C-ITS in the United States:
A Status Update on 5.9 GHz DSRC

ETSI ITS Workshop

John B. Kenney, Ph.D.

Director and Principal Researcher

Toyota InfoTechnology Center, USA

jkenney@us.toyota-itc.com

March 8, 2016

Outline

TOYOTA
INFOTECHNOLOGY
CENTER, U.S.A., INC.

- DSRC Background
- DSRC Deployment
- DSRC Standards
- DSRC Challenges

US DSRC Background

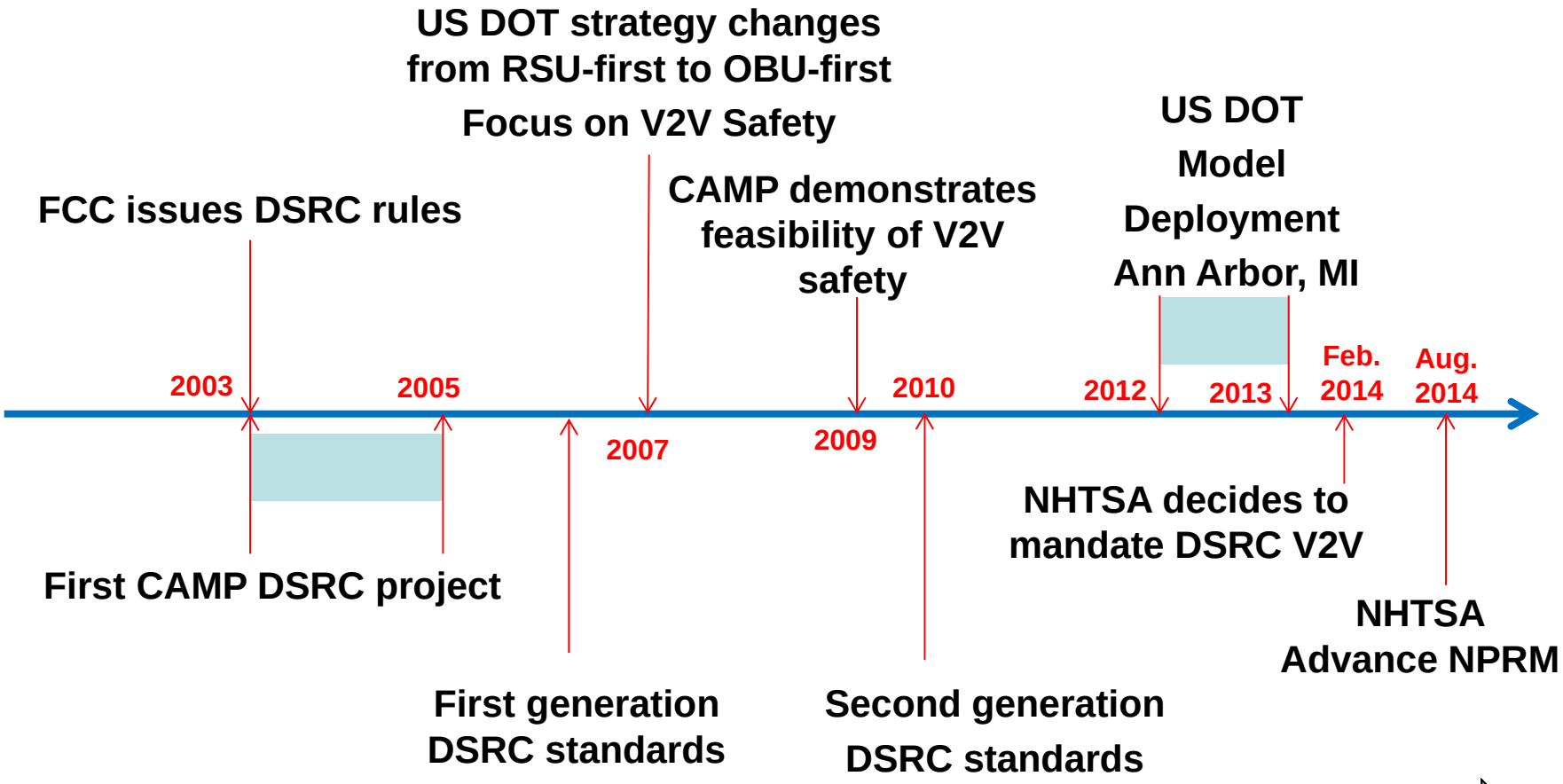
TOYOTA InfoTechnology Center, U.S.A., Inc.

- Dedicated Short Range Communication
- Vehicle ad hoc networking
- V2X communication: Vehicle to/from
  - Vehicle (V2V)
  - Infrastructure (V2I)
  - Pedestrian (V2P)
  - etc.
- 5.850-5.925 GHz (5.9 GHz band)
- Primary application categories:
  - Safety, Mobility, Environment, Commerce, …
- DSRC Term used differently in US, EU, JP

DSRC Deployment:
NHTSA DSRC Rulemaking

TOYOTA InfoTechnology Center, U.S.A., Inc.

Events prior to 2015 …

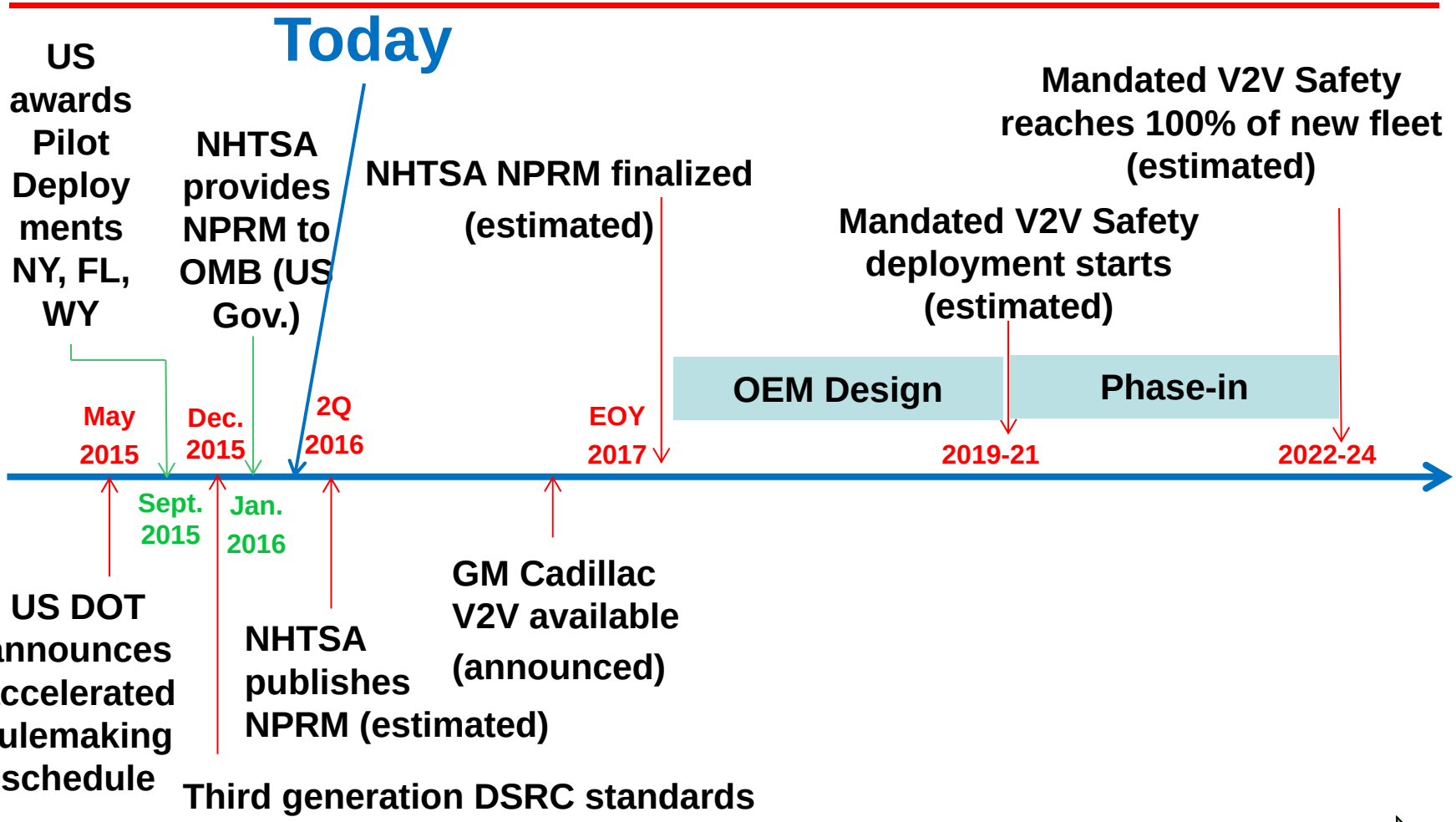


US DOT research in V2I, mobility, environment

NHTSA = National Highway Transportation Safety Agency, NPRM = Notice of Proposed Rulemaking

Events moving to deployment

TOYOTA InfoTechnology Center, U.S.A., Inc.



US DOT research in V2I, mobility, environment

RSU Deployment: Road authorities

OMB = Office of Management and Budget

Expectations for NHTSA NPRM

TOYOTA InfoTechnology Center, U.S.A., Inc.

- Propose to modify Federal Motor Vehicle Safety Standard (FMVSS)
- US DOT estimates April 2016 publication
- 60 day public comment period
- Require “V2V Safety” transmission equipment in new “light vehicles”
  - i.e. DSRC transmitters sending Basic Safety Messages according to standards
- Will not apply to existing vehicles, trucks, buses, etc.
  - Additional regulations may follow for some other vehicle types. Voluntary deployment also permitted.
  - Aftermarket devices likely to become available
- Will not require executing specific applications at receiver
  - Expectation is market forces will cause applications
  - Applications will be proprietary to automaker, not standardized
- Will likely require only a single radio, tuned to Ch. 172.
  - Second radio to access other channels would be optional – key decision for OEMs
- Some details may be left to industry MOU – e.g. Security infrastructure organization

V2I Deployment Coalition

TOYOTA InfoTechnology Center, U.S.A., Inc.

- Formed June 2015 (AASHTO, ITS America, ITE)
- Supported by US DOT
- Goal: promote deployment of V2I (RSUs)
- 5 Working Groups

TWG1: Deployment Initiatives	TWG2: Deployment Research	TWG3: Infrastructure Operator, OEM, and Supplier Partnership	TWG4: Deployment Guidance	TWG5: Deployment Standards

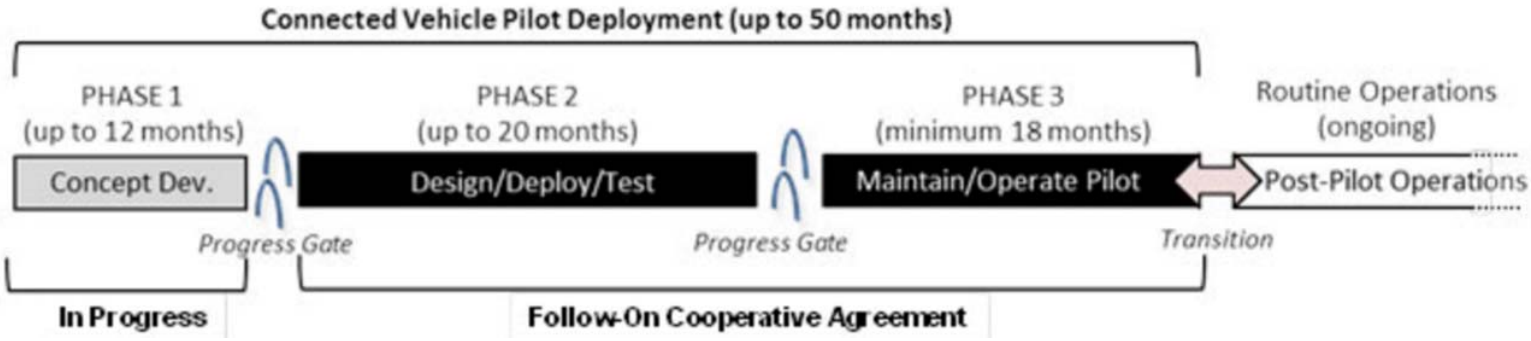
- Next F2F meeting planned April 20-21, Ann Arbor MI

AASHTO = American Association of Sate Highway and Transportation Organizations
ITE = International Transportation Engineers FHWA = Federal Highway Administration

US DOT – Connected Vehicle Pilot Deployment program

TOYOTA InfoTechnology Center, U.S.A., Inc.

- Goal: To advance deployment, measure impact, uncover and address the barriers to deployment. V2I & V2V.
- Program schedule:



- Three sites were selected in September 2015: New York City, Tampa and Wyoming
- They will share up to $42 Million funding
- Intended to be permanent, not just for testing
- Another set of winners will be named in 2017

CV Pilot Sites

TOYOTA InfoTechnology Center, U.S.A., Inc.

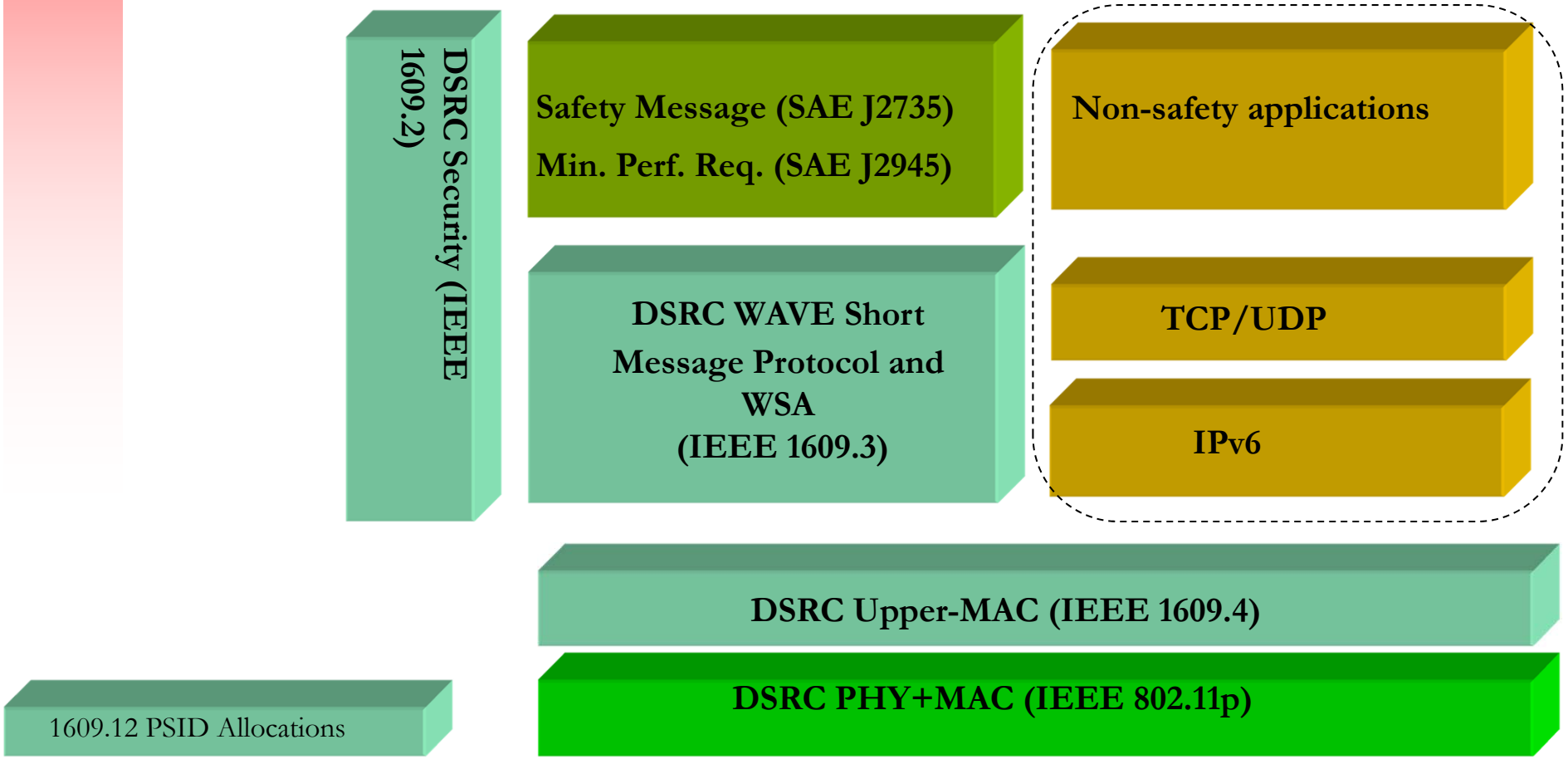
- New York City: Pedestrian safety and travel improvement
  - 10,000 vehicles and 100s of intersections
  - V2V and V2I
  - Apps: Pedestrian safety, Red light warning, Freight-specific travel demand
- Tampa, Florida: Alleviate expressway and urban congestion
  - V2V and V2I
  - Apps: Curve speed warning, Intelligent signals, Intersection movement assist, pedestrian safety, transit signal priority
- Wyoming: Focus is weather events on 402 mile interstate corridor used heavily by trucks.
  - V2V and V2I
  - Apps: Road weather advisory, Variable speed limit, Situational awareness

DSRC Standards

TOYOTA InfoTechnology Center, U.S.A., Inc.

- **All IEEE 1609 and SAE standards revised in 2015**
- **SAE J2945/1 V2V Safety Communication Requirements was published for the first time:**

On-Board System Requirements for V2V Safety Communications



Summary of Standards Revisions: IEEE

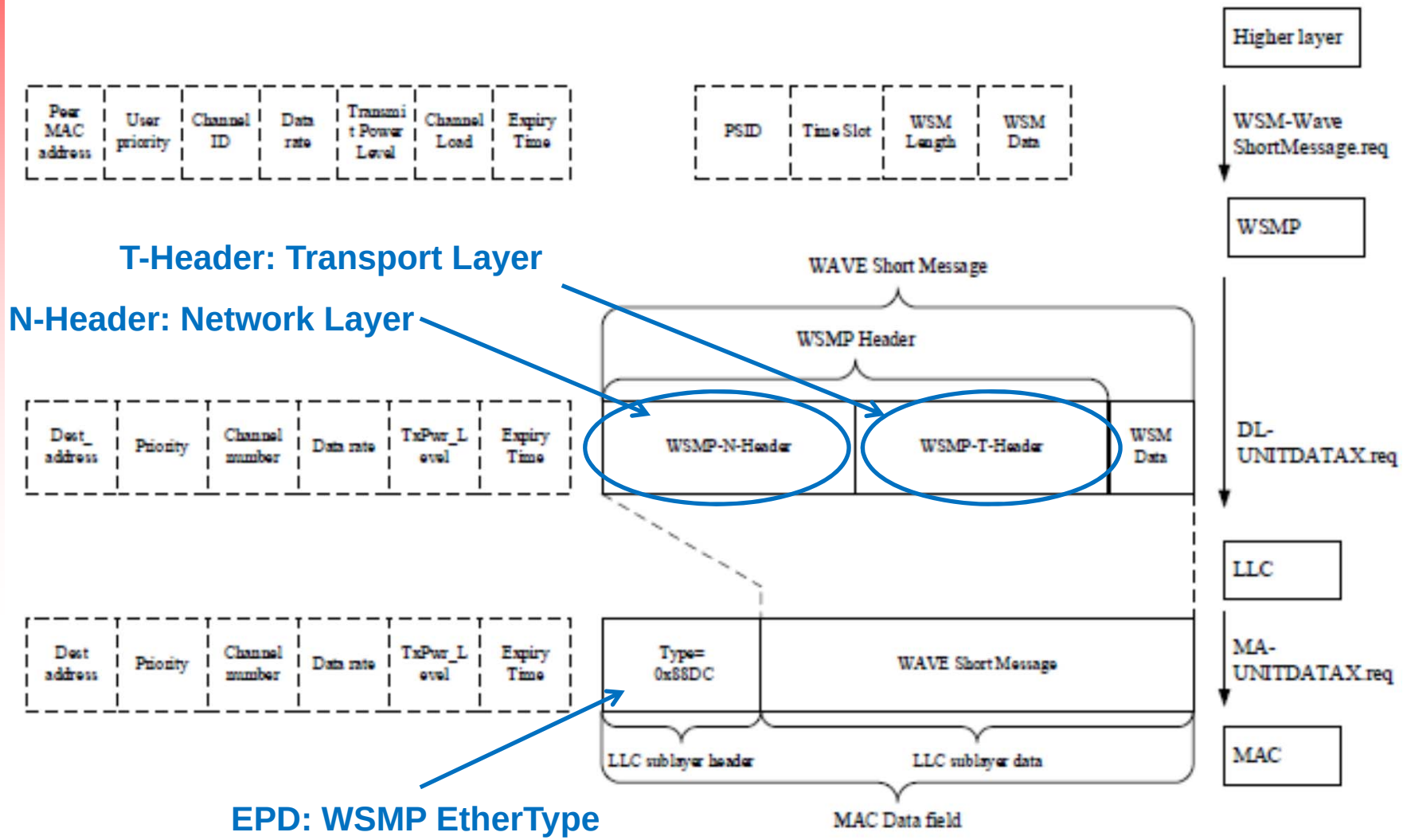
TOYOTA InfoTechnology Center, U.S.A., Inc.

- IEEE 802.11: under revision, but no changes expected for "communication outside the context of a BSS"
- IEEE 1609.4: minor revisions to keep aligned with 1609.3
- IEEE 1609.3:
  - Major update to WAVE Short Message Protocol
  - Significant update to WAVE Service Advertisement
  - Adopted EtherType Protocol Discrimination (EPD)
    - Shift from LLC SNAP

  More below
- IEEE 1609.12: A few additional PSID allocations
  - e.g. WAVE security, CAM, DENM, Vulnerable Road User, Misbehavior Report, Certificate Revocation List
  - Alignment with ISO/ETSI allocations continues
  - IEEE 1609 WG is working to formalize procedures for requesting a PSID allocation. IEEE Registration Authority Committee (RAC) now publishing 1609.12 allocation list as well.

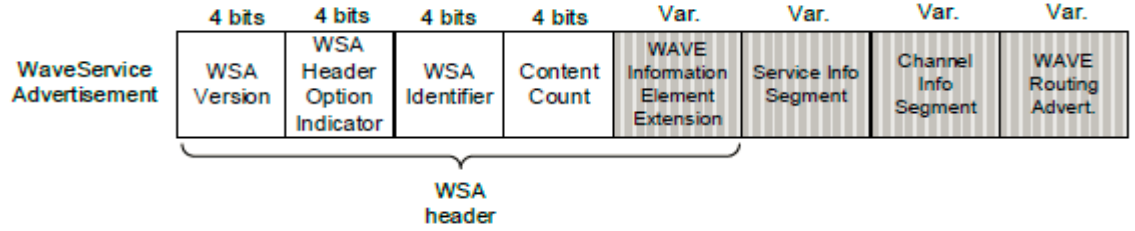
WSMP

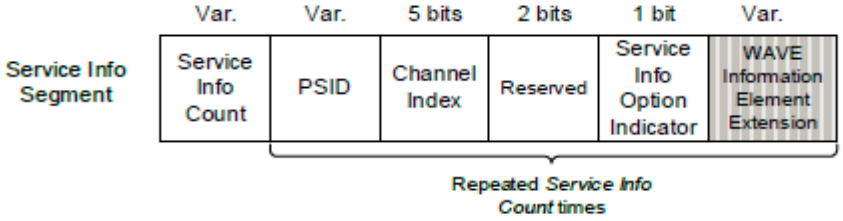
TOYOTA InfoTechnology Center, U.S.A., Inc.

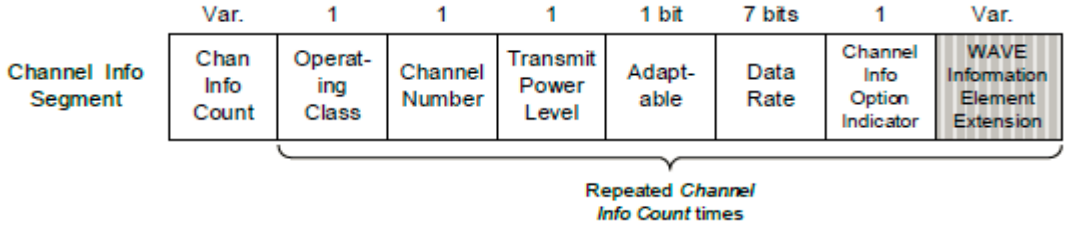


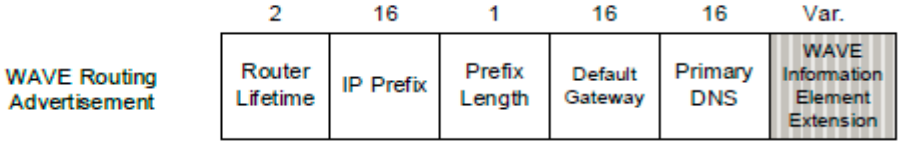
WSA

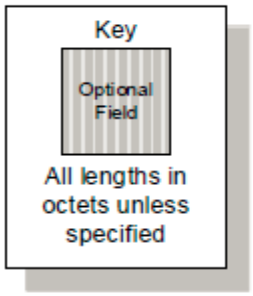
TOYOTA InfoTechnology Center, U.S.A., Inc.











IEEE 1609.2 Security

TOYOTA INFOTECHNOLOGY CENTER, U.S.A., INC.

- Data structures defined in ASN.1
- Encoding: OER – Octet Encoding Rules
- Several new features added to 2013 std

Summary of Standards Revisions: SAE

TOYOTA InfoTechnology Center, U.S.A., Inc.

- SAE J2735:
  - BSM encoding now Unaligned Packed Encoding Rules (UPER)
  - Minor restructuring of BSM
  - Updates to intersection messages (SPaT, MAP, Preemption)
  - New Personal Safety Message (PSM) to be sent by Vulnerable Road User (VRU)
    - i.e. pedestrian, bicyclist, road worker
    - Modeled on BSM
    - Not stable, intended only for testing at this time

SAE J2945/1

TOYOTA InfoTechnology Center, U.S.A., Inc.

- Specifies behavior for V2V safety devices operating on Ch. 172
- First publication of this standard, not a revision
- Main Requirement Areas:
  - Standards requirements: 802.11,1609.x, SAE J2735, and FCC
  - Positioning and Timing
  - Channel, data rate, EDCA
  - Element accuracy and minimum transmission criteria
  - Scheduling and Congestion Control
  - Radiated power, Receiver sensitivity
  - Security and Privacy
  - Security Management

Selected Accuracy Requirements

TOYOTA InfoTechnology Center, U.S.A., Inc.

- 2-D position: 1.5 meters
- Elevation: 3 meters
- Speed: within 1 km/hour
- Heading: 2 or 3 degrees depending on speed
- Longitudinal acceleration: 0.3 m/sec^2
- Yaw Rate: 0.5 degrees/second
- Size: 0.2 meters

Most of these are specified to be achieved for at least 68% of measurements in “open sky” conditions

Congestion Control (simplified)

TOYOTA InfoTechnology Center, U.S.A., Inc.

- When to send BSM:
  - Send at 10 Hz during specified “events”
  - If vehicle dynamics and channel conditions cause “suspected tracking error” to become large
  - Otherwise, at a background rate that decreases based on number of neighbor vehicles within 100 meters (10 Hz → 1.6 Hz)
- What power to send BSM:
  - Decreases from 20 dBm → 10 dBm as Channel Busy Ratio grows from 50% to 80%

Additional US Standards

TOYOTA InfoTechnology Center, U.S.A., Inc.

SAE is working on additional standards, beyond those critical for NHTSA rulemaking:

- V2V safety for other vehicles (to be J2945/2)
- Requirements for SPaT, MAP, Preemption (doc. number is TBD)
- Personal Safety Message – for pedestrians, bicyclists, road workers …
  - Requirements to be published as a recommended practice in J2945/9
- Cooperative Adaptive Cruise Control
- Platooning

- New attention to Traveler Information Message (I2V)

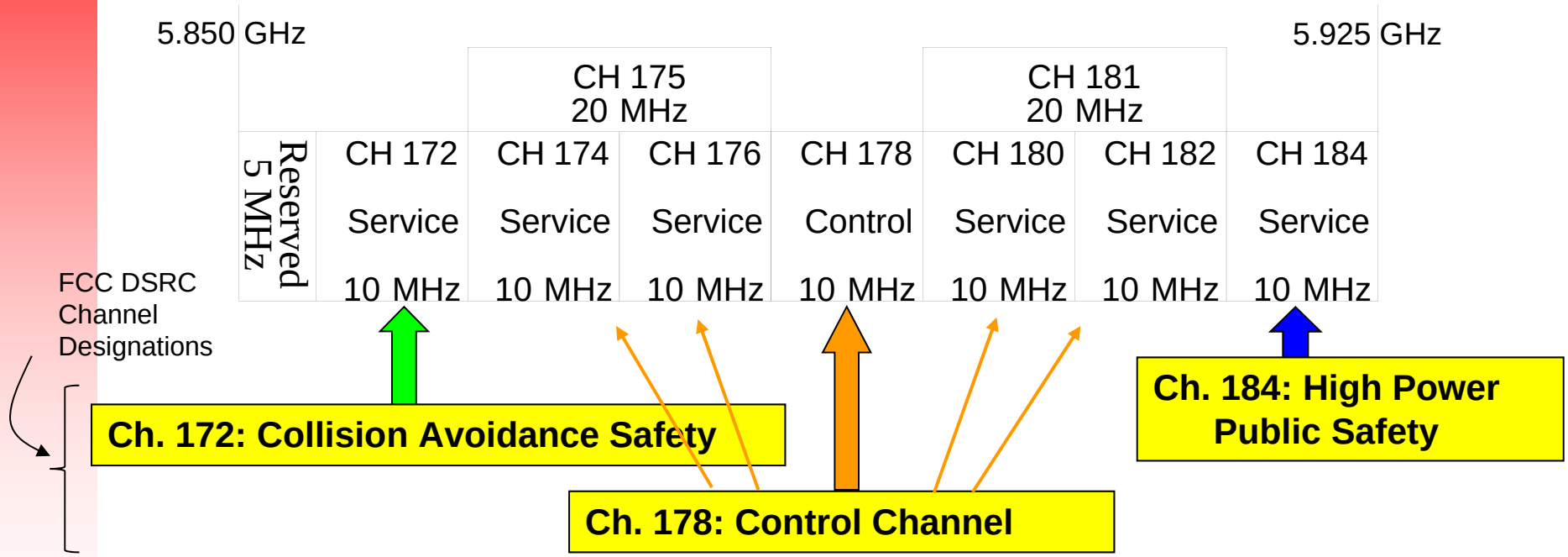
Planned joint work with ETSI

Challenges

TOYOTA
INFOTECHNOLOGY
CENTER, U.S.A., INC.

- Spectrum sharing
- Spectrum management
- Security and privacy management
- Certification

DSRC Band Plan



- Ch. 172 likely to be limited to BSM, MAP, SPaT (and possibly a few others)
- Most DSRC applications will use other channels.
- Many of those applications have safety implications and critical communication performance requirements
- Automated Driving-related applications are prominent among these

DSRC Spectrum Sharing Issue

TOYOTA InfoTechnology Center, U.S.A., Inc.

- DSRC/C-ITS operates in licensed 5.9 GHz spectrum in the US
- Unlicensed devices (Wi-Fi, LAA) want access to more spectrum
  - Government regulators see economic growth advantages
- Sharing between licensed & unlicensed devices is new emphasis
  - Unlicensed must not cause "Harmful Interference" to licensed
  - Sharing with radar systems works, based on "detect & vacate"
  - But, sharing with short range V2V and V2I is quite different
- US FCC initiated formal question about 5.9 GHz sharing in 2013
- IEEE 802 "Tiger Team" completed work March 2015 without consensus
- Biggest risk to successful DSRC deployment

Major US Stakeholders

TOYOTA InfoTechnology Center, U.S.A., Inc.

US Congress

US President

cable

IEEE WiFi

AUTO ALLIANCE
DRIVING INNOVATION®

GlobalAutomakers

FEDERAL COMMUNICATIONS COMMISSION · USA ·

NTIA U.S. DEPARTMENT OF COMMERCE NATIONAL TELECOMMUNICATIONS & INFORMATION ADMINISTRATION

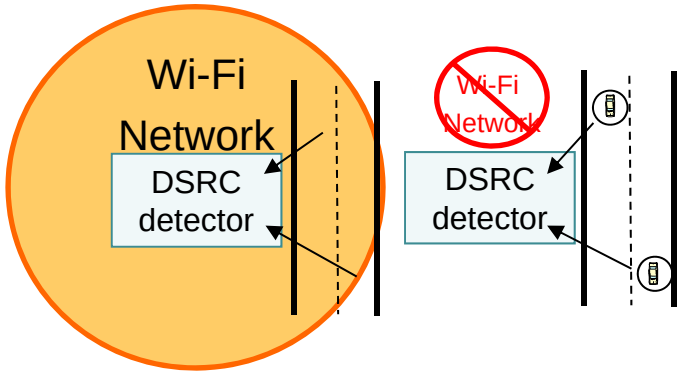
DEPARTMENT OF TRANSPORTATION UNITED STATES OF AMERICA

Two sharing proposals

TOYOTA InfoTechnology Center, U.S.A., Inc.

DETECT & VACATE:

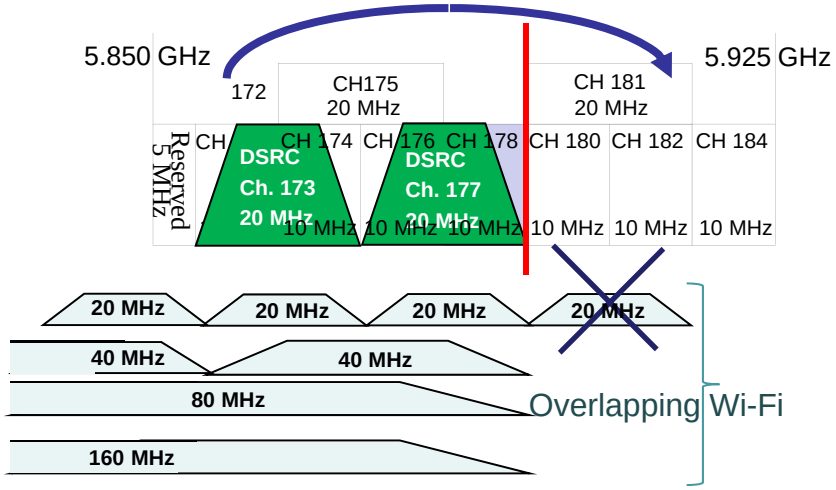
- Proposed by Cisco
- Currently being tested
- No changes needed to DSRC
- Each Wi-Fi device has a DSRC detector
- When DSRC detected, no WLAN
- When no DSRC present, WLAN ok



No DSRC present ***DSRC present***

RECHANNELIZATION:

- Proposed by Qualcomm
- Auto industry opposes this
- Not completely defined – cannot yet be tested
- Requires significant changes to DSRC operation
  - Shift key safety messages
  - Use 20 MHz channels



Current Status

TOYOTA InfoTechnology Center, U.S.A., Inc.

Focus is turning to testing:

Cisco Detect & Vacate:

- Cisco developed prototype DAV hardware
- Cisco and auto groups told FCC in May about plans for joint testing
- Cisco provided preliminary test results in August, -95 dBm detection

Testing Principles

- DSRC, Wi-Fi, and Satellite stakeholders agreed on a set of "Testing Principles" in September 2015

FCC/US DOT:

- US DOT published a DSRC-Unlicensed Device test plan in August
- **FCC will announce public test plan soon: 3 Phases**
  1. **Lab testing**
  2. **Outdoor, small number of devices**
  3. **Outdoor, large number of devices**

Proposal companies (Cisco, Qualcomm) should provide prototypes

Spectrum sharing in EU

TOYOTA InfoTechnology Center, U.S.A., Inc.

- EU regulators and stakeholders watching US developments
- ETSI BRAN working on TR 103 319: Mitigation to enable sharing between RLAN and TTT/ITS
- Cisco Detect & Vacate
- Detect & Mitigate (Broadcom)
  - A packet-by-packet sharing idea
  - Uses channel access QoS (EDCA) to give ITS packets priority after an ITS packet is finished
  - Does not address fact that RLAN packets are hidden from ITS sensing
  - Likely to result in high interference to ITS in many scenarios

Spectrum Management

TOYOTA InfoTechnology Center, U.S.A., Inc.

- Separate issue from spectrum sharing
- Focus in US has been on V2V Safety, Ch. 172
- To realize promise of DSRC, need to address overall band usage
  - Application-to-channel assignment will generally vary in time and space
    - Static/Nationwide exceptions for some services, e.g. V2V Safety, Pedestrian Safety
  - Service Advertisement/Channel Switching paradigm
  - Is there need for central or regional spectrum management function?

Security/Privacy Management

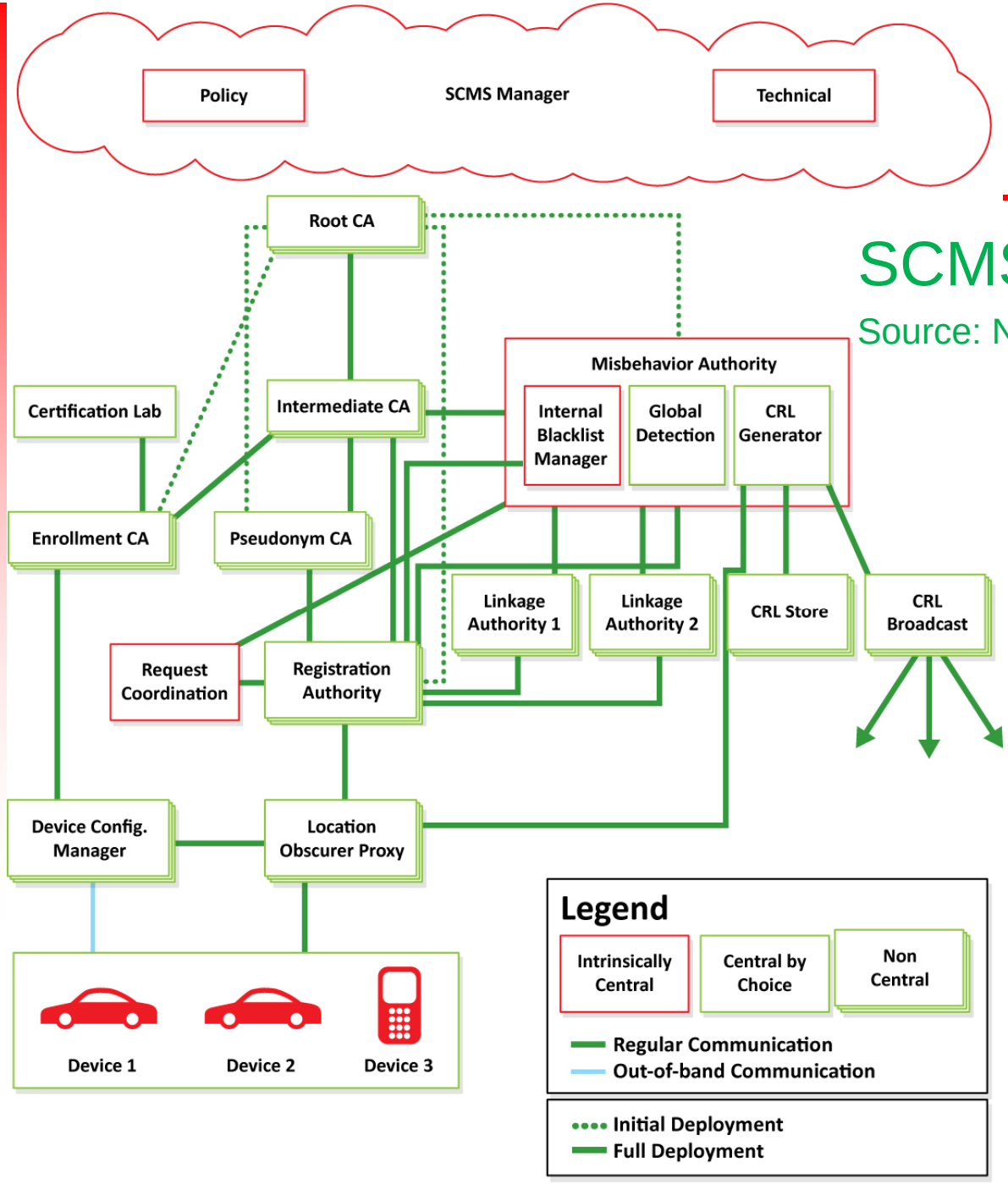
TOYOTA InfoTechnology Center, U.S.A., Inc.

- Packet-by-packet authentication and encryption is well defined
- Cryptography based on Public Key Infrastructure (PKI) – Public/Private keys
- Privacy enhanced by frequent identity change (Certificate, Address, etc.)
- Security Credential Management System (SCMS) – infrastructure to grant new certificates, manage misbehavior, revoke bad actors
- Policy questions: overall ownership/operation of SCMS? Division of individual functions? OEM role? Enforcement?

TOYOTA InfoTechnology Center, U.S.A., Inc.

SCMS architecture:

Source: NHTSA V2V Readiness Report



DSRC Certification

TOYOTA InfoTechnology Center, U.S.A., Inc.

- DSRC equipment must be certified prior to deployment
  - To show it meets NHTSA requirements
  - To qualify for security credentials (certificates)
- US DOT contracting with 3 parties
  1. OmniAir consortium
  2. 7 Layers (testing company)
  3. DanLaw
     - Note: 7 Layers and DanLaw are also members of OmniAir
- US DOT formed Certification Operating Council (COC) to certify equipment for Pilot Deployments, and formulate policy for certification associated with NHTSA Mandate
- OmniAir is partnering with Wi-Fi Alliance (WFA) to develop lower layer (PHY, MAC) certification testing specifications

Summary

TOYOTA InfoTechnology Center, U.S.A., Inc.

- DSRC in the US has reached deployment stage
- NHTSA V2V Safety NPRM expected 2Q16
  - First mandated deployment estimated 2019 to 2021
- Six NHTSA-critical standards revised 2015 (SAE, IEEE)
- Other activities promote DSRC, including:
  - Additional standards (C-ACC, VRU, …)
  - V2I Deployment Coalition
  - CV Pilot Deployments
  - Harmonization opportunities
- Challenges and risks include:
  - Spectrum sharing
  - Spectrum management
  - Security and Privacy
  - Certification
- Opportunities for innovation and societal improvement

Questions?

TOYOTA
INFOTECHNOLOGY
CENTER, U.S.A., INC.

Thank You

John Kenney
jkenney@us.toyota-itc.com