ITS Michigan
Lunch & Learn
C-V2X
V2X CONCEPTS

Image Source: USDOT
V2X CONCEPTS

V2X CONCEPTS

- V2V: Vehicle to Vehicle
- V2I: Vehicle to Infrastructure
- V2P: Vehicle to Pedestrian
- V2N: Vehicle to Network (Cloud)

Image Source: P3 North America
DSRC vs C-V2X
Networking 101

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**Host Layers**
- **Data**
- **Presentation**
  - Network Process to Application
  - Data Representation and Encryption
- **Session**
  - Interhost Communication
- **Transport**
  - End-to-End Connections and Reliability

**Media Layers**
- **Segments**
- **Network**
  - Path Determination and Logical Addressing (IP)
- **Packets**
  - Data Link
    - Physical Addressing (MAC and LLC)
- **Frames**
- **Physical**
  - Media, Signal and Binary Transmission

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DSRC Networking Stack

IEEE 1609.2
WAVE Security

IEEE 802.11p
based

IEEE 1609.4
WAVE MAC
(Including channel coordination)

802.11p
Lower MAC + PHY

LLC

WPDSM

SAE J2735
SAE J2945
Message
Sub-layer

HTTP/FTP

UDP / TCP

IP

Non-safety application

Safety app. sublayer

Application Layer

Networking Layer

Data Link Layer

Physical Layer

DSRC / WAVE

Image Source: https://doi.org/10.3390/s23031421
C-V2X Overview

**PC5 Sidelink**
- Message-focused
- Low-latency, short-range, high speed
- No tower communications
- No SIM card / subscription

**Uu Network Link**
- Network-focused, aka “V2N”
- Typical cellular LTE/5G connectivity
- Higher latency, higher bandwidth apps
- Requires tower and subscription

*Image Source: Qualcomm.com*
C-V2X Networking Stack

- Application Layer
- Networking Layer
- Data Link Layer
- Physical Layer

Image Source: https://doi.org/10.3390/s23031421
## Differences Summary

<table>
<thead>
<tr>
<th>DSRC</th>
<th>C-V2X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range: 1000m (proven)</td>
<td>Range: Up to 1400m (purportedly)*</td>
</tr>
<tr>
<td>Limitations of Wi-Fi transceivers</td>
<td>Purportedly Higher Performance</td>
</tr>
<tr>
<td>Direct-only Mode</td>
<td>Direct and Network-Based Modes</td>
</tr>
<tr>
<td>Older, years of proven performance</td>
<td>Newer, has undergone less testing</td>
</tr>
<tr>
<td>“Dead-end” fork of Wi-Fi family</td>
<td>Ever-evolving cellular standards</td>
</tr>
<tr>
<td>Mature product (WSA example)</td>
<td>Still has components in development</td>
</tr>
<tr>
<td>Heavy adoption in Europe / Japan</td>
<td>Heavy adoption in China</td>
</tr>
</tbody>
</table>

*https://ieeexplore.ieee.org/document/9866543
SPECTRUM CHANGES
• **Need:** Dedicated spectrum, no interference
  • 75MHz reserved for “safety spectrum” (1999)
  • Rules specifically referenced “DSRC”

• **Problem:** OEMs never mandated to include it
  • FCC re-assessed the spectrum in 2019
  • Determined 75Mhz not adequately used

• **Result:** NPRM issued in December 2019 to shrink the spectrum and endorse C-V2X
  • Ignored comment from industry and IOOs
  • NPRM passed in 2020
  • No new official rules yet
Spectrum Rules

DSRC (Safety Spectrum)

CH 175 (20 MHz)

CH 172

5.850

5.860

5.870

5.880

5.890

5.900

5.910

5.920

CH 181 (20 MHz)

CH 180

CH 182

CH 184

Control Channel

Service Channels

Reserved

Safety Channel

Image Source: DOI:10.1088/1757-899X/477/1/012052, CC 3.0
45MHz opened for unlicensed Wi-Fi use

30Mhz remaining for V2X
SPECTRUM

Spectrum Timeline

- **FCC revokes 45MHz and endorses C-V2X over DSRC (Oct 2020)**
- **DSRC channel deadline (July 5, 2022)**
- **FCC issues first C-V2X joint waiver (April 2023)**

- **FCC issues NPRM regarding 5.9GHz (Dec 2019)**

All V2X deployments effectively halted
Spectrum Rules

45MHz opened for unlicensed Wi-Fi use

C-V2X to operate on single 20Mhz channel 183

10MHz channel 180 temporarily available for DSRC transition

Image Source: DOI:10.1088/1757-899X/477/1/012052, CC 3.0
READINESS FOR C-V2X DEPLOYMENT
C-V2X Readiness

<table>
<thead>
<tr>
<th>FCC Readiness</th>
<th>Application Readiness</th>
<th>Infrastructure Readiness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need waivers/experimental licenses for C-V2X</td>
<td>Identify applications that work best over direct V2X</td>
<td>Communication requirements</td>
</tr>
<tr>
<td>Need to register new RSUs</td>
<td>Identify applications that work best over network comms</td>
<td>Remote accessibility and maintainability</td>
</tr>
<tr>
<td>RSU FCC certification</td>
<td>Identify applications that could be deployed using both</td>
<td>Edge processing</td>
</tr>
<tr>
<td>Tip: joint waivers; temporary</td>
<td>Tip: “surrogate” V2V apps</td>
<td>Tip: CTI 4001, CTI 4501</td>
</tr>
</tbody>
</table>
Funding Sources

DOT Discretionary Grants Dashboard

The DOT Discretionary Grants Dashboard provides communities with an overview of discretionary grant opportunities that can help meet their transportation infrastructure needs. Designed with all communities in mind, the Dashboard identifies grant programs with rural and Tribal set-asides or match waivers available. The Dashboard also includes Federal grant programs outside of DOT that may be of particular interest to rural communities. The Dashboard is updated weekly.

Additional Resource: The DOT Navigator is a resource to help communities understand the best ways to apply for grants, and to plan for and deliver transformative infrastructure projects and services.

Source: https://www.transportation.gov/grants/dashboard
Funding Sources

Bipartisan Infrastructure Law Grant Programs

The following list is five-year totals for all grant programs authorized under the Bipartisan Infrastructure Law for the Department of Transportation. This does not include programs that were authorized but are subject to appropriation.

The [BILL Launchpad](https://www.transportation.gov/bipartisan-infrastructure-law/bipartisan-infrastructure-law-grant-programs) provides customized information on available funding, interactive technical support, data on successful awards, and essential resources. With this platform, localities can accelerate their grant application process and access the necessary tools to enhance their transportation infrastructure.

To view additional information and quickly sort programs funded under the law by fields like amount, eligible recipient, or program name, visit [Build.gov](https://www.build.gov).

Applicants for funding should consult program-specific guidance. For additional information and to apply, visit [Grants.gov](https://www.grants.gov).

<table>
<thead>
<tr>
<th>Program Name</th>
<th>Category</th>
<th>Five-year Funding Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accelerated Implementation and Deployment of Advanced Digital Construction</td>
<td>Roads, Bridges and Major Projects</td>
<td>$100,000,000</td>
</tr>
<tr>
<td>Management Systems (Set-aside)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accelerated Implementation and Deployment of Pavement Technologies (Set-</td>
<td>Roads, Bridges and Major Projects</td>
<td>$60,000,000</td>
</tr>
<tr>
<td>aside)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advanced Transportation Technologies &amp; Innovative Mobility</td>
<td>Roads, Bridges and Major Projects</td>
<td>$300,000,000</td>
</tr>
</tbody>
</table>
# Funding Sources

## Key Notices of Funding Opportunity

In order to provide stakeholders with more visibility into upcoming funding opportunities, DOT is publishing a list of anticipated dates for upcoming Notices of Funding Opportunity (NOFOs) for key programs within the Bipartisan Infrastructure Law (BIL) and the Inflation Reduction Act (IRA), as well as adjacent programs that support BIL and IRA objectives. This list is not comprehensive and will be updated periodically with additional programs and revised dates as appropriate.

The [USDOT Discretionary Grants Dashboard](https://www.transportation.gov/bipartisan-infrastructure-law/key-notices-funding-opportunity) provides communities with an overview of discretionary grant opportunities that can help meet their transportation infrastructure needs.

<table>
<thead>
<tr>
<th>Opening Date</th>
<th>NOFO</th>
<th>Operating Administration/Office</th>
<th>Closing Date (to be added for each program after the NOFO is issued)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Bridge NOFO: September 27, 2023</td>
<td><a href="https://www.transportation.gov/bipartisan-infrastructure-law/key-notices-funding-opportunity">Bridge Investment Program</a></td>
<td>Federal Highway Administration</td>
<td>Large Bridge: August 1, 2024</td>
</tr>
<tr>
<td>Bridge Projects: December 20, 2023</td>
<td><a href="https://www.transportation.gov/bipartisan-infrastructure-law/key-notices-funding-opportunity">Bridge Projects</a></td>
<td>Federal Highway Administration</td>
<td>Bridge Project Grants: 3/19/2024</td>
</tr>
<tr>
<td>Bridge Planning Grants: December 20, 2023</td>
<td><a href="https://www.transportation.gov/bipartisan-infrastructure-law/key-notices-funding-opportunity">Planning and other Bridge Projects</a></td>
<td></td>
<td>Planning Project Grants: 10/1/2024</td>
</tr>
</tbody>
</table>
## Funding Sources

<table>
<thead>
<tr>
<th>Program</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMCSA HP-ITD*</td>
<td>Technology deployment program specifically for CMVs</td>
</tr>
<tr>
<td>SSFA: “Safe Streets 4 All”**</td>
<td>Focused on multimodal roads and street applications</td>
</tr>
<tr>
<td>ATTAIN**</td>
<td>Focused on advanced technologies for safety, mobility, efficiency, system performance, intermodal connectivity, and infrastructure ROI</td>
</tr>
<tr>
<td>SMART</td>
<td>Grants for conducting demonstration projects on smart community technologies with a second phase for scaled deployment</td>
</tr>
<tr>
<td>CMAQ Funding</td>
<td>Any solutions that improve congestion mitigation, including V2X</td>
</tr>
</tbody>
</table>

* Must align with the State’s Program Plan/Top Level Design (PP/TLD)

** Requires a 20% total project cost match
WHERE DO I START?
Helpful Documents

**CTI 4001 v01.01 – Amendment 1**
Connected Transportation Interoperability (CTI)

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**Roadside Unit (RSU) Standard**

A connected intersection-ready Standard of AASHTO, ITE, NEMA and SAE International

September 2022

This document is produced by the RSU Standardization Working Group.

Published by the following organizations:

![AASHTO Logo](https://www.aashto.org/)

![ITE Logo](https://www.ite.org/)

![NEMA Logo](https://www.nema.org/)

![SAE International Logo](https://www.sae.org/)

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

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Source: https://www.ite.org/technical-resources/standards/rsu-standardization/
Helpful Documents

**CTI 4501 v01.01**
Connected Transportation Interoperability (CTI)

**Connected Intersections Implementation Guide**

Guidance to Setting Up and Operating a Connected Intersection (CI)

June 2022

This document is produced by the Connected Intersections (CI) Committee.

Published by the following organizations:

- American Association of State Highway and Transportation Officials (AASHTO)
- ITE (Institute of Transportation Engineers)
- NEMA (National Electrical Manufacturers Association)
- SAE International

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

Source: https://www.ite.org/technical-resources/standards/connected-intersections/
ITS America National V2X Deployment Plan
An Infrastructure & Automaker Collaboration
April 2023

Helpful Documents