Introduction to Vehicle-to-Vehicle (V2V) Communication

Overview

Vehicle-to-Vehicle (V2V)

- ❑Vehicles "talk" to each other
  - ❑Directly exchange wireless messages
- ❑Coordinate with nearby vehicles
  - ❑Movement, speed, intersections, …

https://bit.ly/3y4DJFn

https://bit.ly/3836O9q

- ❑Support non-line-of-sight (NLOS)
- ❑Allow 360^0 coordination

V2V Applications for Safety

- ❑Provide 360° awareness of nearby vehicles
  - ❑Wirelessly exchange safety messages
  - ❑Key step towards fully autonomous vehicles
  - ❑Sensors work in LOS scenarios:


Camera


Radar

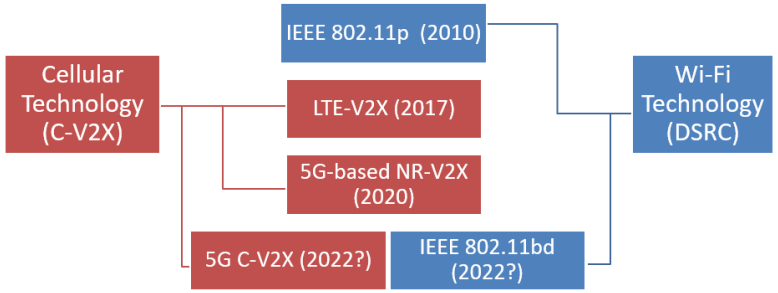

LiDAR

- ❑V2V complement sensors to "see" (in NLOS) what sensors cannot


Cameras can only detect what they can see (LOS)


V2V can often penetrate obstructions (NLOS)

V2V Technology Evolution



V2V in the United States

- ❑Adoption and deployment lags both E.U. and China
- ❑Many connected vehicles pilot sites across U.S.

https://www.transportation.gov/research-and-technology/interactive-connected-vehicle-deployment-map

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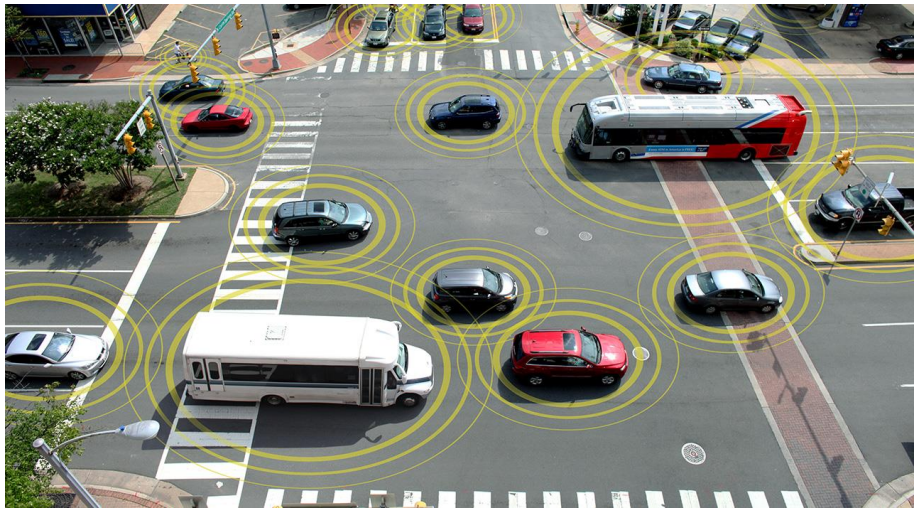

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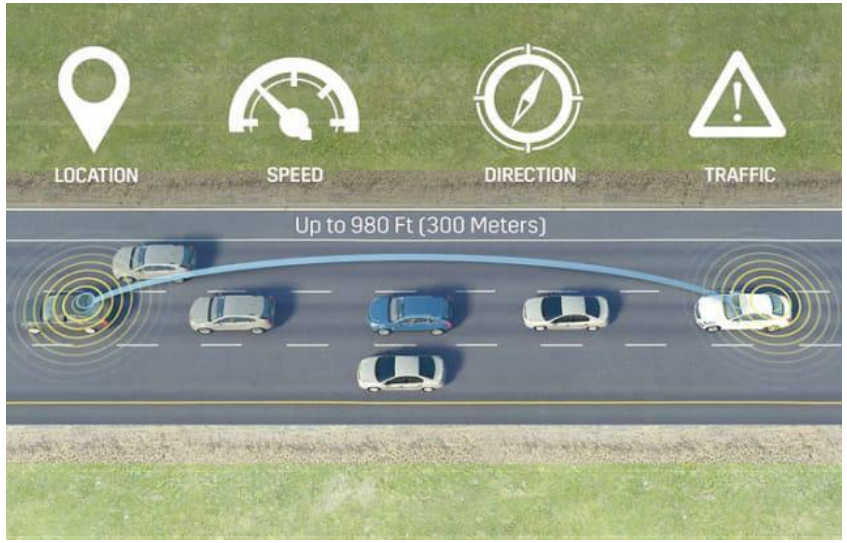

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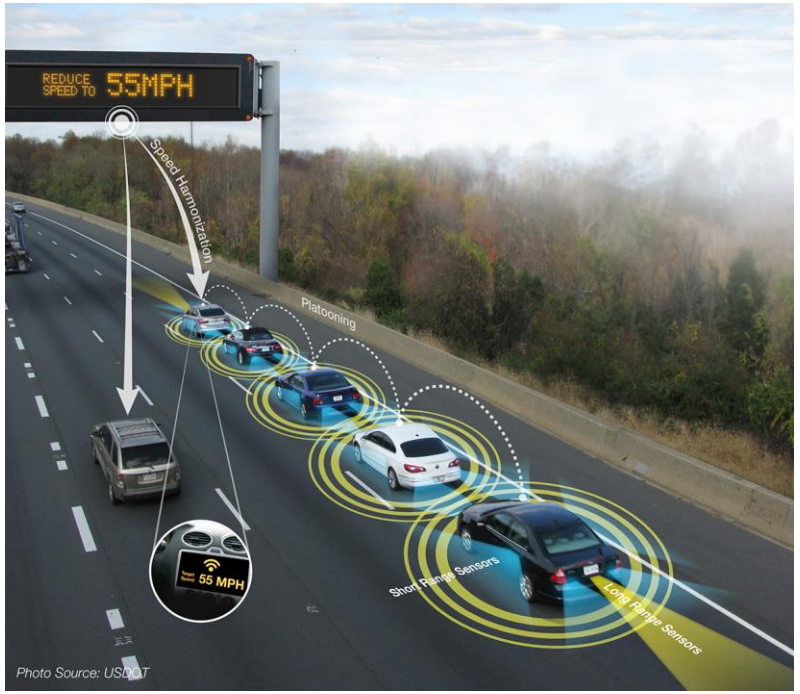
(Some of) the Applications of V2V

- Primary application is to improve safety
  - Awareness of nearby vehicles → collision avoidance
- Vehicle platooning
  - Increase travel speed and efficiency
  - Reduce carbon emissions
- Real-time navigation assistance
  - Up-to-the-ms obstacle/closure alerts
- And much more!



https://en.wikipedia.org/wiki/Platoon_(automobile)

Technical Challenges in V2V

- High-mobility, noisy environment
  - Doppler shifts, frequency offsets, high likelihood of packet errors
- Vehicle density may cause problems
  - Must receive, process, securely verify, and act on thousands of messages per second
- V2V requires latency to be minimal
  - Consider a collision warning – need time to receive, process, etc. and still have time to stop the vehicle!
  - Latency $< 1\ ms$ generally considered necessary

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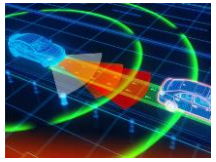
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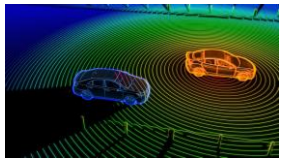
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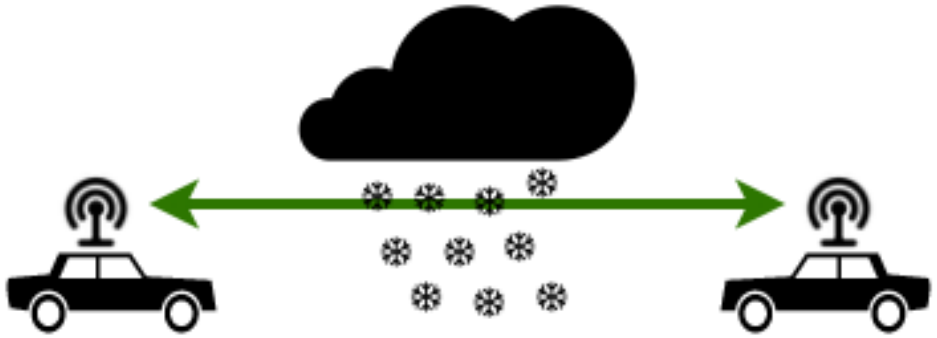
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Basic Safety Messages (BSMs)

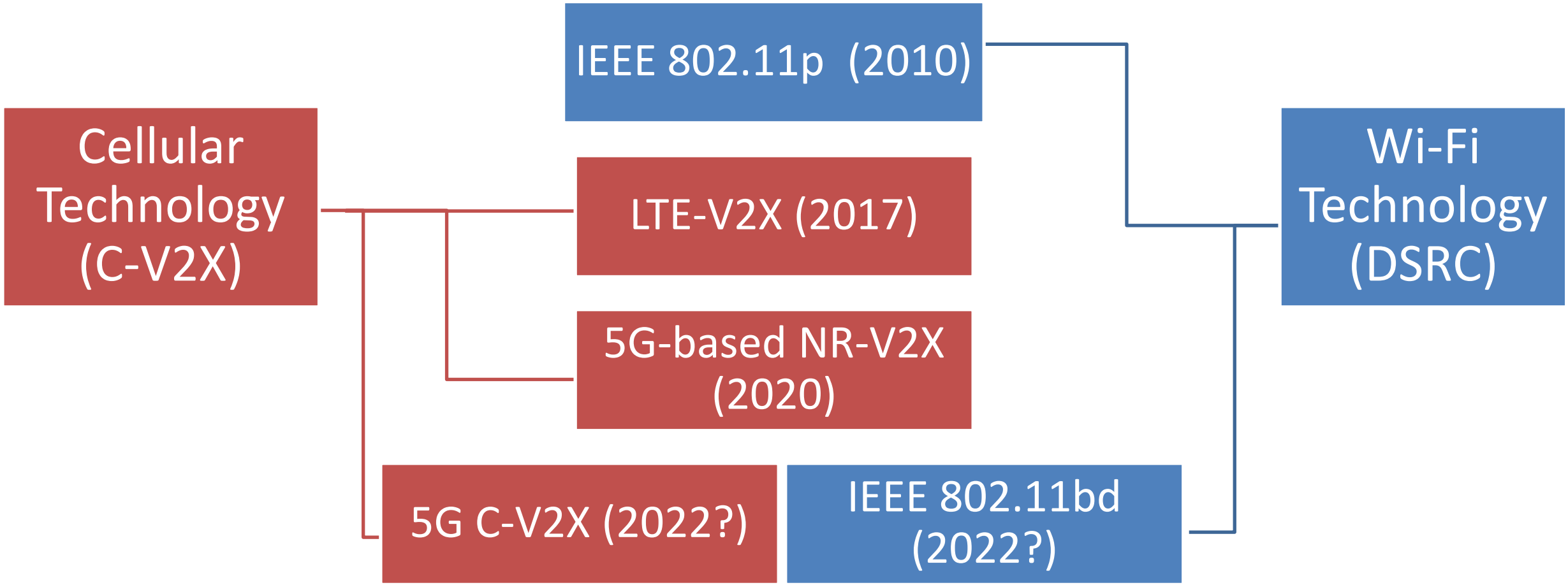
- Broadcasted periodically every $20 - 100ms$
  - Every $100\ ms$ is (by far) the most common interval
- Type 1 BSM: Core Data
  - Position, speed, heading, vehicle size, brake status, ...
  - Data that is critical for avoiding collisions
- Type 2 BSM: Event-based
  - Collision warning, brake failure, etc.
  - Attached to Type 1 BSMs as necessary

Examples of Type 2 BSMs

Scenario and Warning Type		Scenario Example
Rear-End Collision Scenarios	**Forward Collision Warning** Approaching a Vehicle That Is Decelerating or Stopped	
	Emergency Electronic Brake Light Warning Approaching a Vehicle Stopped in Roadway but Not Visible Due to Obstructions	
Lane-Change Scenarios	**Blind Stop Warning** Beginning Lane Departure That Could Encroach on the Travel Lane of Another Vehicle Traveling in the Same Direction; Can Detect Vehicles Not Yet in Blind Spot	
	Do Not Pass Warning Encroaching Onto the Travel Lane of Another Vehicle Traveling in Opposite Direction; Can Detect Moving Vehicles Not Yet in Blind Spot	
Intersection Scenario	**Blind Intersection Warning** Encroaching Onto the Travel Lane of Another Vehicle With Whom Driver Is Crossing Paths at a Blind Intersection or an Intersection Without a Traffic Signal	

S. Stone, "Connected, Autonomous Cars: Passive Pothole Patrollers," in *IEEE Potentials*, vol. 39, no. 1, pp. 52-58, Jan.-Feb. 2020.

V2V Technology Evolution



Security Challenges in V2V

- V2V creates new attack surfaces!
  - Eavesdropping and tracking (identity, velocity, trace, etc.)
  - Spoofing, including replaying (manipulated) messages
  - Jamming
- BSM-specific attacks
  - Spoofing, message modification, replay, etc.
  - Can be life threatening, specially for autonomous vehicles
  - Should we be concerned about confidentiality of BSMs?

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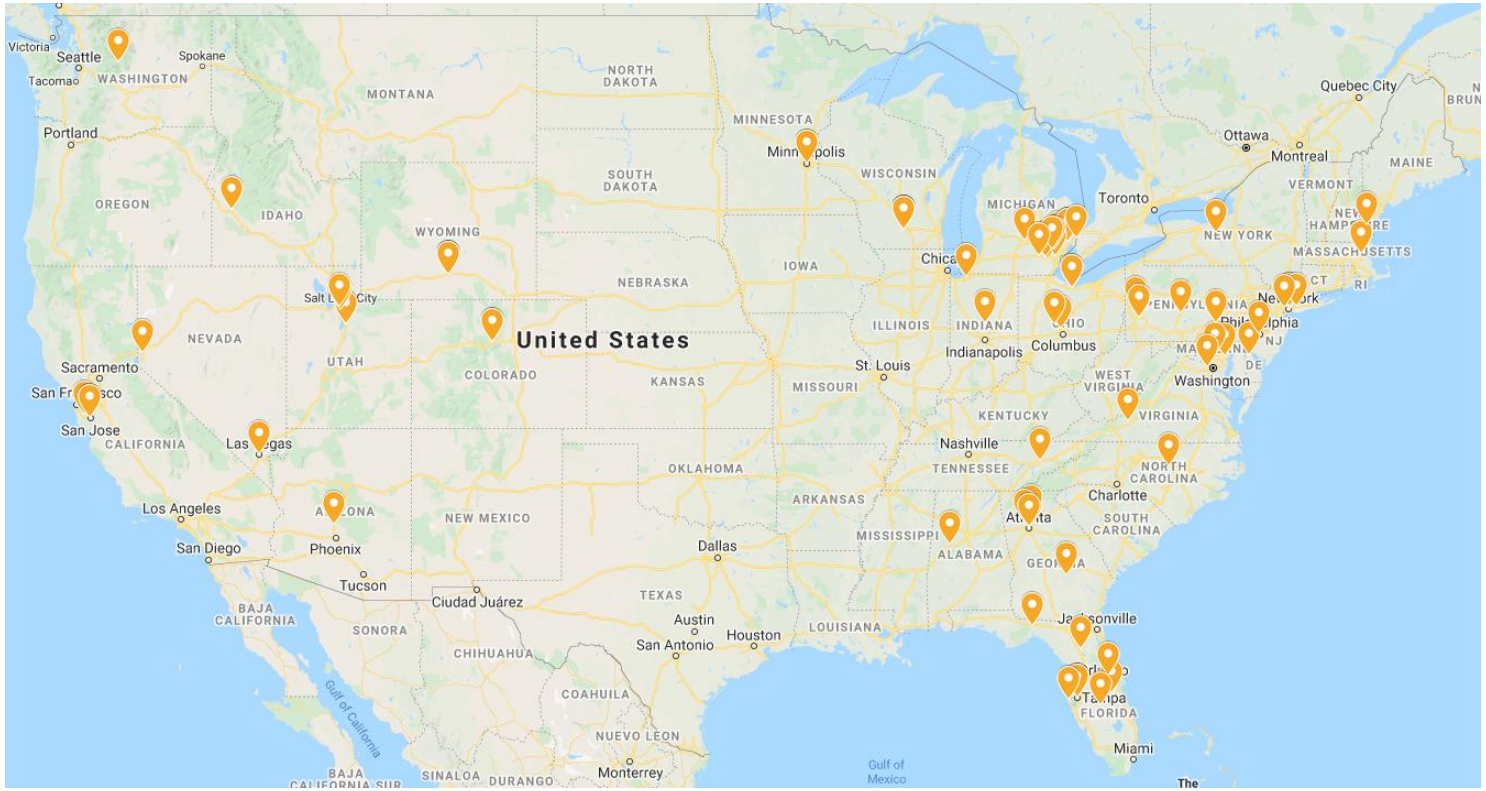

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V2V in the United States (cont.)

- DSRC vs. C-V2X is undecided
- USDOT policy is officially “technology-neutral”
  - However, no spectrum allocated for DSRC after Dec. 2021
- Industry favors C-V2X
  - Ford will install C-V2X in new vehicles from 2022
  - 5G Automotive Alliance (5GAA), Intelligent Transportation Society of America, other industry groups

Regulatory Challenges in the U.S.

- Legal authority split between FCC and NHTSA
  - But it is not clear who specifically controls what
- From 2004, 5.9 GHz was exclusively for DSRC
- Nov/Dec 2020 – FCC proposed reallocating V2V band
  - DSRC: 75 MHz → **nothing!**
  - C-V2X: nothing → 30 MHz
  - Remaining 45 MHz → new Wi-Fi bands
- July 2021 - FCC order took effect
  - One year transition - DSRC effectively banned beginning July ’22

Regulatory Challenges in the U.S.

- FCC strongly condemned by USDOT, NHTSA, 5GAA
  - FCC action will "defer accident reduction for another 5 years"
- Jun. 2021 – ITS America, AASHTO sued the FCC demanding reversal of order, claiming:
  - Decision was "arbitrary and capricious"
  - The FCC exceeded their authority, encroached on NHTSA powers
  - The FCC ignored evidence from auto safety experts
- Pending in D.C. Circuit Court, ruling expected in 2022

Regulatory challenges in U.S.

❑Timeline of conflict between FCC and NHTSA

2004	FCC allocates 75 MHz (5850-5925 MHz) to DSRC
2013	FCC proposes sharing lower 45 MHz with Wi-Fi
2014	NHTSA decides to mandate DSRC on new vehicles
Jan. 2017	NHTSA officially proposes V2V mandate for new vehicles
Mar. 2017	New administration decides not to pursue V2V mandate
2018	Industry begins petitioning for C-V2X to share DSRC's 75 MHz
Nov. 2020	FCC proposes stripping 45 MHz from V2V for new Wi-Fi, reallocating remaining 30 MHz to C-V2X.
Dec. 2020	NHTSA and major industry groups file petitions opposing FCC plans. FCC acts despite objections, issues order confirming the above reallocations.
2021	ITS America, AASHTO file federal lawsuit demanding reversal of FCC decision

Questions and Uncertainties

- What still "fits" in remaining 30 MHz?
  - Some applications may get dropped from development
- Will new Wi-Fi bands cause cross-channel interference?
- How will FCC define "C-V2X?"
  - Could mean LTE- or NR-V2X, no one knows which
- Compensation for 1,000s of deprecated DSRC devices?

Bottom Line: Industry is hesitant to move forward with V2V until future of technologies and spectrum are clarified.