An Update on V2X in the United States

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Outline

1. DSRC Deployment Increasing

2. US Standards – IEEE Next Gen. V2X

3. Spectrum: Interference and Interoperability

   – Protect spectrum from Wi-Fi interference

   – Protect spectrum to ensure Interoperability

V2X uses **DSRC** in the **US**

- V2X = Vehicle-to-everything (V2V, V2I, V2P, …)
- V2X is ad hoc, device-to-device communication
- V2X provides benefit only if devices **interoperate**, i.e. "speak the same language"
- Therefore, each global region needs consensus on <u>one</u> V2X technology
- US FCC <u>requires</u> DSRC in the 5.9 GHz band
  - DSRC = Dedicated Short Range Communication
  - DSRC is based on IEEE 802.11p standard

DSRC Deployment Increasing

Toyota and Lexus to Launch Technology to Connect Vehicles and Infrastructure in the U.S. in 2021

Will Provide Enhanced Safety Benefits to Drivers, Including Increased Road Safety and Efficiency, While Enabling Greater Advances in Connected- and Automated-Driving Systems

Plan Accelerates Adoption of Vehicle-to-Vehicle and Vehicle-to-Infrastructure Communications Capabilities

Will Begin Deploying 5.9GHz Dedicated Short-Range Communications (DSRC); Encourages All Automakers to Adopt DSRC in the U.S.
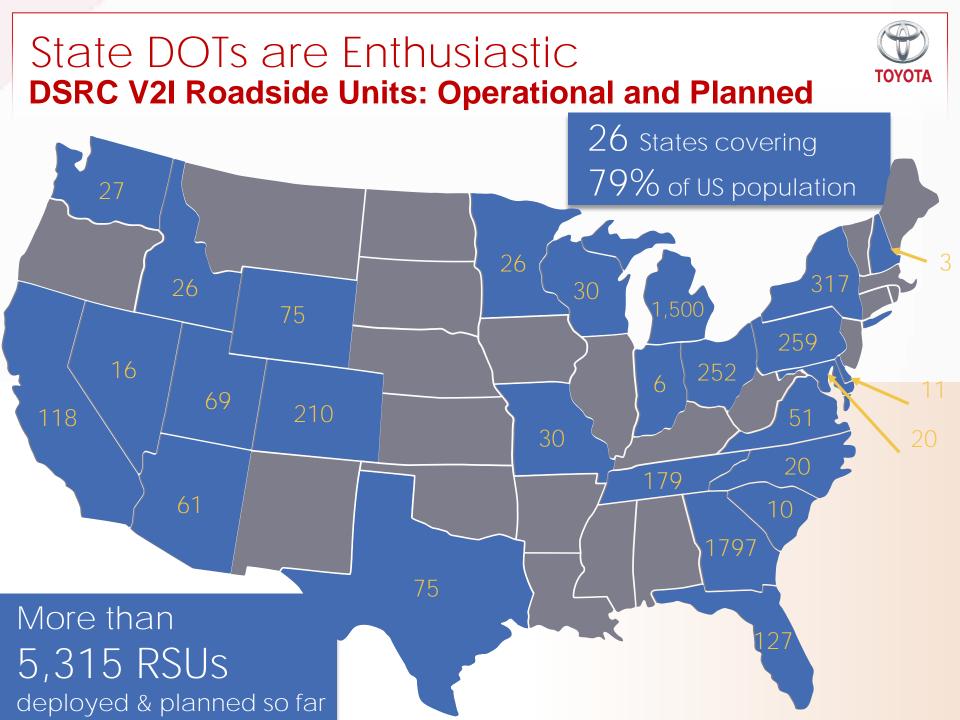
April 16, 2018

PLANO, Texas, April 16, 2018 – Imagine a world where vehicles could 'talk' to each other and to the surrounding environment to help keep their drivers and their passengers safe.

Toyota and Lexus want to advance that conversation, which is why the companies plan to start deployment of Dedicated Short-Range Communications (DSRC) systems on vehicles sold in the United States starting in 2021, with the goal of adoption across most of its lineup by the mid-2020s.
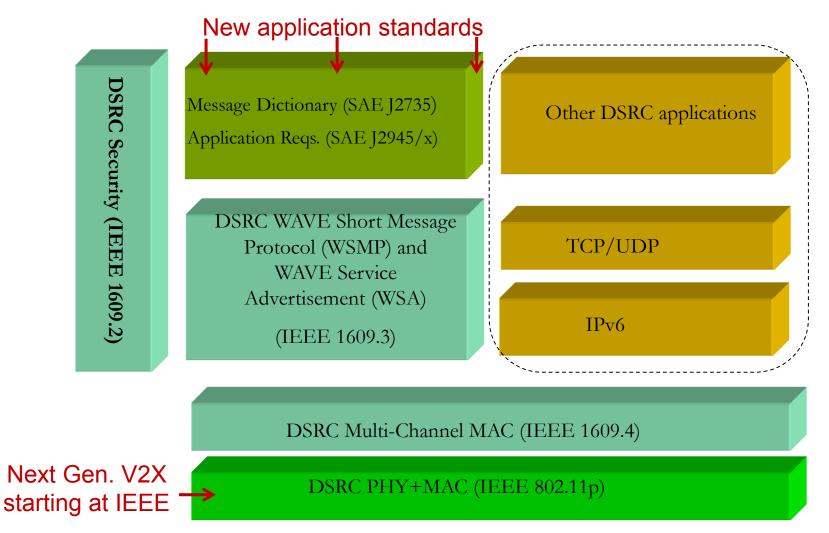
DSRC Deployment Increasing

- GM announced expanded DSRC deployment in June 2018: More cars, More services

- US DOT funding key deployments
  - Example: New York City, 8000 vehicles, 100s intersections

- 10s of thousands of DSRC vehicles in the US

- Most US states committed to DSRC for infrastructure and fleet vehicles

- Truck industry starting DSRC-based platooning

- Deployment picture is <u>very positive</u>

DSRC Standards: mature, expanding

Standards are necessary for interoperability

New application standards

DSRC Security (IEEE 1609.2)

Message Dictionary (SAE J2735)

Application Reqs. (SAE J2945/x)

Other DSRC applications

DSRC WAVE Short Message
Protocol (WSMP) and
WAVE Service
Advertisement (WSA)

(IEEE 1609.3)

TCP/UDP

IPv6

DSRC Multi-Channel MAC (IEEE 1609.4)

Next Gen. V2X
starting at IEEE

DSRC PHY+MAC (IEEE 802.11p)

See: J. Kenney, "DSRC Standards in the United States", Proc. IEEE, July 2011, Vol. 99, No. 7, pp. 1162-1182

IEEE 802.11 NGV

- Next Generation V2X amendment (802.11bd)

- Improves range and reliability

- True backward compatibility with DSRC
  - NGV can transmit to DSRC devices and NGV devices
  - NGV can understand DSRC transmissions
  - NGV can co-exist with DSRC <u>in the same channel</u>
  - Contrast to C-V2X, which cannot co-exist or interoperate with DSRC in the same channel

- NGV represents <u>seamless evolution path for DSRC</u> in years to come

- IEEE work is just starting

SAE DSRC Application Standards

SAE DSRC TC standards published and in process

- J2735   Message Set Data Dictionary (2016)
- J2945/0 – Common Design Concepts (2017)
- J2945/1 – Basic Safety Message application (2016)
- J2945/2 – Emergency Vehicle Alert, Roadside Alert, etc. (2018)
- J2945/3 – Weather alert (in process)
- J2945/4 – Road Safety Message applications (in process)
- J2945/5 – Security topics (early)
- J2945/6 – Cooperative Automation (early)
- J2945/7 – Positioning Enhancements (early)
- J2945/8 – Cooperative Perception (early)
- J2945/9 – Vulnerable Road User (V2P) application (2017)
- J2945/10 – MAP/SPAT (in process)
- J2945/11 – Signal priority/preemption (early)
- J2945/12 – Probe data collection (early)

Spectrum: I & I

Two major spectrum challenges in US 5.9 GHz

- Interference:
  - Allow unlicensed sharing while protecting DSRC from harmful interference?
  - Changing DSRC rules would dilute investment.

- Interoperability:
  - With interoperability ➔ V2X Benefits (saving lives!)
  - Without interoperability ➔ **No V2X Benefits!**

- Interference & Interoperability are separate, but related. Wi-Fi sharing is inconsistent with non-DSRC V2X protocols

Interference: Wi-Fi Sharing

- FCC: open question since 2013

- Two proposals
  - Detect & Vacate: no change for DSRC required
  - Re-channelization: aggressive packet-by-packet sharing, requires changes to how DSRC operates even when no Wi-Fi present

- FCC 3-phase test plan
  - First phase results released October 2018
  - Shows signs of interference
  - Need to perform outdoor tests with vehicles (Phase II, III)
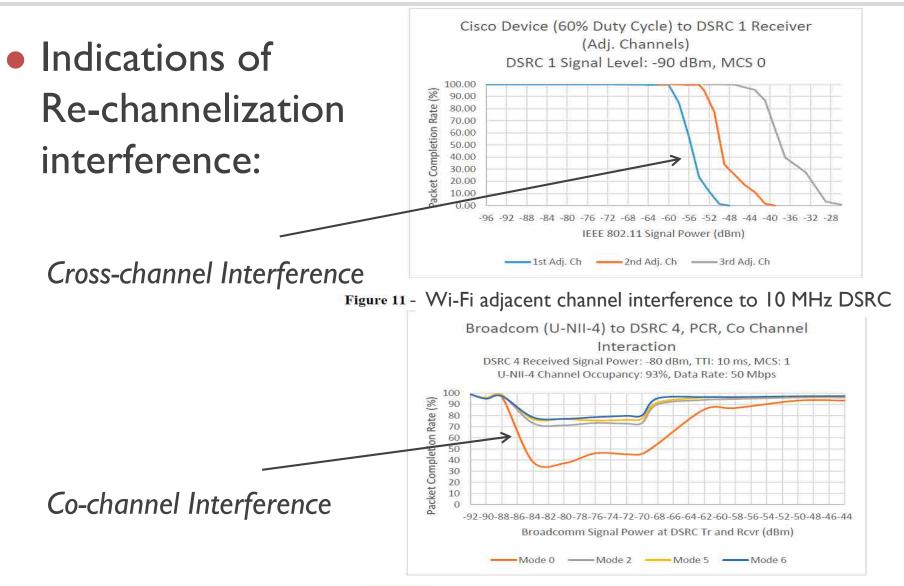
FCC Phase 1 Test Report

- Indications of Re-channelization interference:

Cross-channel Interference

Cisco Device (60% Duty Cycle) to DSRC 1 Receiver (Adj. Channels)
DSRC 1 Signal Level: -90 dBm, MCS 0

Figure 11 – Wi-Fi adjacent channel interference to 10 MHz DSRC

Co-channel Interference

Broadcom (U-NII-4) to DSRC 4, PCR, Co Channel Interaction
DSRC 4 Received Signal Power: -80 dBm, TTI: 10 ms, MCS: 1
U-NII-4 Channel Occupancy: 93%, Data Rate: 50 Mbps

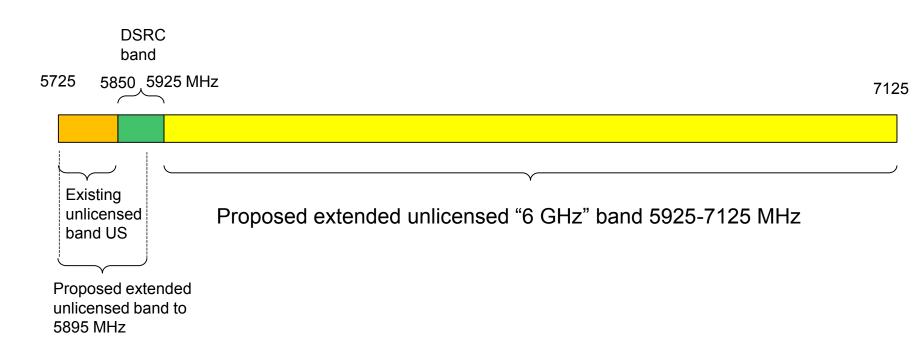**Figure 48** - Wi-Fi co-channel interference to 20 MHz DSRC

"Preserving the 5.9 GHz band for transportation communications is essential to public safety today and in the future. …

With lifesaving safety capabilities at stake, the Department maintains that all three phases of research must be completed before any decisions about spectrum reallocation can be made.

https://www.nhtsa.gov/press-releases/us-department-transportations-national-highway-traffic-safety-administration-issues

New Wi-Fi bandwidth: 6 GHz

DSRC band

5725 5850 5925 MHz 7125

Existing unlicensed band US

Proposed extended unlicensed band to 5895 MHz

Proposed extended unlicensed "6 GHz" band 5925-7125 MHz

- A major strategic initiative of FCC to create more Wi-Fi spectrum
  - NPRM announced Oct. 2018
- 45 MHz in DSRC band small compared to 1200 MHz in 6 GHz band
- Incumbents must be protected (just as with DSRC)
- Main incumbents: Fixed Service, Fixed Satellite Service
- DSRC also needs protection from adjacent interference at 5925 MHz

Importance of single standard

- V2X is ad hoc, short range, decentralized
- No access point or base station to relay or translate protocol languages
- Devices MUST speak the same language!
- Each global region must have ONE consensus protocol (i.e. technology). Could be:
    - DSRC(802.11p) or IEEE NGV, since they can interoperate
    - 3GPP LTE V2X (Rel. 14)
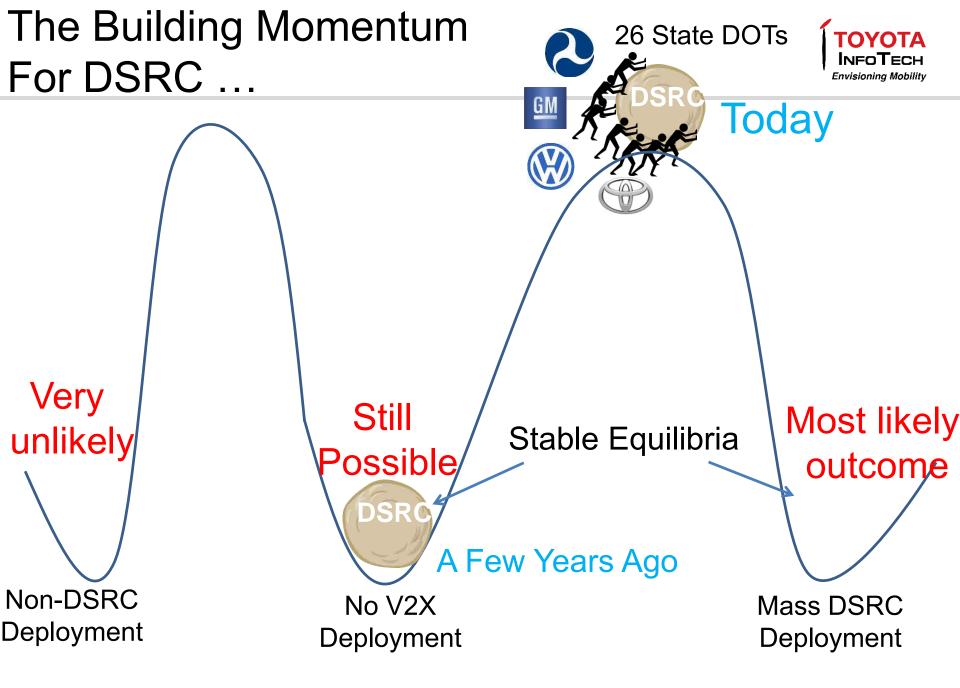   - 3GPP New Radio V2X (Rel. 16)
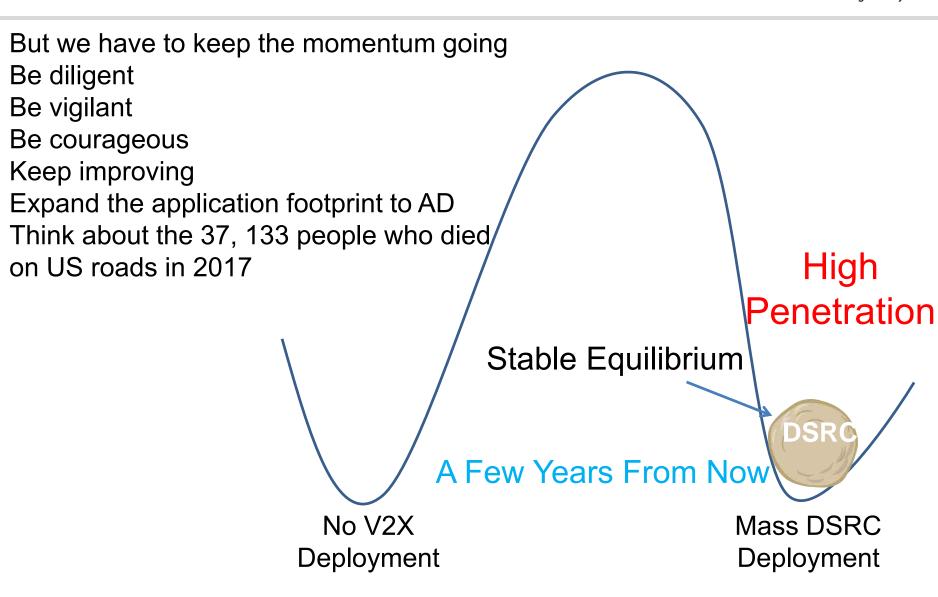- Do not combine 2 or 3 incompatible technologies

Split Spectrum? No

Every channel used for safety apps

Ch. 172	BSM safety and small set of V2I safety apps
Ch. 174	I→V safety and mobility, to avoid cross-channel interference to Ch. 172
Ch. 176	VRU safety (PSM) D→V, and download from SCMS (I→V)
Ch. 178	Control channel: WSAs, and low-bandwidth safety (I→V)
Ch. 180	Non-BSM V2V safety (e.g. C-ACC, sensor sharing), and mobility (I→V)
Ch. 182	I→V safety and mobility
Ch. 184	FCC designation for public safety. Ex: Preemption, Emergency Alert

Interleaved V2V and V2I limits interference

SAE J2945/0 Spectrum Usage Plan

- Reassign 2 channels for LTE V2X?
- Duplicating apps (e.g. BSM/SPAT/MAP) wastes precious spectrum
- Drives up cost for automakers (2 radios → 4 or 6 radios)
- Not technology neutral
- Does not scale for future incompatible technologies
- Note: IEEE NGV does <u>not</u> need separate channels

The Building Momentum For DSRC …

26 State DOTs

DSRC

Today

Very unlikely

Still Possible

Stable Equilibria

Most likely outcome

A Few Years Ago

Non-DSRC Deployment

No V2X Deployment

Mass DSRC Deployment

This is where we expect to be

But we have to keep the momentum going
Be diligent
Be vigilant
Be courageous
Keep improving
Expand the application footprint to AD
Think about the 37, 133 people who died
on US roads in 2017

High
Penetration

Stable Equilibrium

DSRC

A Few Years From Now

No V2X
Deployment

Mass DSRC
Deployment

Summary

- DSRC deployment in US is very healthy

  - 10,000s vehicles, 1000s RSUs

- NHTSA says entire 75 MHz DSRC band must be protected

- FCC Phase 1 test report → Signs of interference

  - More testing needed

- Each region (US, JP, EU, CH, …) needs one consensus V2X technology to get benefits

  - Splitting spectrum is a bad idea: wasteful, expensive, non neutral, does not scale

Thank You!

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The Building Momentum For DSRC …