V2X Deployment: Safety and Beyond

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Questions

• What is happening with DSRC deployment?
  – Cooperative dilemma
  – Regional approaches
  – Challenges to be met

• What happens after initial deployment?
  – Challenges
  – Opportunities
  – Other communication options
Toyota InfoTechnology Center

Japan HQ
Investors: Toyota, Denso, KDDI, Toyota Tsusho, Aisin, Kyocera, Toyoda Gosei, Toyota Industries

Headquarters: Akasaka, Tokyo, Japan
Personnel: about 70
Established: January, 2001

US Center

US HQ and R&D: Mountain View, CA
Personnel: about 35
Established: April, 2001

Location: New York City, NY
Business Research
Why we’re here

32,719 US Traffic Fatalities in 2013

NHTSA Says 32,719 Died in U.S. Traffic Accidents in 2013 ...
247wallst.com/.../12/.../32719-died-in-traffic-accidents-in-the-us-last-year...
Dec 20, 2014 - The rate of deadly traffic accidents dropped 24% from 2004 to 2013. However, 32,719 people were killed last year, according to the National ...
A sampling of DSRC apps ...

### CONNECTED VEHICLE APPLICATIONS

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<td><strong>Road Weather</strong></td>
<td><strong>Smart Roadside</strong></td>
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<td>Probe-based Pavement Maintenance</td>
<td>Motorist Advisories and Warnings (MAW)</td>
<td>Wireless Inspection</td>
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<td>Probe-enabled Traffic Monitoring</td>
<td>Enhanced MDSS</td>
<td>Smart Truck Parking</td>
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<td>Work Zone Traveler Information</td>
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DSRC V2V Safety Concept

- Concept: each vehicle sends **Basic Safety Messages** frequently.
- Receiving vehicles assess collision threats
- Threat: Warn driver or take control of car

<table>
<thead>
<tr>
<th>SAE J2735 Basic Safety Message</th>
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<tbody>
<tr>
<td>Basic Vehicle State</td>
</tr>
<tr>
<td>(Temp ID, Seq. #, Time, Position</td>
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<tr>
<td>Motion, Control, Vehicle Size)</td>
</tr>
<tr>
<td><strong>Mandatory in Basic Safety Message</strong></td>
</tr>
<tr>
<td>Vehicle Safety Extension</td>
</tr>
<tr>
<td>Event Flags</td>
</tr>
<tr>
<td>Path History</td>
</tr>
<tr>
<td>Path Prediction</td>
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<tr>
<td><strong>Required for V2V Safety Applications</strong></td>
</tr>
<tr>
<td>Other optional safety-related data</td>
</tr>
</tbody>
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5.9GHz DSRC Spectrum Allocation

- **Accident Avoidance, Safety of Life**
- **Control Channel**
- **Hi-Power, Long Range**

Dedicated Vehicle Crash Avoidance Channel
Cooperative Deployment Dilemma

• Usual situation:
  – Market forces reward early deployment
  – Boost sales and reputation
  – Example: autonomous safety features

• Cooperative Technology Situation:
US Approach: NHTSA V2V Mandate

2014
Start Regulatory Process

2016-17
Propose and finalize specific regulation

2019-20
Deployment in new car fleet begins

NHTSA Acting Administrator David Friedman

Also:
- US DOT expanding test beds and field trials
- US DOT Pilot Deployments
- GM announced voluntary deployment 2017
EU Approach: MOU

CAR 2 CAR COMMUNICATION CONSORTIUM

Press release

European vehicle manufacturers working hand in hand on deployment of cooperative Intelligent Transport Systems and Services (C-ITS)

The twelve vehicle manufacturers organised in the CAR 2 CAR Communication Consortium are signing a Memorandum of Understanding (MoU) to commonly bring cooperative Intelligent Transport Systems and Services (C-ITS) onto European roads. Herewith they approve to follow a joint guideline to make traffic and transport even safer, more sustainable and more comfortable in the near future.

vital importance of C-ITS by working together in the CAR 2 CAR Communication Consortium. As a decisive initiative to bring cooperative systems into the market, the twelve vehicle manufacturers currently sign a Memorandum of Understanding (MoU) on a common strategy for the deployment of C-ITS.

By signing the MoU, the leading vehicle manufacturers signalise their intention to provide cooperative systems from 2015 on. Meanwhile they will take into account prescribed technical
Japan Approach: V2X Option

Toyota City, Japan, November 26, 2014 - Starting next year, some of Toyota Motor Corporation’s new models will be compatible with advanced vehicle-infrastructure cooperative systems that use a wireless frequency reserved for Intelligent Transport Systems (ITS). This compatibility will be offered as an option for the "Toyota Safety Sense P" active safety package that will be made available in 2015 on select new models sold in Japan.

The systems will use the dedicated ITS frequency of 760 MHz for road-to-vehicle and vehicle-to-vehicle communication to gather information that cannot be obtained by onboard sensors. At intersections with poor visibility, information about oncoming vehicles and pedestrians detected by sensors above the road will be conveyed via road-to-vehicle communication, and information about approaching vehicles will be conveyed via vehicle-to-vehicle communication, with audio and visual alerts warning drivers when necessary.

In addition, Toyota’s newly-developed Communicating Radar Cruise Control feature allows preceding and following vehicles to maintain safe distances between one another on highways.
Implications of Deployment Models

Voluntary/Optional Model (EU, JP)

– Customer pays explicitly
– Phase into higher end models first, ramp up slowly
– Immediate benefit must be apparent
– More emphasis on “Day 1” applications
  • V2I in designated corridors & cities
  • Sparse V2V, longer range, multi-hop, awareness
– Less emphasis V2V safety, but still important
  • V2V Safety Benefit proportional to (Penetration)^2

Mandate Model (US)

– Customer pays implicitly
– Ramp up more rapidly, but start later
– More emphasis on V2V safety
– Still important to find ways to provide early benefits
Rest of World?

• High interest in IEEE 802.11p-based systems used in US & EU
  – Where US & EU differ, not clear which will be used
  – Canada, Mexico (?) will follow US
• In Asia, interest growing in 760 MHz-based system used in Japan
• China engaging, direction not clear
• Experiences in early US/EU/JP deployment will be watched closely
• Opportunities for 5G? More later
What about V2I in US?

- New V2I Deployment Coalition
- Funding from USDOT
  - Many Connected Vehicle Research Applications are V2I
- Sponsored by AASHTO, ITS America, ITE
- First meeting June 4-5, 2015

Source: ITS America, 4/16/15
We’ve come a long way
Still to go … near term

- Security
- Scalability
- Spectrum Sharing
- Deployment
Scalability

Basic question: will all this still work here?
Biggest concern: BSM safety channel congestion

- Subject of much published research
- Automaker consortium has researched two main approaches, in cooperation with US DOT
- Main distinction: Reactive vs. Adaptive Control
- Secondary distinction: Emphasis on message rate vs. transmit power control
Distributed Reactive Control

Each vehicle determines its message rate $r_i(t)$ from current channel load (e.g. look up rate in a table).

$CBR = \text{Channel Busy Ratio}$

$A \text{ channel loading metric}$

Can equivalently control power, or both power & rate
Distributed Adaptive Control

Each vehicle computes its message rate $r_i(t)$ adaptively based on difference between channel load and a target load.

Algorithm Goals: controlled load, convergence, fairness
Why drive CBR to target?

Test Parameters
- 30 radios
- 6 Mbps
- 544 μsec
- AIFSN = 6
- CWmin = 7

PER and CBR corresponding to max. throughput
Throughput maximized when CBR in 60-70% range

**References**
- An Adaptive DSRC Message Transmission Rate Control Algorithm, Weinfeld, Kenney, Bansal, ITS World Congress, October 2011
LIMERIC

- Linear MEssage Rate Integrated Control
- Provable stability, convergence and fairness

\[ r_j(t) = (1 - \alpha)r_j(t-1) + \beta(r_g - r(t-1)) \]

Rate for node j

\( e(t - 1) \)

\( \beta > 0 \): linear gain adaptive parameter, impacts stability, convergence speed

\( 0 < \alpha < 1 \): contraction parameter, impacts fairness, convergence speed

CBR Target

Current CBR

LIMERIC: A Linear Adaptive Message Rate Algorithm for DSRC Congestion Control, Bansal, Kenney, Rohrs, IEEE TVT Nov. 2013
Example fair convergence

Provable, fair convergence
Tested with 100s vehicles
LIMERIC Joint Rate-Power Control

Rate-Based Power Control

Rate-Power Mapping Function

LIMERIC Adaptive Rate Control

Paper will be presented at ITS World Congress 2015, Bordeaux
Congestion Control Decision

• Critical for NHTSA Rulemaking, so needs to be standardized in 2015
  – SAE will standardize in J2945/1

• EU (ETSI/Car2Car) facing similar choice
  – Decided on a “reactive” approach for Day 1
  – Considering allowing adaptive approach
  – Mixed network behavior is critical
5 GHz Spectrum Sharing

- 2013: 5 GHz rules allow some unlicensed use:

  - New IEEE 802.11ac (Gigabit Wi-Fi) standard allows 80 MHz and 160 MHz channels. Need large new blocks.
  - Potential to add 4 new 80 MHz and 3 new 160 MHz channels in 5 GHz band.
    - One 80 and one 160 MHz channel in DSRC 5.9 GHz band

Source: Cisco
Zoom in to 5.9 GHz band

<table>
<thead>
<tr>
<th>5.850 GHz</th>
<th>5.925 GHz</th>
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<tr>
<td>CH 172: Collision Avoidance Safety</td>
<td>CH 184: High Power Public Safety</td>
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<tr>
<td>CH 175</td>
<td>CH 181</td>
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<tr>
<td>20 MHz</td>
<td>20 MHz</td>
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<tr>
<td>CH 172</td>
<td>CH 180</td>
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<tr>
<td>Service</td>
<td>Service</td>
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<tr>
<td>10 MHz</td>
<td>10 MHz</td>
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<tr>
<td>CH 174</td>
<td>CH 182</td>
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<tr>
<td>Service</td>
<td>Service</td>
</tr>
<tr>
<td>10 MHz</td>
<td>10 MHz</td>
</tr>
<tr>
<td>CH 176</td>
<td>CH 184</td>
</tr>
<tr>
<td>Service</td>
<td>Service</td>
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<tr>
<td>10 MHz</td>
<td>10 MHz</td>
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<tr>
<td>CH 178</td>
<td></td>
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<tr>
<td>Control</td>
<td></td>
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<tr>
<td>10 MHz</td>
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</table>

Reserved 5 MHz

FCC DSRC Channel Designations

Overlapping Wi-Fi
Major Stakeholders

US Congress

US President

FCC

IEEE WiFi

Auto Alliance

NTIA

Department of Transportation

Global Automakers
Rechannelization Proposal

- Move DSRC safety from Ch. 172 to upper band (non-overlap portion)
- Cancel highest 20 MHz Wi-Fi (Ch. 181)
- DSRC use 20 MHz channels in overlap portion instead of 10 MHz
- Problems include: Safety in non-Ch. 172 not protected, Interference in upper channels, 20 MHz is sub-optimal, …
  - See https://mentor.ieee.org/802.11/dcn/14/11-14-1101-01-0reg-a-response-to-the-re-channelization-proposal.pptx for complete critique
Detect-and-vacate Proposal

- Wi-Fi devices listen for DSRC
- If no DSRC → Wi-Fi ok to operate in 5.9 GHz
- Continues to listen while WLAN operates

- When car appears, Wi-Fi detects DSRC
- If DSRC detected → Wi-Fi NOT ok to operate in 5.9 GHz (minimum TBD second delay after each DSRC packet)
- Detection leverages DSRC’s heritage as 802.11p
- Note: in-car Wi-Fi will never use 5.9 GHz
Spectrum Sharing Milestones

- **Feb. 2013**: FCC issues NPRM for 5 GHz
  - Asks if 5.9 GHz sharing is feasible
- **Aug. 2013**: IEEE forms “Tiger Team”
  - DSRC stakeholders participate fully
- **Fall 2013**: Qualcomm and Cisco offer sharing proposals
- **Nov. 2013**: Congressional hearing
- **Winter 2014**: Sen. Rubio bill on timeline for FCC decision
- **Sept. 2014**: DSRC critiques Rechannelization proposal
  - Also indicates Detect-and-vacate proposal has potential
- **March 2015**: Tiger Team ends
  - Poll of participants shows strong support for additional work on Cisco proposal, weak support for Qualcomm
- **May 5 2015**: Auto Trade Associations and Cisco tell FCC about plans for joint testing of Detect-and-vacate prototypes

*Spectrum Sharing is the #1 risk for DSRC deployment in US*
Deployment … Then what?

• Challenge: Technology evolution?
• Opportunity: New applications?
• Other communication options: 5G V2X?
Post-deployment challenge: Protocol evolution

- How to update technology without disenfranchising legacy vehicles?
- Contrast master-slave network with ad hoc
- Master (Base station, Access Point) can manage multiple generations of clients
- Ad hoc:
  - Unicast or small group: Negotiation to common protocol generation
  - Broadcast: ???
- Lower layers more difficult than higher layers
Non-line-of-sight (NLOS) obstacles are a major challenge for automated vehicles, especially at intersections.

Sharing sensor information can improve an automated vehicle’s awareness of potential hazards, including pedestrians, bicyclists, other vehicles, road works …
Augmenting & Sharing Real-Time Map

- Scalability is a concern
- Need adaptive content management
- “Connected, automated vehicles that can sense the environment around them and communicate with other vehicles and with infrastructure have the potential to revolutionize road safety and save thousands of lives.” – US DOT Sec. Foxx 5/13/15

What about 5G for V2X?

3GPP/ITU-R Timeline for 5G (3/17/15)
3GPP New Work on V2X

- Recent study begun in SA1 (Services WG)
- Many use cases brought to April 2015 meeting:

  - Forward Collision Warning
  - Control Loss Warning
  - Emergency Vehicle Warning
  - Emergency Stop
  - C-ACC
  - Queue Warning
  - Road Safety Services
  - Automated Parking
  - Wrong way driving
  - Message Transfer
  - Pre-crash Sensing
  - Traffic Flow Optimization
  - Curve Speed Warning
  - Pedestrian Collision
  - Vulnerable Road User Safety

- Company contributions: LG, Ericsson, Huawei, Qualcomm, ETRI, Samsung, CATT, IPCom, Intel, Interdigital, Nokia, KT Corp., Sony
3GPP New Work on V2X

- Observation #1: Most use cases have safety implications
- Observation #2: Automakers are not proposing these use cases
- Toyota believes 5.9 GHz DSRC is the only technology that has been demonstrated to deliver safety-relevant information with sufficiently low latency and high reliability
- LTE/5G may offer excellent vehicle connectivity options
- We are interested to see this work progress
- Use cases emphasizing non-safety applications should be examined
Questions?

Thank You

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