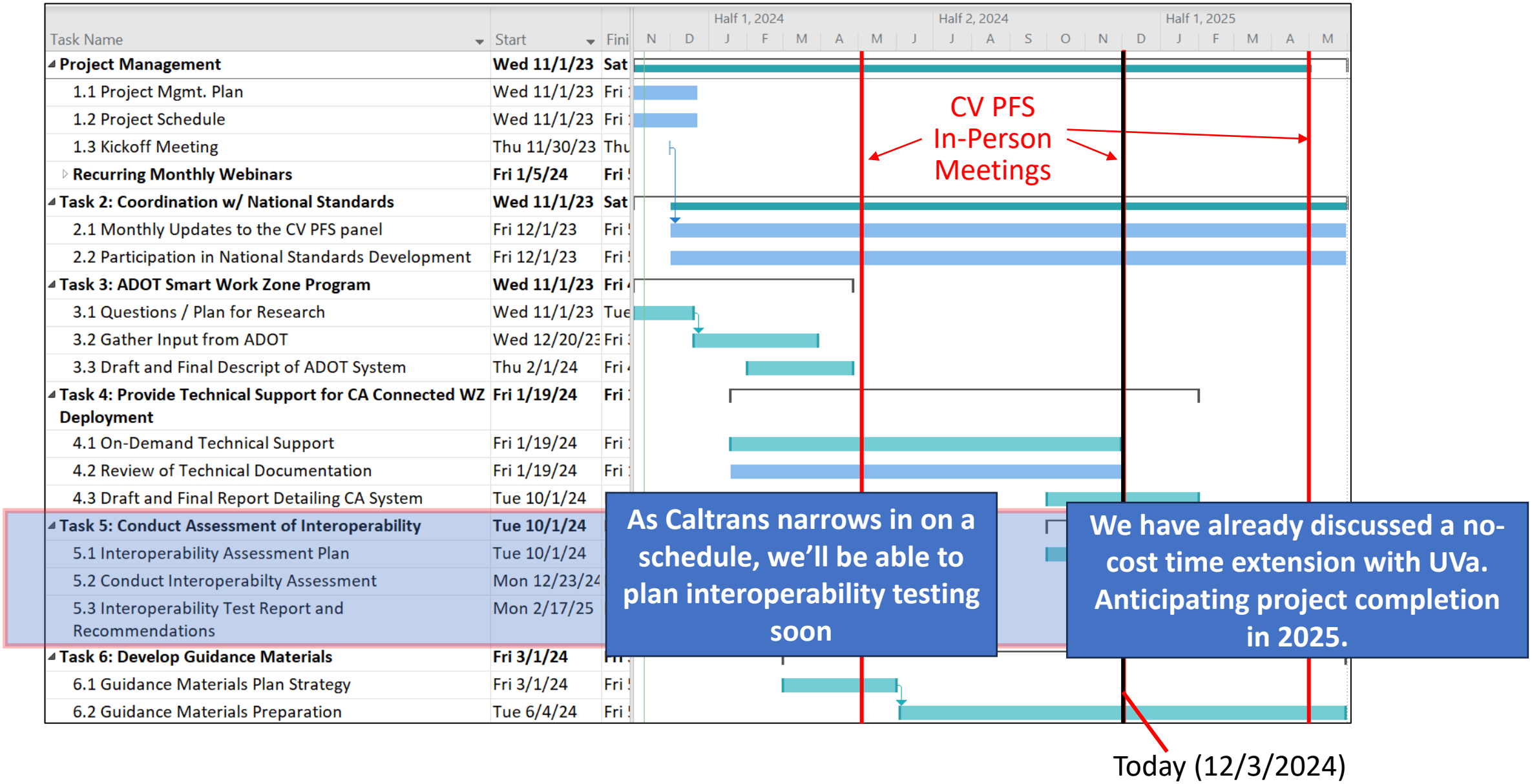


Project Management

Project Management

- Schedule
  - Impacted by Caltrans later start on software than planned
  - Anticipate beginning systems integration soon
  - interoperability testing will follow once system is active
  - Will coordinate and confirm dates with UVA to complete project before their CV PFS support contract ends, and as soon as practical within 2025

- Project champion
  - David Lucas no longer at MCDOT
  - Is there interest from MCDOT or others to take over?


Task Name
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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
Task 5: Conduct Assessment of Interoperability Tue 10/1/24
5.1 Interoperability Assessment Plan Tue 10/1/24
5.2 Conduct Interoperabilty Assessment Mon 12/23/24
5.3 Interoperability Test Report and Recommendations Mon 2/17/25
Task 6: Develop Guidance Materials Fri 3/1/24
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
As Caltrans narrows in on a schedule, we'll be able to plan interoperability testing soon
We have already discussed a no-cost time extension with UVa. Anticipating project completion in 2025.
Today (12/3/2024)

Next Meeting

- Friday January 10th 1:00 ET