Dedicated Short-Range Communication (DSRC)

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V2V Technology Evolution

DSRC
IEEE 802.11p
(2010)

NextG DSRC
IEEE 802.11bd
(2022)

LTE-V2X
3GPP Rel. 14
(2017)

NR-V2X
3GPP Rel. 16
(2020)

5G C-V2X
3GPP Rel. 18
(2022)

5G-Advanced C-V2X
3GPP Rel. 19+
(2025—present)

DSRC Overview

- Dedicated Short-Range Communications
  - Primarily used in the European Union, formerly in the U.S.
  - Effectively defunct after a <0.01% deployment by 2020
- PHY and MAC layers: Adopted from Wi-Fi technology (legacy IEEE 802.11p, newer 802.11bd), struggled with vehicular mobility
- Network/transport layers and security: IEEE 1609 family
- Payload and performance requirements: SAE standards

Classic DSRC: IEEE 802.11p (2010)

- Similar to 802.11a, but only 10 MHz bandwidth
  - First standardized V2V communication protocol
- Fast connection setup → skips association or authentication
- Latency: $1 - 100$ms, good only for basic applications
- Legacy limitations (reflecting age – requirements date to 1999)
  - Performance concerns: low data rate[1] ($\leq$ 3 Mbps), no retransmissions
  - Design problems: no multi-user support, CSMA/CA → unacceptable latency and exposed/hidden terminal problems

[1]Geoff Twardokus, Nina Bindel, Hanif Rahbari, and Sarah McCarthy, "When Cryptography Needs a Hand: Practical Post-Quantum Authentication for V2V Communications," *Network and Distributed System Security Symposium* (NDSS 2024), San Diego, CA, Feb. 2024.

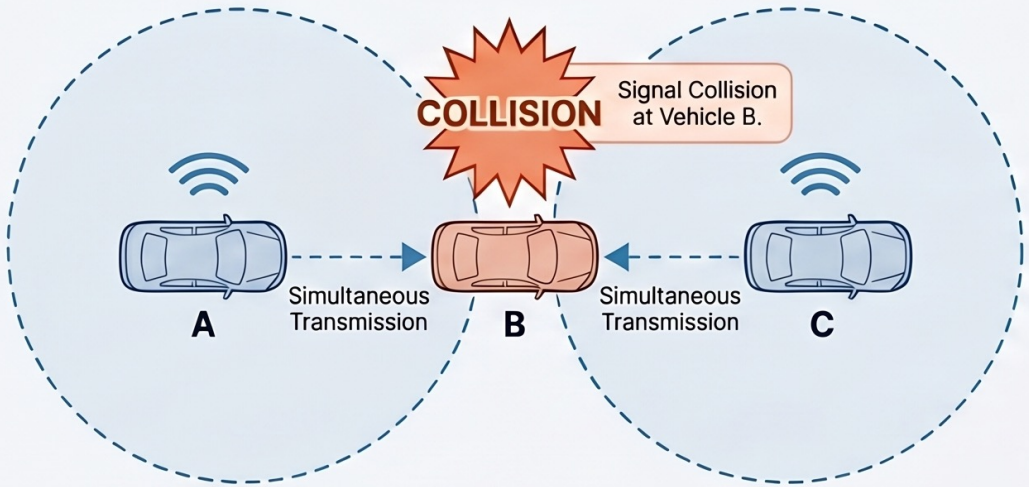
CSMA/CA Causes Unreliable Delays

- **Listen:** Sense if the medium is idle; transmit immediately
- **Defer:** Wait if the channel is busy, and back-off once idle again
  - **Back-off:** Set a random timer to prevent simultaneous transmissions
  - **Transmit:** Send the message only when the timer hits zero
- If collision occurs, double the backoff timer and start again
- This causes unacceptable latency in dense scenarios

The DSRC Scalability Wall: Terminal Problems

Visualizing inherent technical flaws in DSRC (CSMA/CA) leading to communication failures in dense traffic.

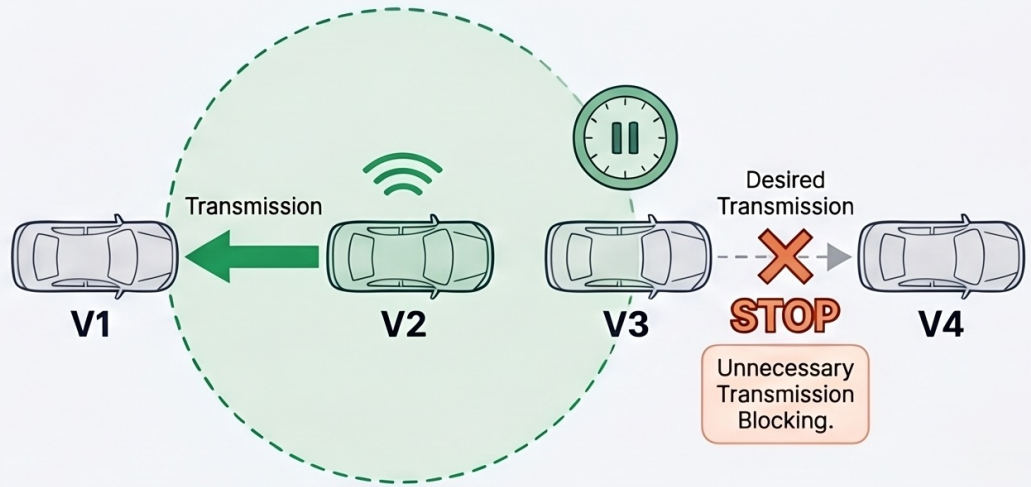
VISUAL 1: THE HIDDEN TERMINAL PROBLEM



Invisible Interference: Vehicles A and C are out of range of each other but both target B.

Signal Collision at Vehicle B: Simultaneous transmissions from A and C collide, preventing B from receiving either message.

VISUAL 2: THE EXPOSED TERMINAL PROBLEM



Unnecessary Transmission Blocking: V2 transmits to V1; V3 hears V2 and "waits" to transmit to V4.

Artificial Latency: V3 waits despite V4 being far enough from V2 to avoid any interference.

TECHNICAL POST-MORTEM

Decentralized Fallure: These scalability issues are inherent to DSRC's CSMA/CA (802.11p) medium access protocol.

Latency & Reliability Risk: These problems cause dropped safety messages and unpredictable delays in dense traffic scenarios.

NotebookLM

NextG DSRC: IEEE 802.11bd (2022)

- Enhancements for Next-Generation V2X (NGV)
  - High-bandwidth apps (maneuver, camera feed, platooning, remote driving)
- Design goals
  - Latency < 5 ms
  - Double data rate and range (to > 1 km)
  - Support relative velocities up to 500 kph
- How? Using advanced PHY-layer technologies
  - MIMO, sub-THz bands, beamforming, midambles, ...

Courtesy: Keysight Technologies

New Features in 802.11bd

- Packet re-transmission fixes 802.11p packet-loss problem
- Midambles reduce bit error rate
  - Like a preamble, but positioned inside the frame
  - Allows channel re-estimation *during* transmission
- Channel access mechanism
  - Addresses CSMA/CA latency by moving contention to a separate channel
  - 20 MHz set aside for channel contention
    - One **Contention Channel:** Used for initial/primary channel contention
    - One secondary **extension Channel**: Additional capacity once access is granted

Too Little, Too Late

- By 2022, industry and regulation was moving away from DSRC
- 802.11bd also introduced new, unique challenges
  - MIMO is very challenging in mobile environments
  - Sub-THz communication largely untested for mobile scenarios
- Backward-compatibility may limit use of advanced features
  - Legacy (802.11p) devices cripple; cannot process MIMO, midambles, etc.

The FCC effectively banned DSRC in 2024.