Network V2X Evaluation and Scalability

Delaware Department of Transportation

RK&K

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Network V2X Evaluation and Scalability

- Need for V2X
- What is network V2X?
- DelDOT SMART grant
  - V2X architectures
  - Latency findings [preliminary]
  - Scalability
  - Challenges and lessons learned
- V2X deployment status

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Safe Systems Approach

Delaware Traffic Fatalities

2025 Delaware Total Fatalities as of 04/22/25									
	2025	2024				2023			
	Year-to-date	Year-to-Date			Total	Year-to-Date			Total
Fatalities	22	35	↓	-37%	130	50	↓	-56%	137
Delaware Residents	16	31	↓	-48%	110	39	↓	-59%	110
Person Types									
Vehicle Occupant	12	21	↓	-43%	65	35	↓	-66%	89
Pedestrian	8	9	↓	-11%	34	9	↓	-11%	28
Bicyclist	1	2	↓	-50%	5	2	↓	-50%	5
Motorcyclist	0	2	↓	-100%	21	4	↓	-100%	14
Other Person Type	1	1		0%	5	0	↑	+100%	1
Crash Types									
Curve Related	2	4	↓	-50%	23	10	↓	-80%	28
Roadway Departure	9	12	↓	-25%	42	25	↓	-64%	69
Intersection Related	4	11	↓	-64%	48	14	↓	-71%	37
Median Crossover	0	0		N/A	0	3	↓	-100%	8
Wrong Way	2	1	↑	+100%	4	0	↑	+100%	1
Work Zone	1	2	↓	-50%	5	3	↓	-67%	9

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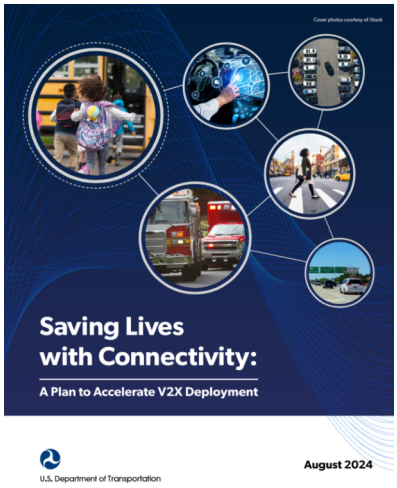
Need for V2X: Saving Lives with Connectivity

Vehicle-to-Everything (V2X)

V2X has the potential to improve safety and accessibility of all road users, including vulnerable users and those with disabilities, by enabling wireless communications among vehicles, roadside infrastructure, and mobile devices.



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Direct vs Network V2X

- Direct V2X
  - Point-to-point field communication
    - Field (RSU) ←→ Client (OBU)
  - Roadside units at intersections (RSUs)
  - On-board units in vehicles (OBUs)
  - Industry move from DSRC to C-V2X
- Network V2X
  - Network-based communication
    - Field/edge → Central/Cloud ←→ Client
  - RSUs – none
  - OBUs – mobile device

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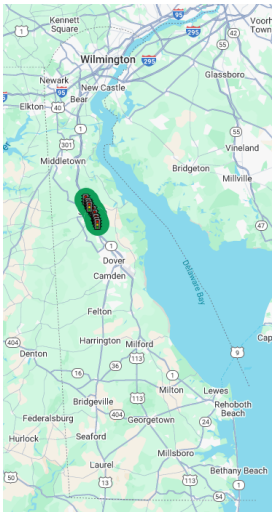
DelDOT SMART Grant

Develop, demonstrate, and evaluate network vehicle-to-everything (V2X) architectures

- Period of Performance: September 2023 – September 2025
- Demonstration use case: Dilemma zone / red light warning
- Location: US 13 in Smyrna (near DelDOT TMC)
- # of Signals: 11
- Evaluation Criteria:
  - Latency — Is network V2X viable for safety critical applications?
  - Scalability — How scalable is network V2X?
  - Lessons learned — Lessons for other deployers.



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Project Team

Team Member	Role
DelDOT Operations	Owner / Operator
BlueHalo	Technology Developer (V2X system and android mobile app)
RK&K	Project Management / Engineering Consultant
Drive Engineering	Testing Administration
University of Delaware	Technology Developer (iOS mobile app)
Verizon	Network V2X Service Provider (Edge Transportation Exchange)
Cisco	Network V2X Vendor (edge device)

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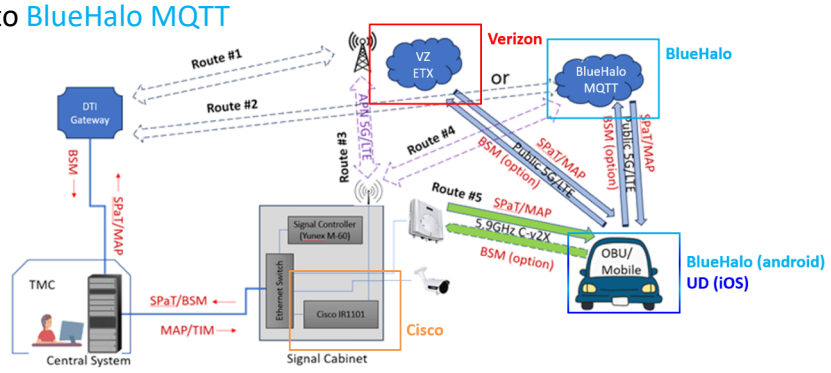
Vehicle-to-Everything (V2X) Architectures

- Route #1 – DelDOT uplink to Verizon ETX
- Route #2 – DelDOT uplink to BlueHalo MQTT
- Route #3 – 5G uplink to Verizon ETX
- Route #4 – 5G uplink to BlueHalo MQTT
- Route #5 – Direct V2X (not evaluated)



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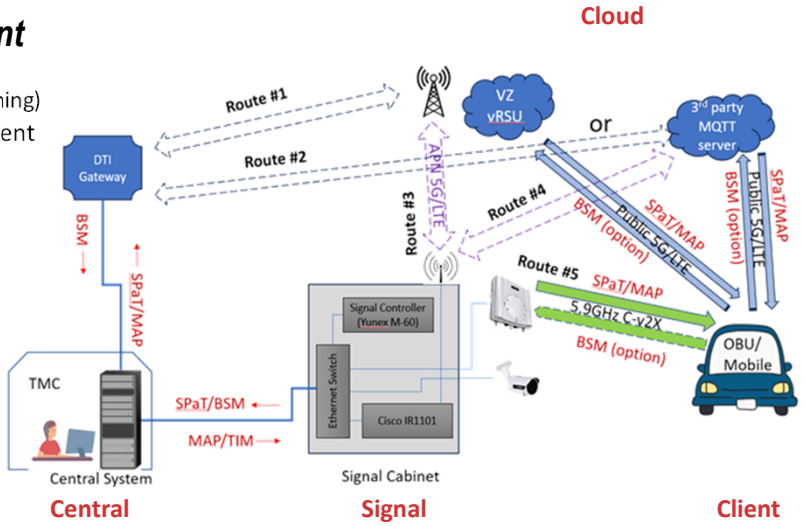
Vehicle-to-Everything (V2X) Messages

DelDOT SMART Grant

- SPaT (Signal Phase and Timing)
  - Signal controller to client
- MAP (geo-based data)
  - Central to cloud
  - Central to client
- BSM (client location)
  - Client to cloud



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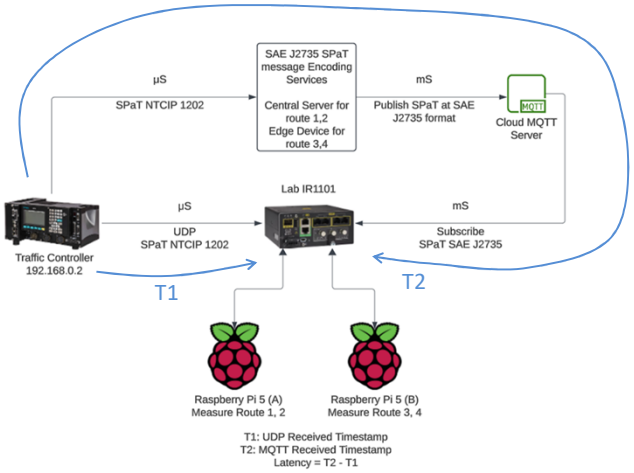
Evaluation - Latency testing methodology

- Challenge: clock synchronization
- BlueHalo test design with Cisco input



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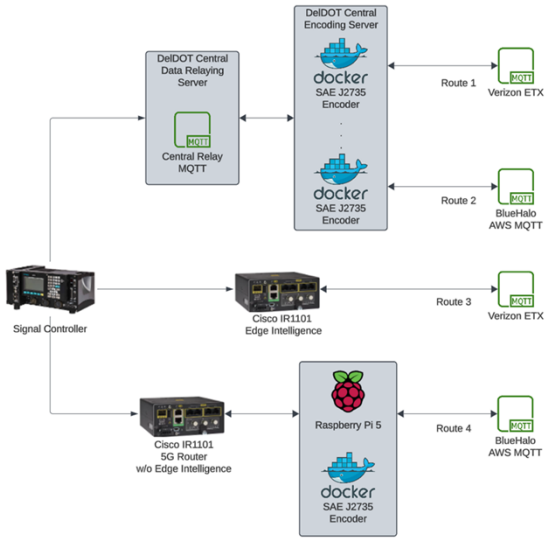
Evaluation - Latency testing methodology

- Test all four network V2X routes at once
- Broadcasting SPaT data for 139 intersections



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Evaluation Criteria - Latency

Is network V2X viable for safety critical applications?

- Required average latency: 100 milliseconds (ms)
- Target average latency: 50 ms

Evaluation Results (preliminary)

Result	Route #1 Fiber/4G	Route #2 Fiber/4G	Route #3 5G	Route #4 5G
Avg latency (ms)	~35/80	~25/65	~60	~45
< Required latency	Yes	Yes	Yes	Yes
< Target latency	Yes/No*	Yes/No*	No*	Yes*

*Performance of cellular network is critical

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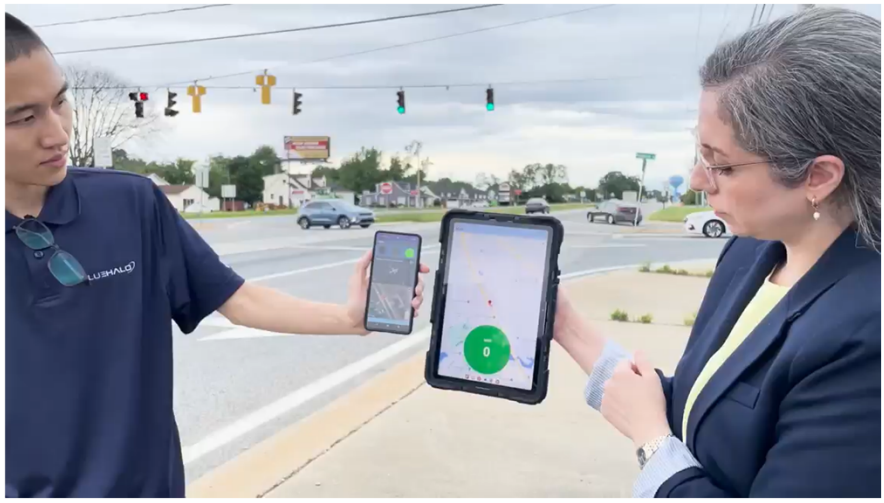
V2X in Action



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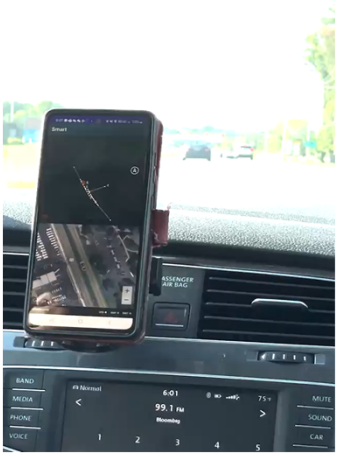
V2X in Action

Approaching red light

1. “Be Prepared to Stop”
2. “Stop”
3. Increasing frequency and volume of audible alert
4. Red countdown (7s Y+R)
5. Green light



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Evaluation Criteria - Scalability

How scalable is network V2X? Factors include:

- V2X Application
  - Traveler information messages (TIM)
  - Safety applications requiring ultra-low latency (RLR, VRU warnings)
- Costs
  - Capital costs
  - O&M costs
  - Cost structure
- Infrastructure
  - Signal controller
  - Communications
  - Edge devices
  - Message exchange servers / subscription
- System performance
  - Cellular network performance
  - Data processing and message exchange
  - Security
- Standards
  - Message format (e.g. SAEJ2735)
  - Message delivery
  - Security
- Automaker engagement
  - Message delivery
  - Automated response
- User acceptance
  - Establish expectations
  - Message understanding
  - User response / compliance

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Evaluation Criteria - Scalability

Evaluation Stage

- V2X Application
  - Traveler information messages (TIM)
  - Safety applications (GLOSA, RLR, VRU warnings) requiring ultra-low latency
- Costs — Expect significant reduction with network V2X
  - Capital costs
  - O&M costs
  - Cost structure

Evaluation Stage

- Infrastructure
  - Signal controller — DelDOT has ~450 M60s
  - Communications — DelDOT has extensive fiber infrastructure
  - Edge devices
  - Message exchange servers
- System performance
  - Cellular network performance
  - Data processing and message exchange
  - Security

Development Stage

- Standards
  - Message format (e.g. SAEJ2735)
  - Message delivery
  - Security
- Automaker engagement
  - Message delivery
  - Automated response
- User acceptance
  - Establish expectations
  - Message understanding
  - User response / compliance

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Evaluation Criteria – Lessons Learned

Some lessons for other deployers

- Dilemma zone warning at actuated signals
  - SPaT time-to-change (TTC) parameter does not account for rest in green. It counts down with min green and passage timers.
  - Used pedestrian clearance interval with rest in walk enabled.
- Latency testing methodology
  - Cannot synchronize clocks in controller and measuring device.
  - Directly connected measuring device to the controller cabinet and measured latency using the measuring device clock.
- V2X deployment status
  - Development stage → Evaluation Stage → Wide-scale deployment
    Current Future

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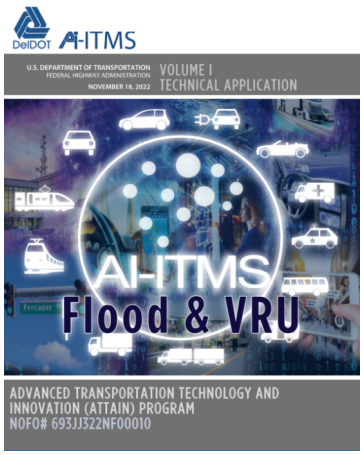
DelDOT V2X Deployment Plan



- SMART Grant – Stage 1 (2025)
  - Red light warning (SPaT, MAP, BSM)
- ATTAIN Grant (2026)
  - Water-on-road warning (TIM, BSM)
  - Vulnerable road user warning (PSM)
  - Red light warning (SPaT, MAP, BSM)
  - Red-light-running (SPaT, MAP, BSM)
- Future
  - Assessing viable projects to meet short-term needs as well as a long-term vision

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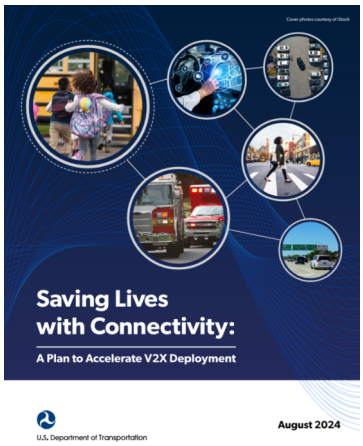
USDOT V2X Deployment Plan



USDOT has defined three timeframes:

- Short-term (2024 – 2028):
  Leading Deployers in Operation
  Development / Evaluation
- Medium-term (2029 – 2031):
  V2X Deployer Community Growth
- Long-term (2032 – 2036):
  Nationwide Secure, Interoperable V2X Deployed and Operational

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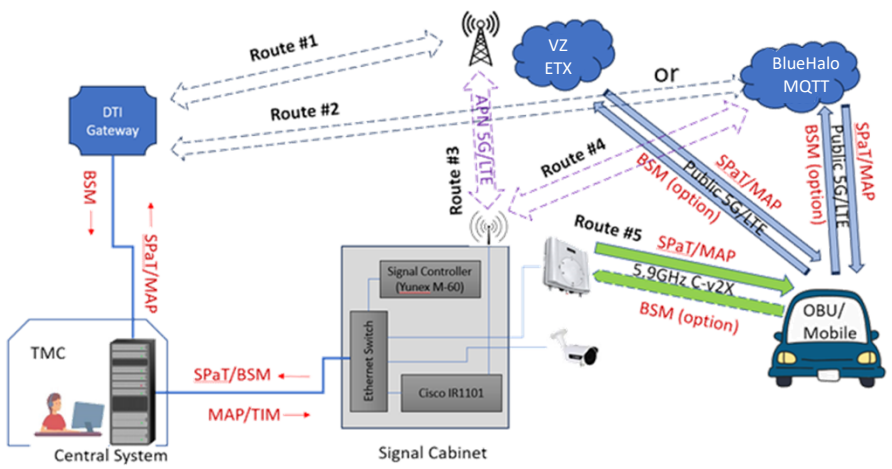
Vehicle-to-Everything (V2X) Architectures



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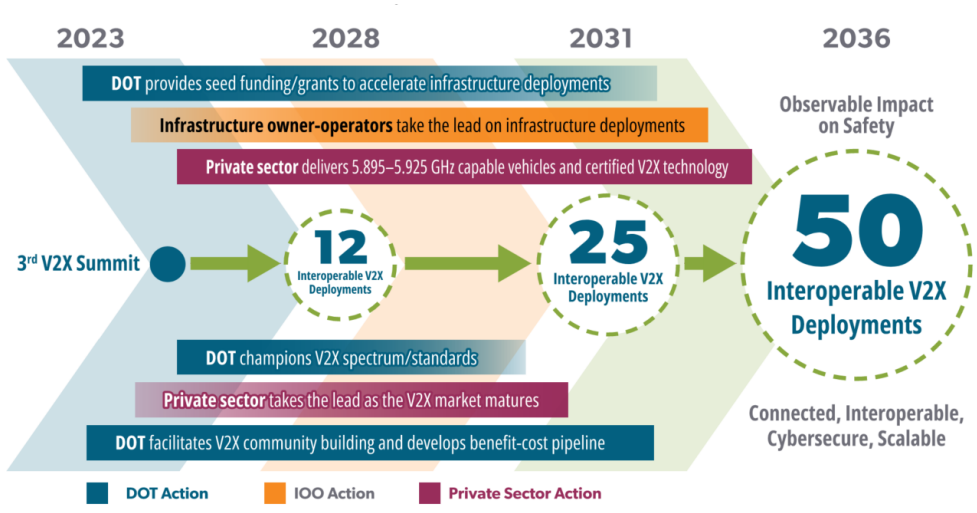
USDOT V2X Deployment Plan



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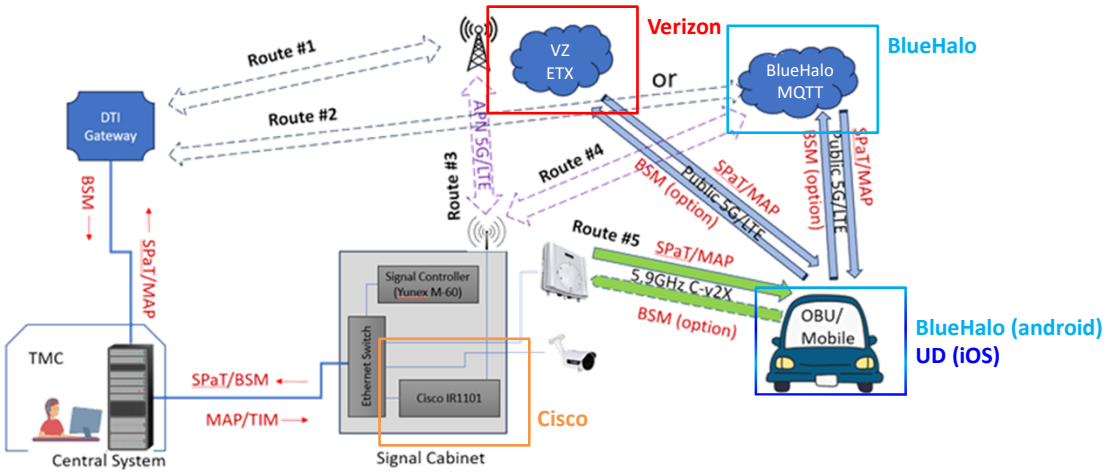
Vehicle-to-Everything (V2X) Architectures



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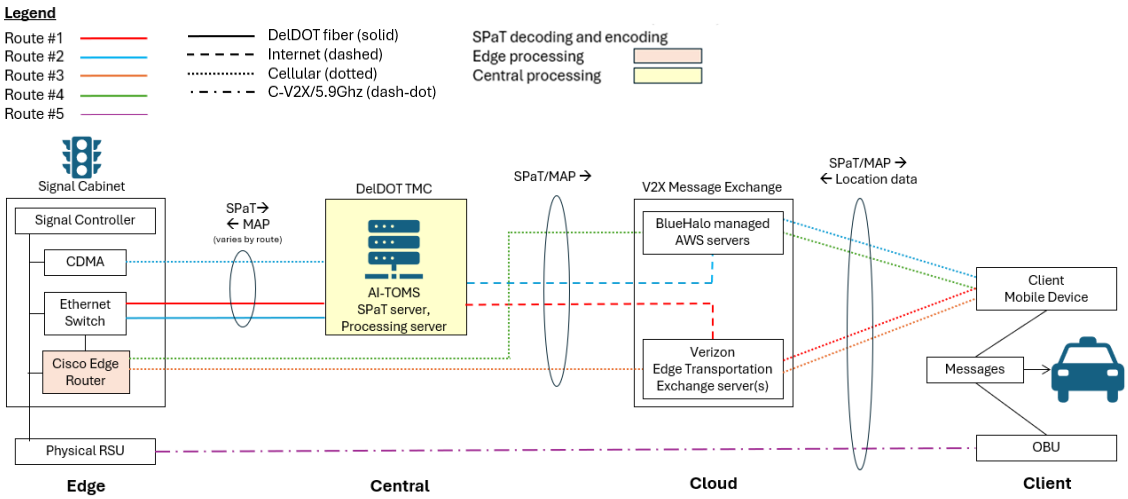
Vehicle-to-Everything (V2X) - Route #1



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Vehicle-to-Everything (V2X)

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