Technology, Business and Regulation of the “Connected Car”

Alison Chaiken  
Mentor Embedded Software  
alison_chaiken@mentor.com

John Kenney 
Toyota InfoTechnology Center  
jkenney@us.toyota-itc.com
Agenda

Alison:
- Connected vehicle safety and traffic management
- Connection modalities: LTE, 802.11p, SMS, satellite . . .

John:
- V2X Protocols and spectrum
- Security and scalability

Alison:
- European and U.S. pilot projects
- Available HW and SW
- Immediate prospects
V2X Terminology

- Vehicle-to-vehicle (V2V)
- Vehicle-to-infrastructure (V2I)
- On Board Unit (US) = ITS Vehicle Station (EU)
- Road Side Unit (US) = ITS Roadside Station (EU)
- Dedicated Short Range Communication (DSRC) = automated tolling in E.U.

*but*

safety messages in U.S.
NXP Multi-Standard Software Defined Radio ICs enable Car2X communication, saving lives, reducing CO₂

- Emergency Vehicle Warning
- Seeing Around Corners
- Hazard Warning

Car2X use cases address increased safety & prevention of traffic congestion (CO₂ reduction)
“Killer App”: Green-light optimal speed advisory

GLOSA will allow drivers to set optimal green-signal speed.
802.11p vs. LTE vs. Satellite and FM

- 802.11p is the only *low-latency* safety channel.
- LTE has the largest install base and is industry-funded.
- Terrestrial and satellite radio, data-over-voice, SMS also:
  - 3G (UMTS) already employed in simTD (Germany) and Smart In-Car (Netherlands).
  - Telcos are investing heavily in automotive.
Automotive networking needs new protocols in every layer

<table>
<thead>
<tr>
<th>OSI Model</th>
<th>Data unit</th>
<th>Layer</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host</td>
<td>Data</td>
<td>7. Application</td>
<td>Network process to application</td>
</tr>
<tr>
<td>layers</td>
<td></td>
<td>6. Presentation</td>
<td>Data representation, encryption and decryption, convert machine dependent data to machine independent data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5. Session</td>
<td>Interhost communication, managing sessions between applications</td>
</tr>
<tr>
<td></td>
<td>Segments</td>
<td>4. Transport</td>
<td>Reliable delivery of packets between points on a network</td>
</tr>
<tr>
<td>Media</td>
<td>Packet/Datagram</td>
<td>3. Network</td>
<td>Addressing, routing and (not necessarily reliable) delivery of datagrams between points on a network.</td>
</tr>
<tr>
<td>layers</td>
<td>Bit/Frame</td>
<td>2. Data link</td>
<td>A reliable direct point-to-point data connection.</td>
</tr>
<tr>
<td></td>
<td>Bit</td>
<td>1. Physical</td>
<td>A (not necessarily reliable) direct point-to-point data connection.</td>
</tr>
</tbody>
</table>
John:
V2X protocols and spectrum
Security and scalability
DSRC Standards Overview

- Necessary for interoperability
- Most standards fairly mature

**DSRC Security (IEEE 1609.2)**
- 2013

**2009**
- Messages (SAE J2735)
- Min. Perf. Req. (SAE J2945) Draft

**Non-safety applications**
- 2010
- DSRC WSMP
- Service Advertisement (IEEE 1609.3)

- 2010
- TCP/UDP
- IPv6

**2010**
- IPv6

**2010**
- DSRC Upper-MAC (IEEE 1609.4)

**2010**
- DSRC PHY+MAC (IEEE 802.11p)

Comparison 802.11p with AP LAN

- Communication is “Outside the Context of a Basic Service Set” (or OCB, i.e. truly ad hoc)
- Avoiding setup delay is critical for high mobility “Wireless Access in Vehicular Environments” (WAVE)
DSRC Network & Transport Layers (1609.3)

Two choices in US

1. WAVE Short Message Protocol (WSMP)
   - Lightweight compared to Internet protocols (5 byte header)
   - No routing
   - Adequate for many DSRC applications

2. IPv6 + TCP/UDP

   • Note: In Europe a “Geo-Networking” protocol is being defined
1609.2 Security Services

Two primary functions:
1. Authentication – Shows sender is authorized, and that data not altered
2. Encryption – keeps data secret (need for this limited)

Both use “elliptic curve” cryptographic algorithms

Note: Privacy is key element of V2X security

1609.2 supports pseudonymous certificates – not linked to car
Identifiers (certificates, MAC, etc.) changed every few minutes
## SAE J2735 Basic Safety Message (BSM)

<table>
<thead>
<tr>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
</tr>
<tr>
<td>3D Position</td>
</tr>
<tr>
<td>Position Accuracy</td>
</tr>
<tr>
<td>Speed</td>
</tr>
<tr>
<td>Heading</td>
</tr>
<tr>
<td>Steering Wheel Angle</td>
</tr>
<tr>
<td>Acceleration</td>
</tr>
<tr>
<td>Brake Status</td>
</tr>
<tr>
<td>Vehicle Size</td>
</tr>
<tr>
<td>Event Flags</td>
</tr>
<tr>
<td>Path History</td>
</tr>
<tr>
<td>Path Prediction</td>
</tr>
<tr>
<td>Other optional fields</td>
</tr>
</tbody>
</table>

Not included in every BSM

BSM is broadcast by each vehicle several times per second over a few hundred meters.
We’ve come a long way
Still to go … near term

- Security
- Positioning
- Scalability
- Deployment
Security Infrastructure

Can I trust you?
Get/Renew credentials?
Detect misbehavior?

Example misbehavior:
BSM with valid signature reports fictitious car.

Certificate
Revocation Lists

New Certificates

Misbehavior Reports

Certificate Authority (CA)

CA Internally segregated to prevent insider attack

What medium?

Example misbehavior:
BSM with valid signature reports fictitious car.

Certificate Authority (CA)

What medium?
Positioning

Relative Distance?

Which Lane?

Where in Lane?

Which Road?
Scalability

Basic question: will all this still work here?
Aspects of Scalability

• Processing resource
  • Collision threat assessment
  • Per-message Security
• Wireless Channel resource
• Security Infrastructure

Hard to throw money at this one
# US DSRC Spectrum: Seven 10 MHz channels

<table>
<thead>
<tr>
<th>Channel</th>
<th>Service/Channel Type</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH 172</td>
<td>Reserved 5 MHz</td>
<td>5.850 GHz</td>
</tr>
<tr>
<td>CH 174</td>
<td>Service 10 MHz</td>
<td>5.870 GHz</td>
</tr>
<tr>
<td>CH 176</td>
<td>Service 10 MHz</td>
<td>5.890 GHz</td>
</tr>
<tr>
<td>CH 178</td>
<td>Control 10 MHz</td>
<td>5.910 GHz</td>
</tr>
<tr>
<td>CH 180</td>
<td>Service 10 MHz</td>
<td>5.920 GHz</td>
</tr>
<tr>
<td>CH 182</td>
<td>Service 10 MHz</td>
<td>5.940 GHz</td>
</tr>
<tr>
<td>CH 184</td>
<td>Service 10 MHz</td>
<td>5.960 GHz</td>
</tr>
</tbody>
</table>

### Diagram:
- **Ch. 172:** Collision Avoidance Safety
- **Ch. 184:** Public Safety

- **Ch. 178:** Control Channel
- **WAVE Service Advertisements:** WAVE Service Advertisements are broadcast here, indicating how to access services on other “Service Channels”
Potential new Wi-Fi channels in 5 GHz band

- 802.11n introduced 40 MHz channels
- 802.11ac introducing 80 MHz and 160 MHz channels
- UNII-2 (A, B, C): radar is primary, Dynamic Frequency Selection (DFS) is required by Wi-Fi
Spectrum Sharing Timeline

Key steps:
- Identify sharing technology candidate(s)
- Test rigorously

- **President:** Make 500 MHz new spectrum available by 2020

- **2010**
  - Global mobile data volume more than doubles for 4th year in a row

- **2011**
  - New law requires:
    - FCC and NTIA to act on 5.3 GHz
    - NTIA to study 5.9 GHz (Feb.)

- **2012**
  - NTIA 5 GHz report: support sharing, note risks (Jan.)
  - Pres. Council Advisors Science & Tech (PCAST) calls for 1000 MHz shared use pilot projects (July)

- **2013**
  - FCC NPRM 13-49: Share 5.3 and 5.9, Simplify 5 GHz rules (Feb.)
  - NPRM 13-49 comments due (May)
  - Auto group met with FCC and White House Science Office (Sept.)

- **2014**
  - IEEE 802.11 forms tech. Tiger Team (Aug.)

- **2015**
  - US House Hearing (Nov.)

**FCC = Federal Communications Commission**
**NTIA = National Telecommunications and Information Administration**
“Detect-and-vacate” concept

• Key is to avoid colliding with or delaying DSRC packets

• Wi-Fi devices already avoid overlapping transmissions via a “listen-then-talk” protocol
  • Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA)

• Wi-Fi can detect DSRC device in area via similar function that looks for 10 MHz DSRC packet “signature”

• Before sending anywhere in 5.9 GHz band, listen for DSRC in all 7 channels
  • If no DSRC detected, ok to operate WLAN
  • If DSRC detected, keep out of the band for [TBD] time

For more information see: https://mentor.ieee.org/802.11/dcn/13/11-13-0994-00-0reg-proposal-for-u-nii-4-devices.docx

Available V2X Hardware and Software
Manufacturers of 802.11p radios

- NEC
- NXP/Cohda
- Cisco/Cohda Wireless
- Commsignia (BSD-based)
- Denso
- Delphi
- Savari
- Kapsch
- Siemens
- UNEX
- AutoTalks
- Arada
- DGE
- Componentality
- Broadcom

UNEX DCMA-86P2 miniPCI

collected by Alexandru Petrescu, cea.fr
RSUs and OBUs are mostly **OpenWRT** (Linux) routers

802.11p chipsets made by Atheros, Ralink, Cohda/NXP

Image: “IntelliDrive Technology based Yellow Onset ® Decision Assistance System for Trucks”, Sharma et al.
Recently completed field trials:

Safety Pilot  simTD  Smart In-Car
Safety Pilot V2V trial in Ann Arbor MI

- Originally 8/2012-8/2013, but extended.
- 2800 cars, trucks and buses from 7 automakers.
- 64 embedded systems, 300 aftermarke, rest transmit-only.
- NHTSA decision expected in December 2013.
  — “Notice of Proposed Rule Making” likely late 2014

AUGUST 28, 2013 AT 7:07 PM
U.S. extends connected vehicle pilot program in Ann Arbor

The National Highway Traffic Safety Administration is extending a pilot project in Ann Arbor on connected vehicles by another six months, but said it won’t change its timetable for deciding whether to move forward with the new technology.
E.U.'s Safe Intelligent Mobility—Test Area Germany (simTD) Pilot

- Emphasizes V2I.
- Opel; Audi; BMW; Daimler; Ford; VW; Bosch; Conti; Deutsche Telekom, plus govs and unis.
- 120 vehicles and 3 motorcycles plus RSUs.
- Data collection 2012-6/2013, 41K hrs and 1.65M km.
- 2015: ‘Cooperative ITS Corridor Rotterdam - Frankfurt am Main - Vienna’
  - Features “Roadworks Warning” and “Detection of Traffic Conditions”.
Unlike SafetyPilot, includes Central Station and emphasizes V2I.
Near Future

13.06.2013

ITS corridor from Vienna to Rotterdam

Austrian Transport Minister Bures signs an agreement with Germany and Netherland: As from 2015, the highway route Rotterdam-Frankfurt/M-Vienna becomes an ITS corridor with state of the art technology.

GAO
Report to Congressional Requesters

November 2013

INTELLIGENT TRANSPORTATION SYSTEMS

Vehicle-to-Vehicle Technologies
Expected to Offer Safety Benefits, but a Variety of Deployment Challenges Exist
Conclusions

- V2X is a key enabler of vehicle autonomy.
- Enormous potential to improve safety and optimize traffic flow.
- Burgeoning opportunities for HW, SW, backhaul, analytics . . .
- Extensive government investment in EU and U.S.
- Now is a great time to get involved.
Resources

- simTD, Safety Pilot, Smart In-Car
- ITSSv6, CALM, ETSI, ISO C-ITS
- SAE, IEEE, ISO, IETF, FCC, NHTSA standards
- IETF-ITS mailing list
- Componentality's FlexRoad and Drivity
- Automotive Grade Linux
- Telematics News
- Wired Autopia
- slideshare.net/chaiken
Extras
SAE Standards

**J2735 Message Set Dictionary**
- Defines 15 messages and constituent data elements
- Key messages:
  - Basic Safety Message (V2V safety)
  - Signal Phase and Timing
  - MAP

**J2945 Minimum Performance Requirements (MPR)**
- Not yet published – expected 2015
- Example content for Basic Safety Message:
  - Message frequency and transmit power
  - Accuracy of sensor data in message (e.g. position, velocity)
DSRC Spectrum Sharing

Wi-Fi has been a tremendous success

US Government supports allowing Wi-Fi to share spectrum in new bands with "primary users" (e.g. radar, satellite)

US FCC considering allowing Wi-Fi to share 5.9 GHz DSRC band


Requested comments from stakeholders

IEEE 802.11 "Tiger Team" considering technical sharing solutions

"Detect-and-vacate" option

"Re-channelize and share packet by packet" option

Auto industry wants to ensure no "Harmful Interference" from Wi-Fi. Not yet clear if a solution exists.

Any candidate solution will require rigorous testing
Safety Channel Scalability

Reasons why we emphasize message rate:

• Predictable impact independent of topology
• Maintain connectivity at distances of interest
• Fine grained control
• Large dynamic range (no obvious minimum)
• Toyota ITC’s LIMERIC algorithm is under investigation in US and EU

DSRC Standards Overview

- Necessary for interoperability
  - DSRC PHY+MAC (IEEE 802.11p)
  - DSRC Upper-MAC (IEEE 1609.4)
  - IPv6
  - TCP/UDP
  - Non-safety applications
  - Message Dictionary (SAE J2735)
  - Min. Perf. Req. (SAE J2945)
- Most standards fairly mature

IEEE 1609.4: Multi-Channel Operation

- Objective: Multiplex one radio effectively among multiple channels
- Approach: use time division
- Optional: **Not used for safety channel in US**

![Diagram](image)
Componentality: open-source 802.11p stack: the bluez of DSRC?

Typical Set Of Technologies

OpenWrt
ATHxK drivers
WAVE library
ITS applications

…and nothing else!

Source: “Using Open Source Solutions for V2V and V2I Communications,” Automotive Grade Linux webinar
802.11p (WAVE) vs. other Comms Modes

- Lower-overhead protocol for safety messages.
- No access point (AP) and no basic service set (BSS)
  - Too much delay for moving vehicles.
  - Lower latency than 802.11a/b/g/n, LTE or satellite.
- Message priorities 0-7.
- Half-width channels; always ad hoc.
- Up to 33 dBm (~1 km) in E.U. and 44 dBm in U.S.
- No upstream Linux driver.
# V2V Model Deployment Safety Applications

<table>
<thead>
<tr>
<th>OEM/Applications</th>
<th>Ford</th>
<th>GM</th>
<th>Honda</th>
<th>Mercedes</th>
<th>Toyota</th>
<th>Hyundai-Kia</th>
<th>Nissan</th>
<th>VW-Audi</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEBL</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>FCW</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>BSW / LCW</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>(BSW)</td>
</tr>
<tr>
<td>DNPW</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IMA</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>LTA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

EEBL: Emergency Electronic Brake Lights  
FCW: Forward Collision Warning  
BSW/LCW: Blind Spot Warning/Lane Change Warning  
DNPW: Do Not Pass Warning  
IMA: Intersection Movement Assist  
LTA: Left Turn Assist

Source: M. Lukuc, Connected Vehicle Public Meeting
Why V2V needs low latency

Target Scenarios for Forward Crash Warning (FCW) & Lane Change Warning (LCW)

**FCW**
- Lead Vehicle Stopped
- Lead Vehicle Slower
- Lead Vehicle Decelerating

**LCW**
- Changing Lanes/Same Direction
- Drifting/Same Direction
- Turning/Same Direction

Source: J. Harding, Connected Vehicle Public Meeting
Dual protocol stacks of simTD

- Based on ETSI ITS G5 plus GeoNetworking.

From Automotive Internetworking, courtesy M. Bechler, BMW.
simTD's “vehicle stations”

Linux router + Windows XP Host

Linux in V2I:
Advanced Transportation Controller (ATC)

Applications: GLOSA; Traffic Surveillance; Ramp Meter; Dynamic Message Signs; Weather monitor; Weigh stations; Rail intersections; Lane usage controls; Roadworks warning . . .

Source: Institute for Traffic Engineers
Internet Engineering Task Force (IETF) work on Geonetworking and ITS

- 3 draft standards in preparation
  - Geonetworking (submitted)
  - 'Scenarios and Requirements for IP in Intelligent Transportation Systems' (submitted)
  - IPv6 over 802.11p (particular GENIVI interest)
  - V2X (with MANET working group of IETF?)

- Info: https://www.ietf.org/mailman/listinfo/its

- chief organizer: Alex Petrescu of CEA

- in contact with GENIVI Networking Expert Group
Special cases

- Transit-service vehicles
- Emergency responders
- Over-the-air software updates
- Agricultural equipment
- Fleet vehicles
- Rental cars

... and many more.
Safety Pilot's transit vehicle system

Source: S. Mortensen, Connected Vehicle Public Meeting
Internet Engineering Task Force

Internet-Draft

Intended status: Informational

Expires: March 23, 2014

Georgios Karagiannis
University of Twente

Geert Heijenk
University of Twente

Andreas Festag
NEC Germany

Alexandru Petrescu
CEA

September 23, 2013

Internet-wide Geo-networking Problem Statement
draft-karagiannis-problem-statement-geonetworking-00

Abstract

This document describes the need of specifying Internet-wide location-aware forwarding IETF-based protocol solutions that provide packet routing using geographical positions for packet transport.
Safety Pilot participants

Roadside:
  Arada, Kapsch, ITRI, Cohda/Cisco, Savari

In-vehicle:
  AutoTalks, Cohda, Denso, DGE, ITRI, Savari, Arada

Aftermarket Safety Devices:
  Cohda/Delphi, Cohda/Visteon, Denso, Kapsch

Automakers:
  GM, Ford, Toyota, Honda, VW, Daimler, Hyundai and Nissan
Resources

- ITSSv6
  https://project.inria.fr/itssv6/users/
- CALM
  http://calm.its-standards.info/
- SAE, IEEE, ISO, IETF, FCC, NHTSA standards
  http://simtd.de/
- Safety Pilot
  http://www.its.dot.gov/presentations.htm
- Smart In-Car
- ETSI, ISO C-ITS
- Automotive Grade Linux
  http://www.linuxfoundation.org/collaborate/workgroups/automotive-grade-linux
- IETF-ITS mailing list
  https://www.ietf.org/mailman/listinfo/its
- Componentality's FlexRoad and Drivity
  http://componentality.com/flexroad/
  http://componentality.com/drivity/
- Telematics News
  http://telematicsnews.info/
- Wired Autopia
  http://wired.com/autopia/
- slideshare.net/chaiken