

# Technology, Business and Regulation of the “Connected Car”

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# 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

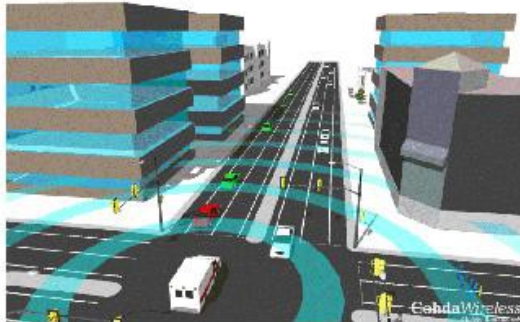
- Vehicle-to-vehicle (V2V)
- Vehicle-to-infrastructure (V2I)
- On Board Unit (US) = ITS Vehicle Station (EU)
- Road Side Unit (US) = ITS Roadside Station (EU)
- Dedicated Short Range Communication (DSRC)  
= automated tolling in E.U.

*but*

safety messages in U.S.

# NXP Multi-Standard Software Defined Radio ICs enable Car2X communication, saving lives, reducing CO<sub>2</sub>

## Emergency Vehicle Warning



## Seeing Around Corners



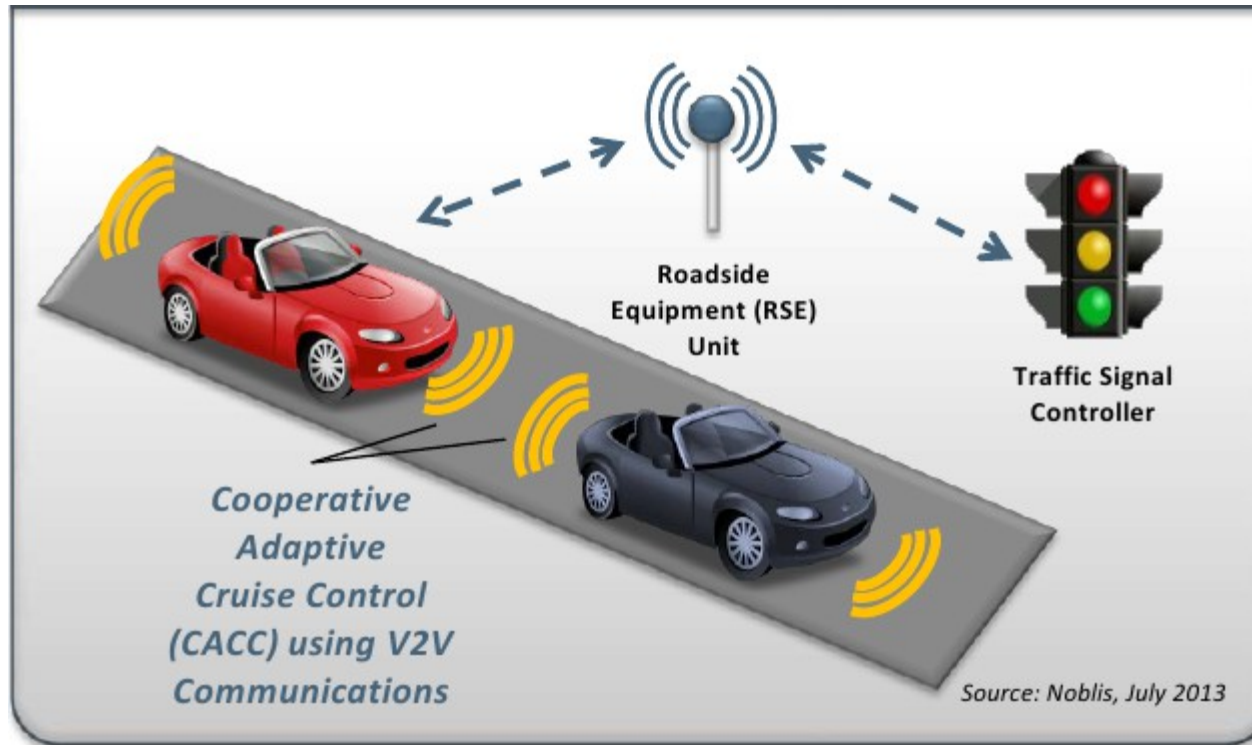
## Hazard Warning



Car2X use cases address increased safety & prevention of traffic congestion (CO<sub>2</sub> 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

OSI Model			
	Data unit	Layer	Function
Host layers	Data	7. Application	Network process to application
		6. Presentation	Data representation, encryption and decryption, convert machine dependent data to machine independent data
		5. Session	Interhost communication, managing sessions between applications
	Segments	4. Transport	Reliable delivery of packets between points on a network
Media layers	Packet/Datagram	3. Network	Addressing, routing and (not necessarily reliable) delivery of datagrams between points on a network.
	Bit/Frame	2. Data link	A reliable direct point-to-point data connection.
	Bit	1. Physical	A (not necessarily reliable) direct point-to-point data connection.





John:

# V2X protocols and spectrum Security and scalability

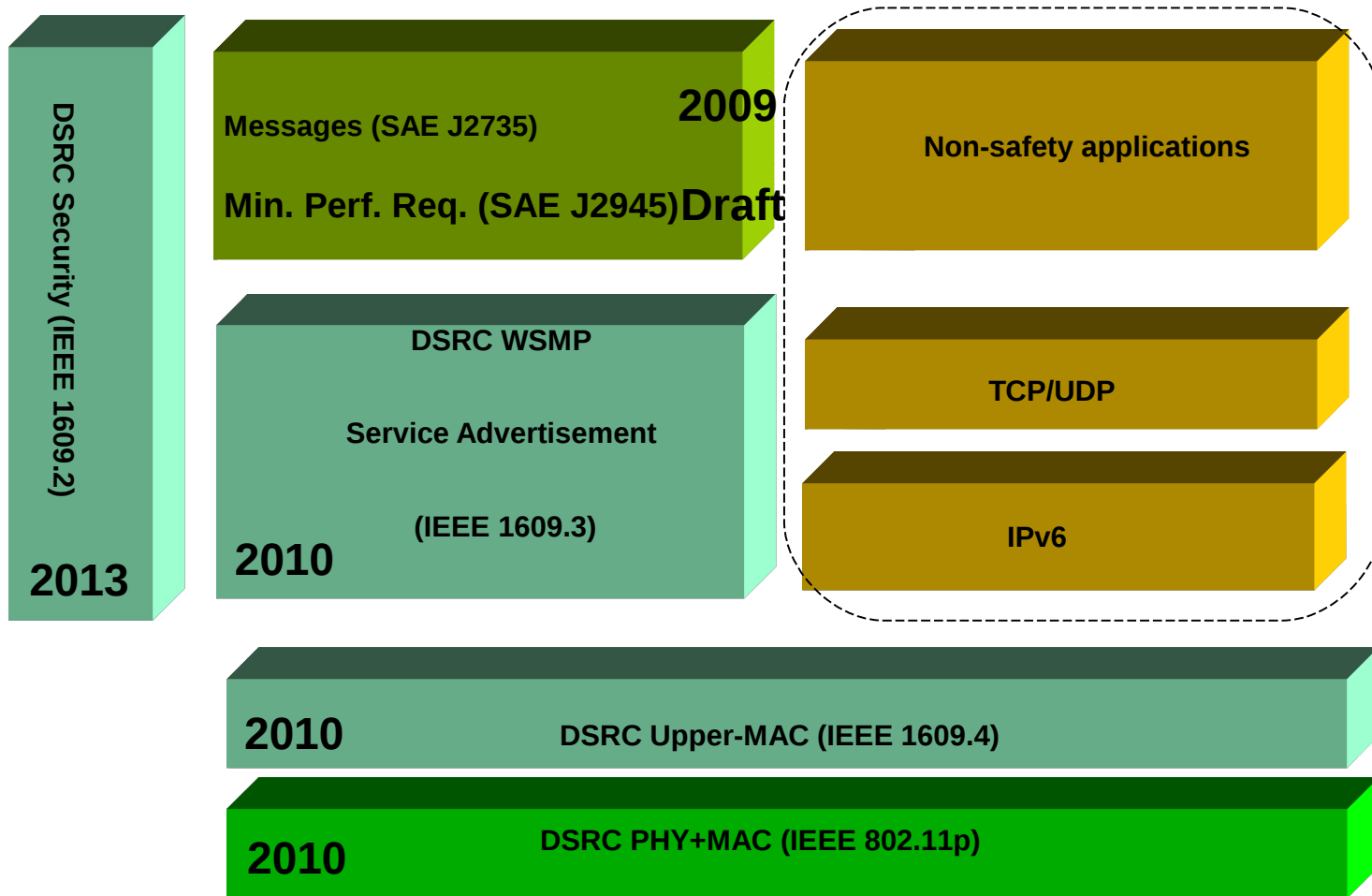


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# DSRC Standards Overview

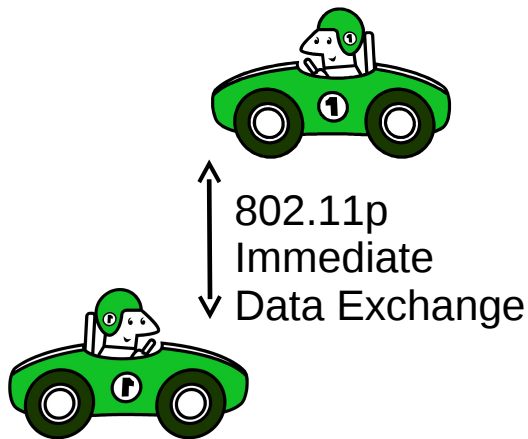
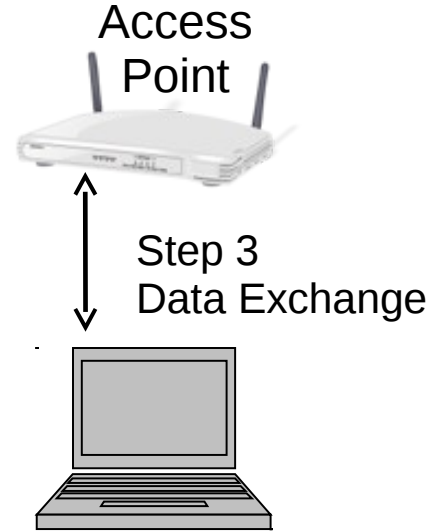
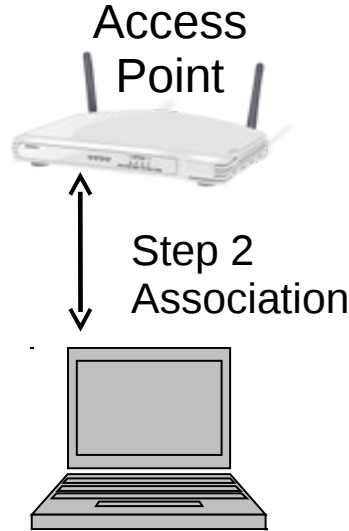
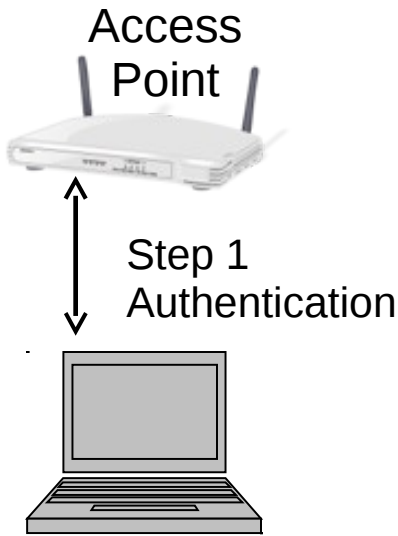
- Necessary for interoperability
- Most standards fairly mature



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



# 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

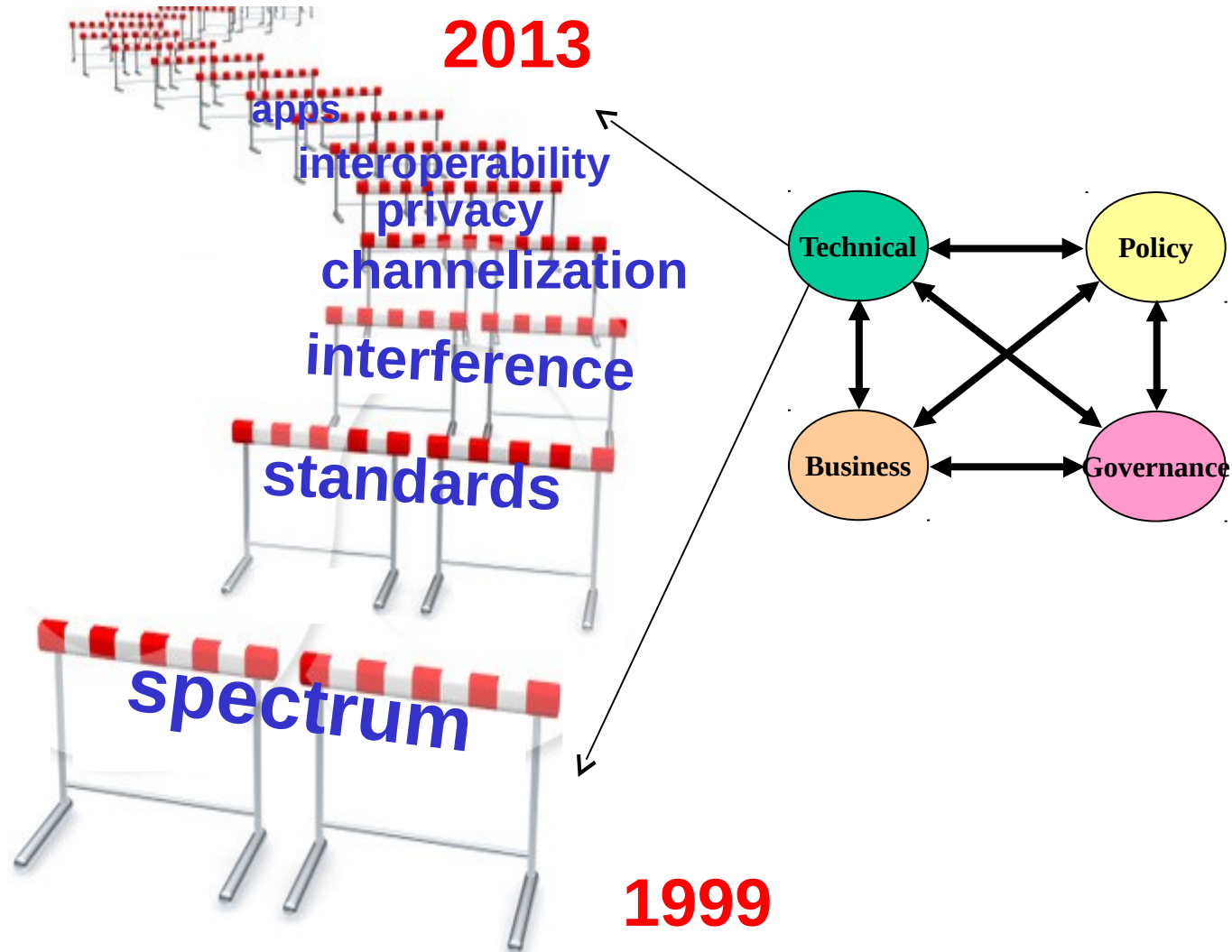
# SAE J2735 Basic Safety Message (BSM)

Item
Time
3D Position
Position Accuracy
Speed
Heading
Steering Wheel Angle
Acceleration
Brake Status
Vehicle Size
Event Flags
Path History
Path Prediction
Other optional fields

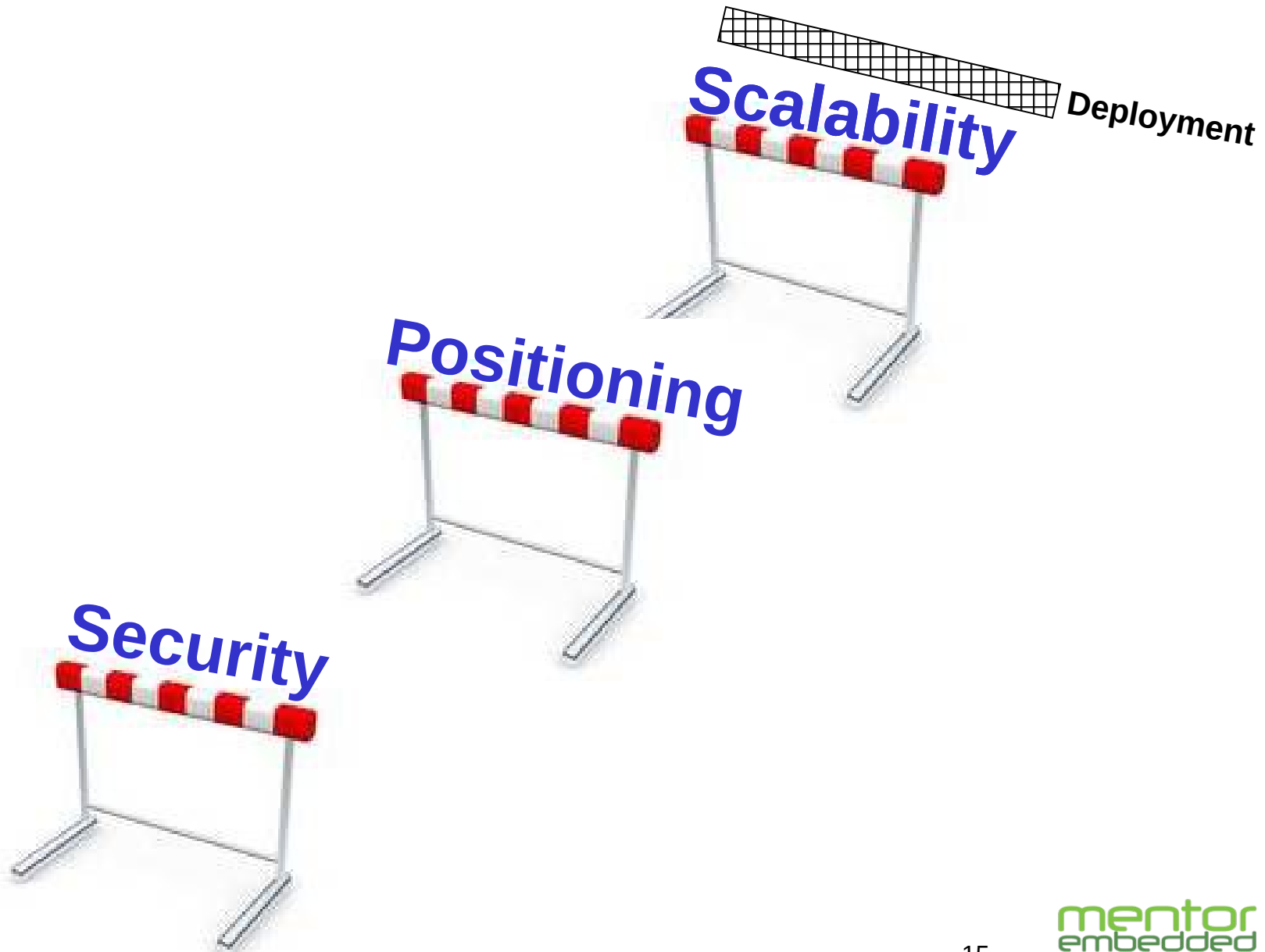
**Not included in every BSM**

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 Infrastructure

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

Example misbehavior:  
BSM with valid signature  
reports fictitious car.

CA Internally segregated  
to prevent insider attack

**Certificate  
Revocation Lists**

**New Certificates**

**Misbehavior  
Reports**



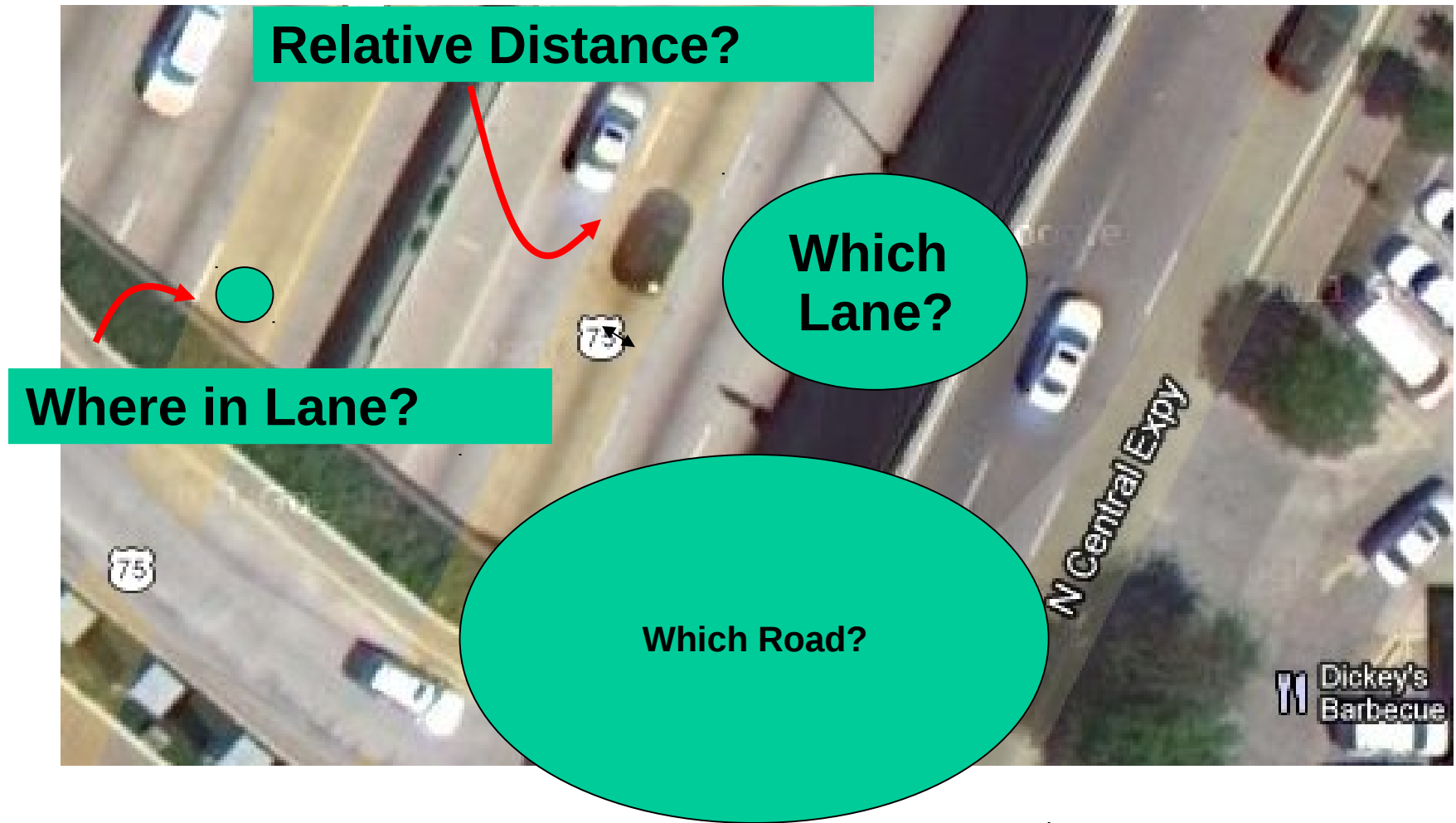
**Certificate  
Authority (CA)**

**What medium?**



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# Positioning



# Scalability

Basic question: will all this still work here?

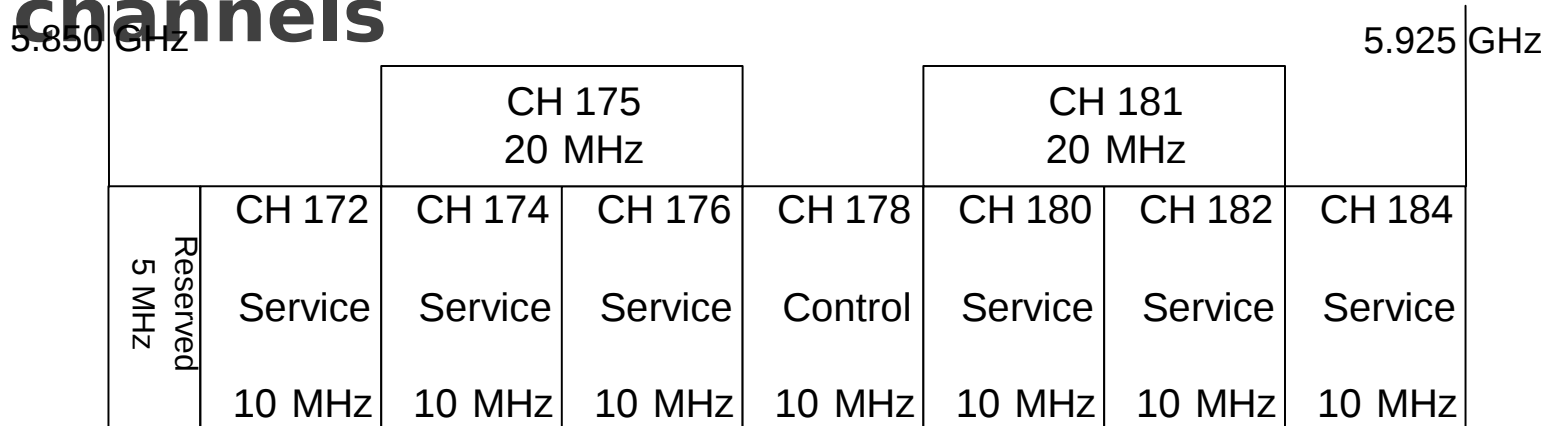


# Aspects of Scalability

- 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



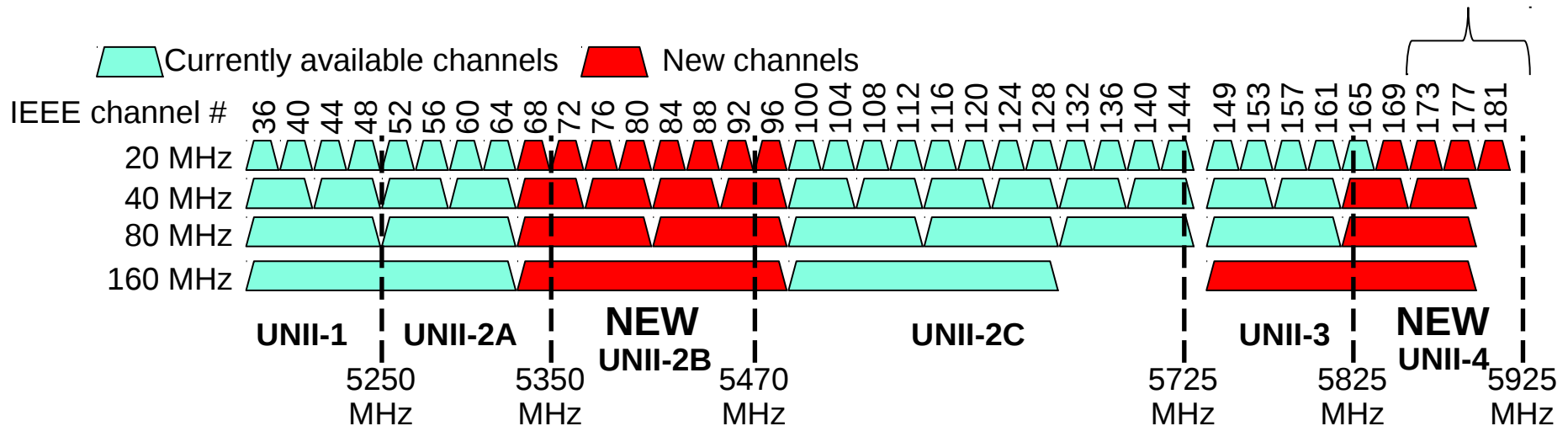
**Ch. 172:**  
**Collision Avoidance Safety**

**Ch. 184: Public Safety**

- Ch. 178:
- Control Channel
- WAVE Service Advertisements are broadcast here, indicating how to access services on other “Service Channels”



# Potential new Wi-Fi channels in 5 GHz band

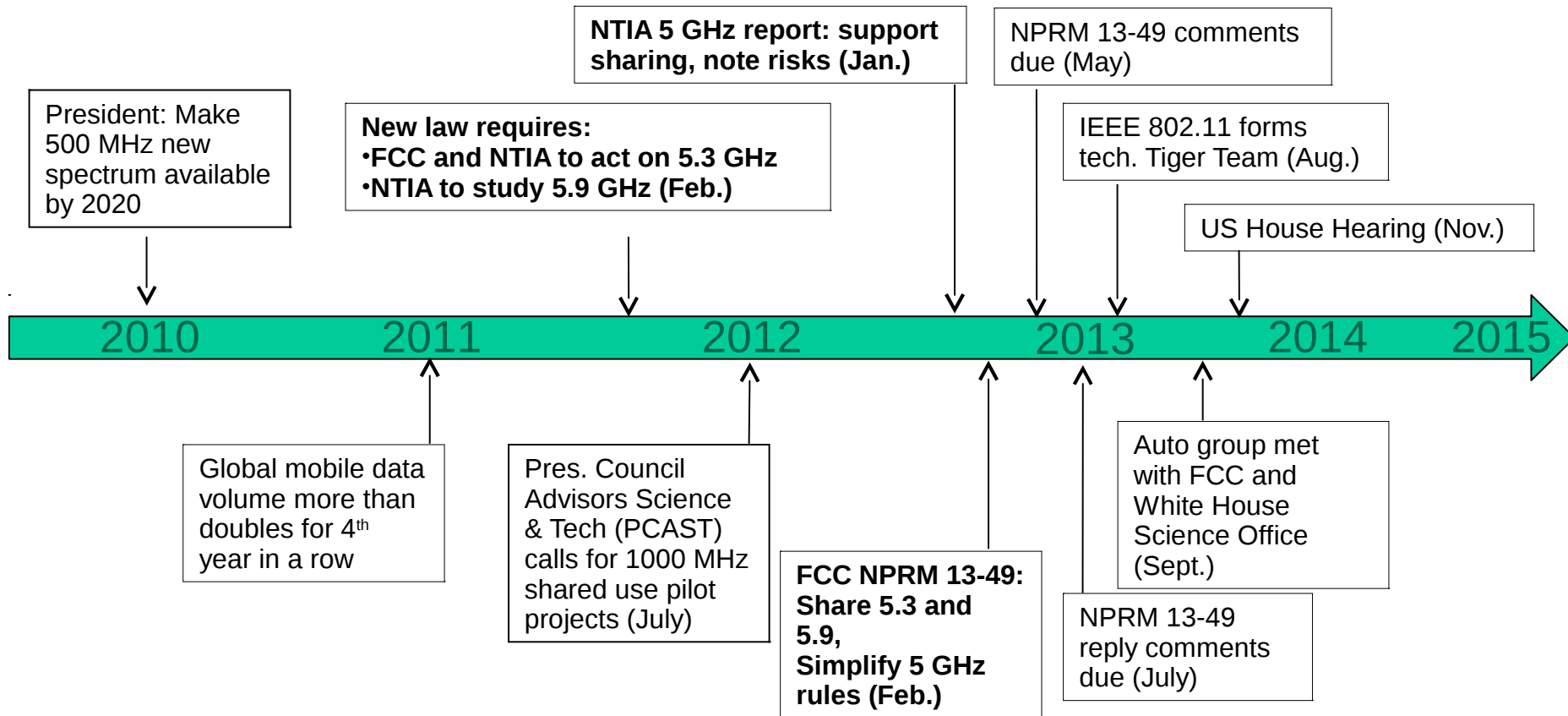


- 802.11n introduced 40 MHz channels
- 802.11ac introducing 80 MHz and 160 MHz channels
- UNII-2 (A, B, C): radar is primary, Dynamic Frequency Selection (DFS) is required by Wi-Fi

# Spectrum Sharing Timeline

## Key steps:

- Identify sharing technology candidate(s)
- Test rigorously



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





# Available V2X Hardware and Software

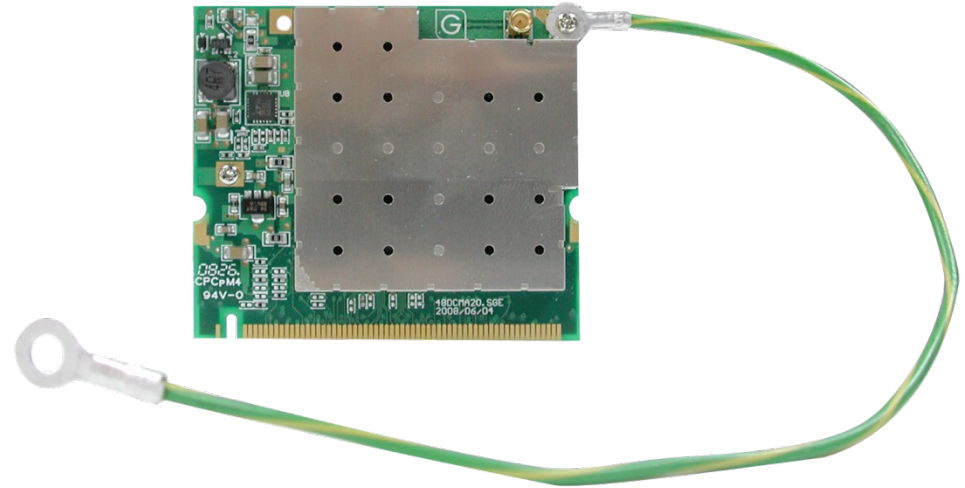


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# Manufacturers of 802.11p radios

- 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

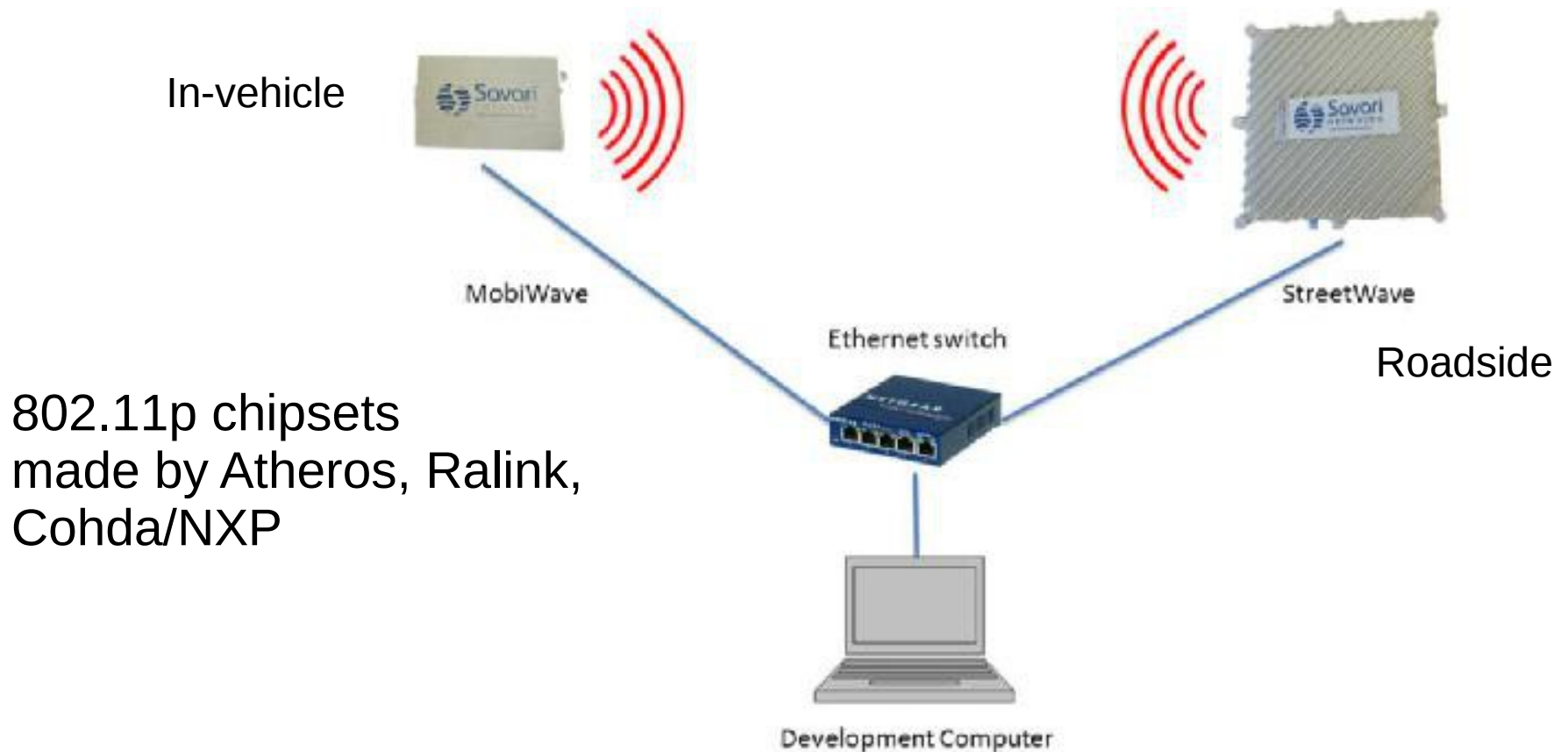


Image: “IntelliDrive Technology based Yellow Onset ® Decision Assistance System for Trucks”, Sharma et al.



Recently completed field trials:

Safety Pilot simTD Smart In-Car



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# 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 aftermarket, 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

DAVID SHEPARDSON AND MELISSA BURDEN COMMENTS 

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.

[• Email](#)



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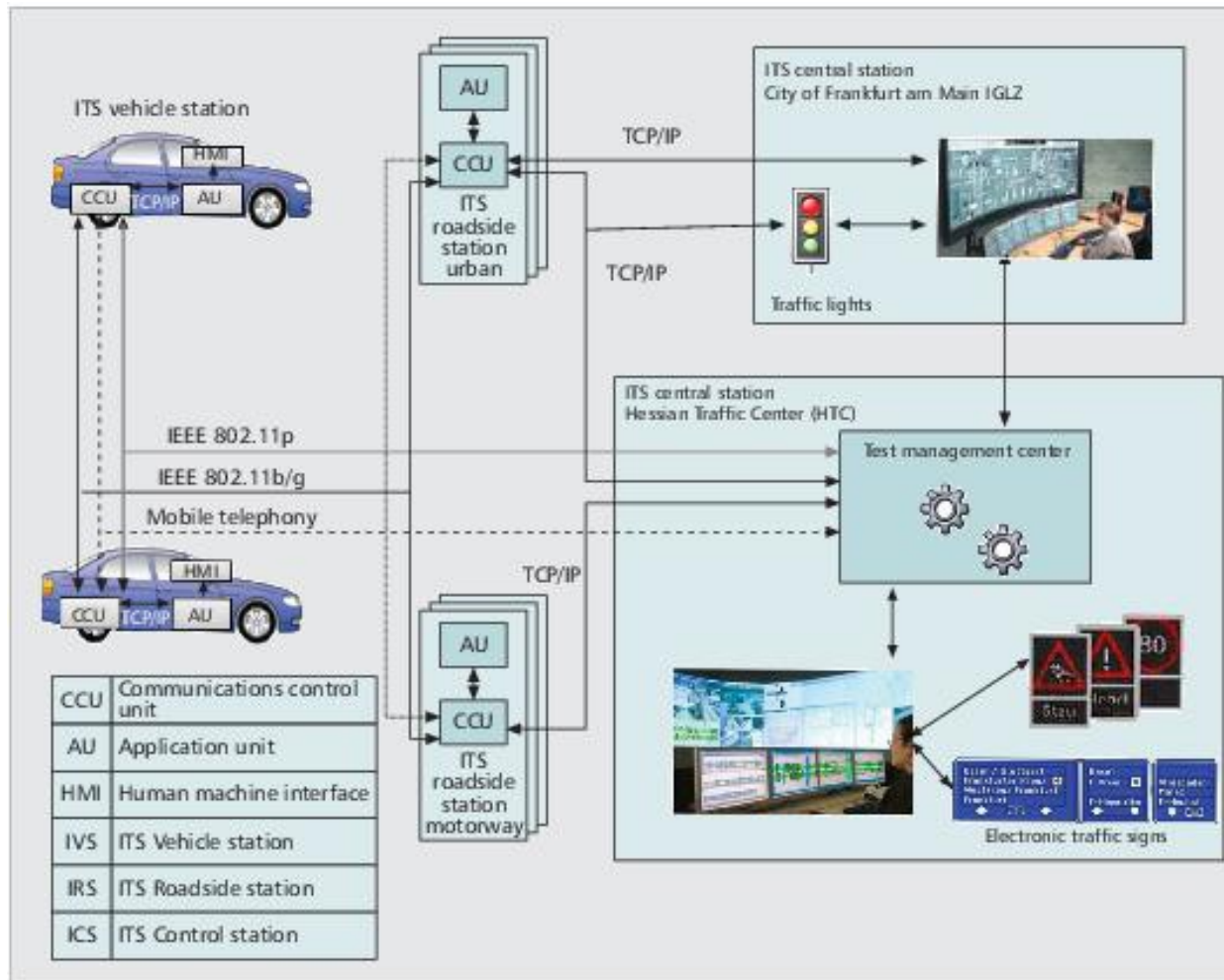
# E.U.'s Safe Intelligent Mobility—Test Area Germany (**simTD**) Pilot

- 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”.





# Architecture of simTD



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.



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



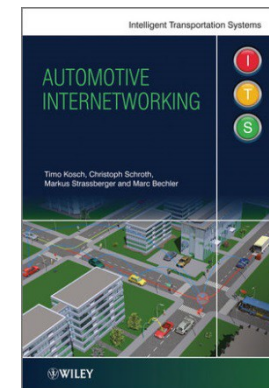
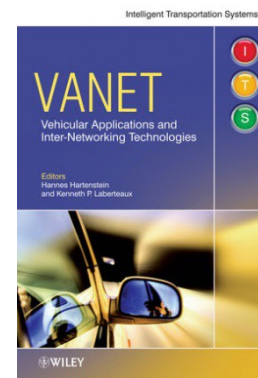
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# Conclusions

- 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](http://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
- Typically sent by roadside unit at intersection

## 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

Issued “Notice of Proposed Rule Making” Feb. 2013

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



- Lots of control knobs
- Can be used in combination or alone
- Can be responsive to different stimuli

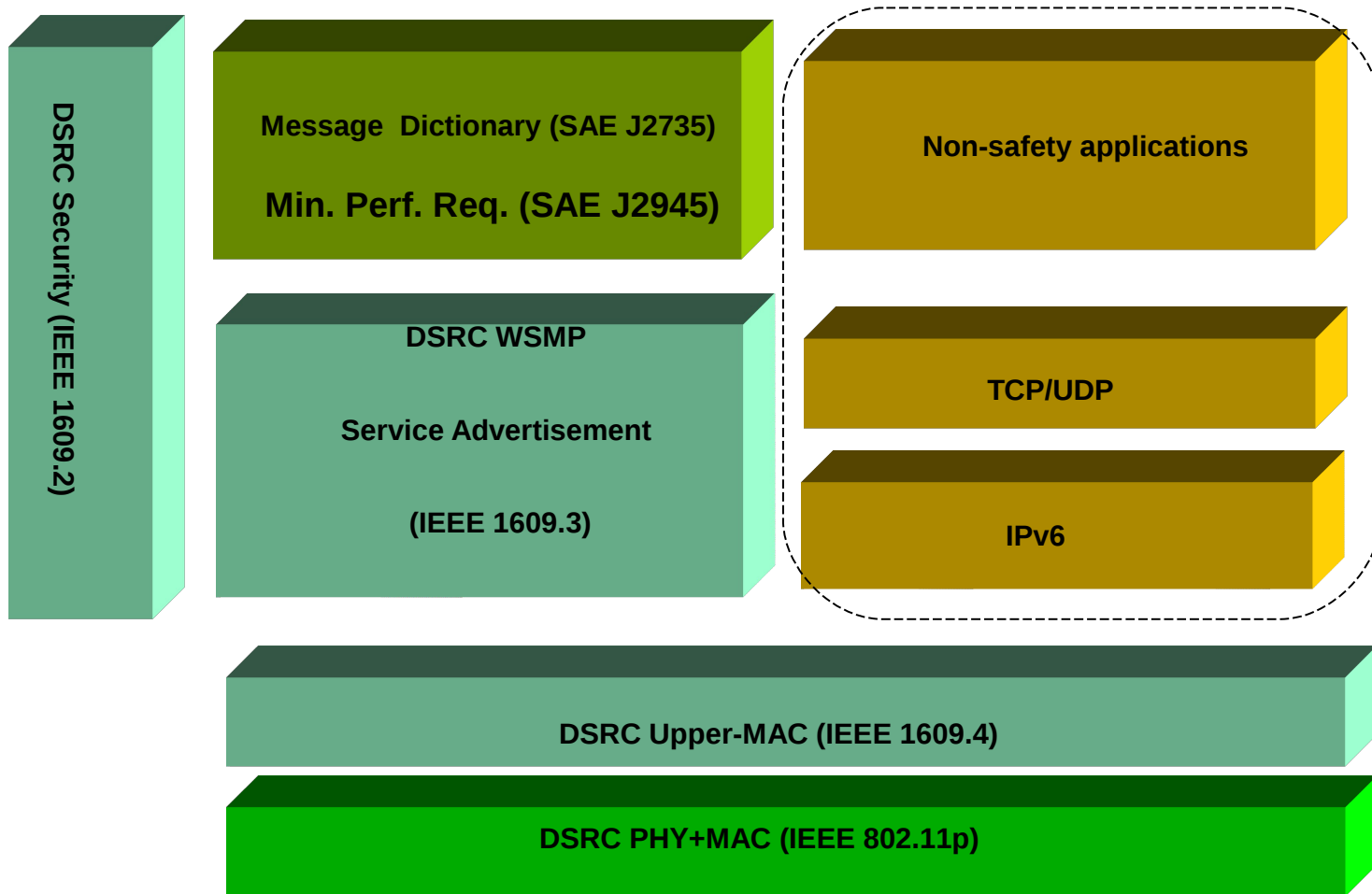
## Reasons why we emphasize message rate:

- 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

See: G. Bansal, J. Kenney, and C. Rohrs, "LIMERIC: A Linear Adaptive Message Rate Control Algorithm for DSRC Congestion Control," IEEE Trans Vehicular Technology, Vol. 62, Issue 9, pp. 4182-4197, November 2013

# DSRC Standards Overview

- Necessary for interoperability
- Most standards fairly mature



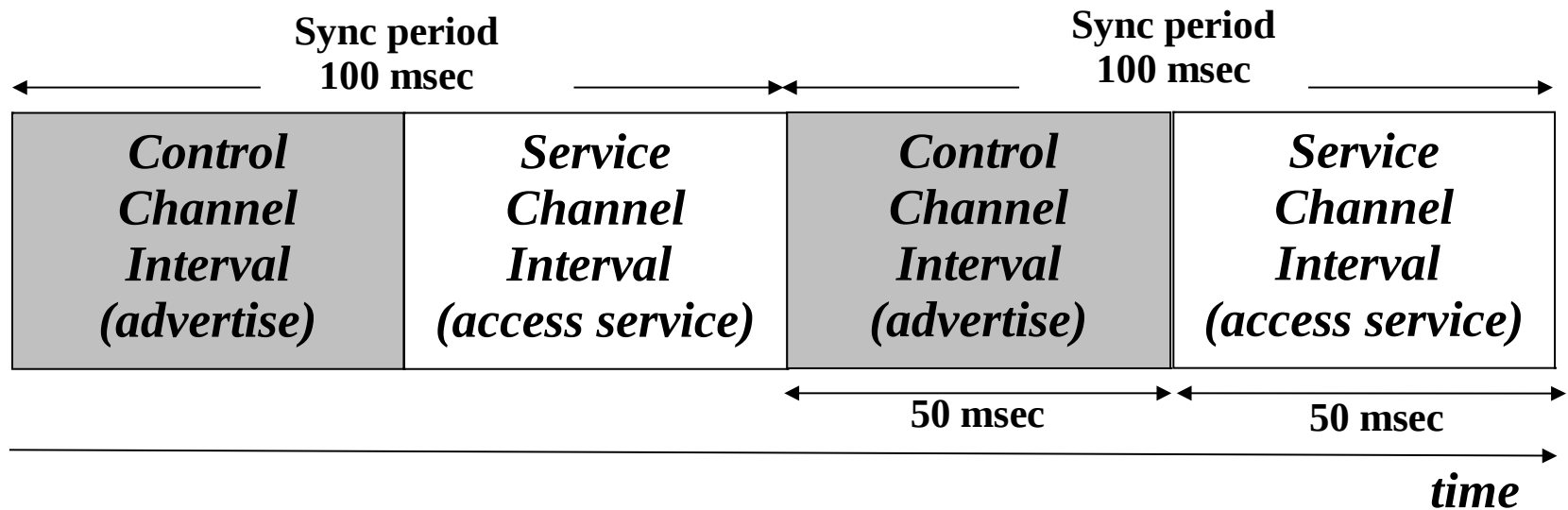
See: J. Kenney, "DSRC Standards in the United States", Proc. IEEE, July 2011, Vol. 99, No. 7, pp. 1162-1182



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# 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**



# 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

OEM/Applications	Ford	GM	Honda	Mercedes	Toyota	Hyundai-Kia	Nissan	VW-Audi
EEBL	X	X	X	X	X			X
FCW	X	X	X	X		X	X	X
BSW / LCW	X	X	X	X	X	X	X (BSW)	
DNPW	X	X	X					
IMA	X	X	X	X	X			X
LTA							X	

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



U.S. Department of Transportation

*This is US Government work and may be  
copied or distributed without permission*

5



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

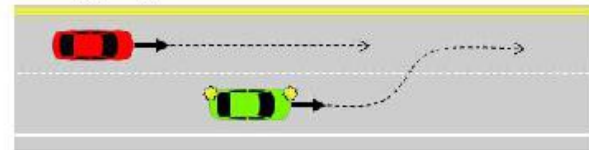


Lead Vehicle Decelerating

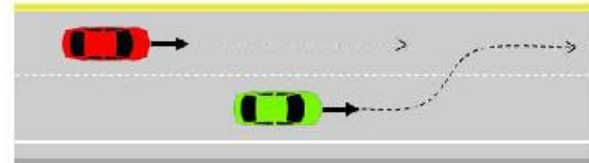


### LCW

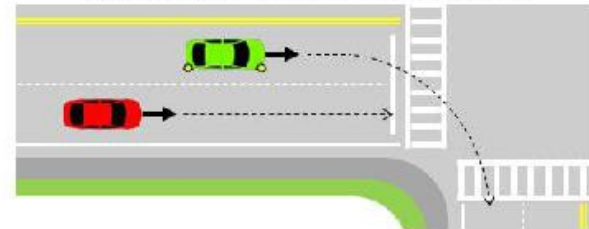
Changing Lanes/Same Direction



Drifting/Same Direction



Turning/Same Direction



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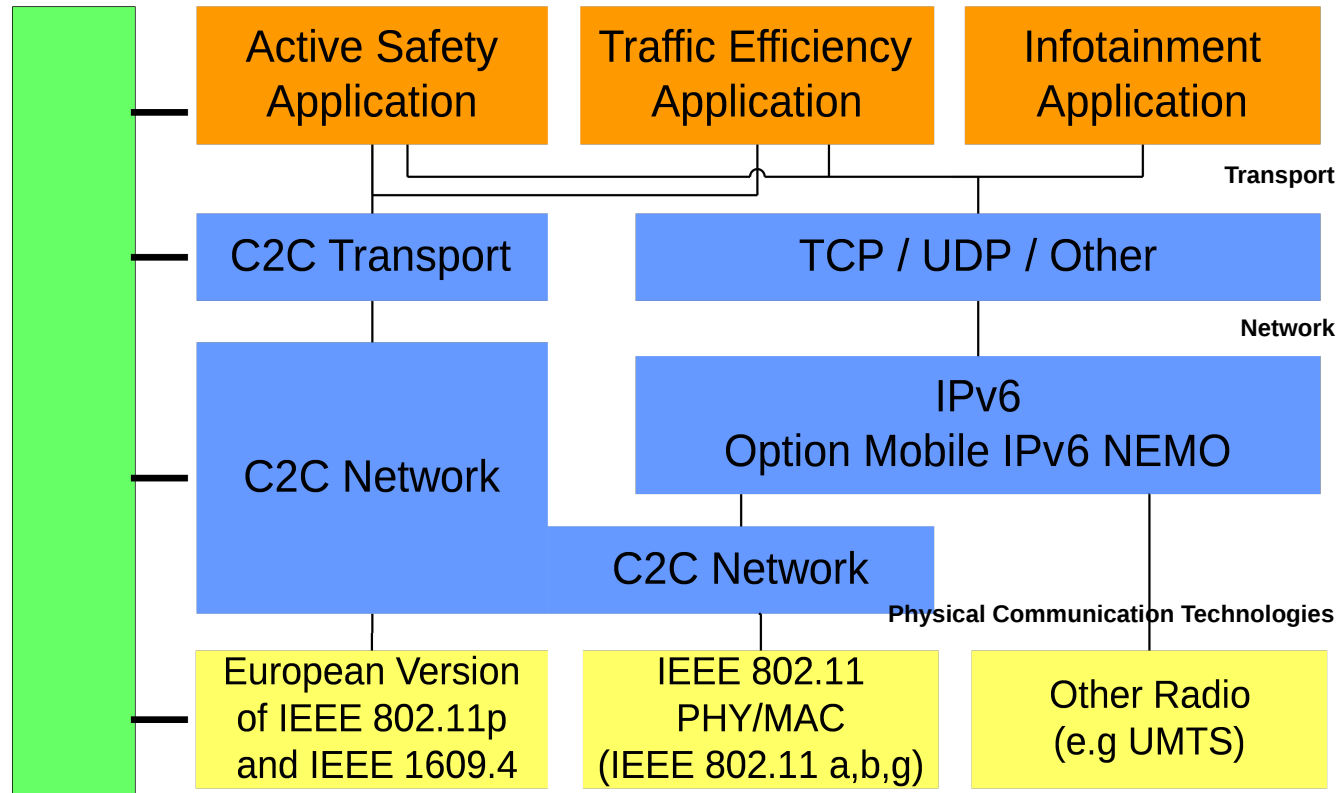
Source: J. Harding, Connected Vehicle Public Meeting

# Dual protocol stacks of simTD

- Based on ETSI ITS G5 plus GeoNetworking.

Management

Applications

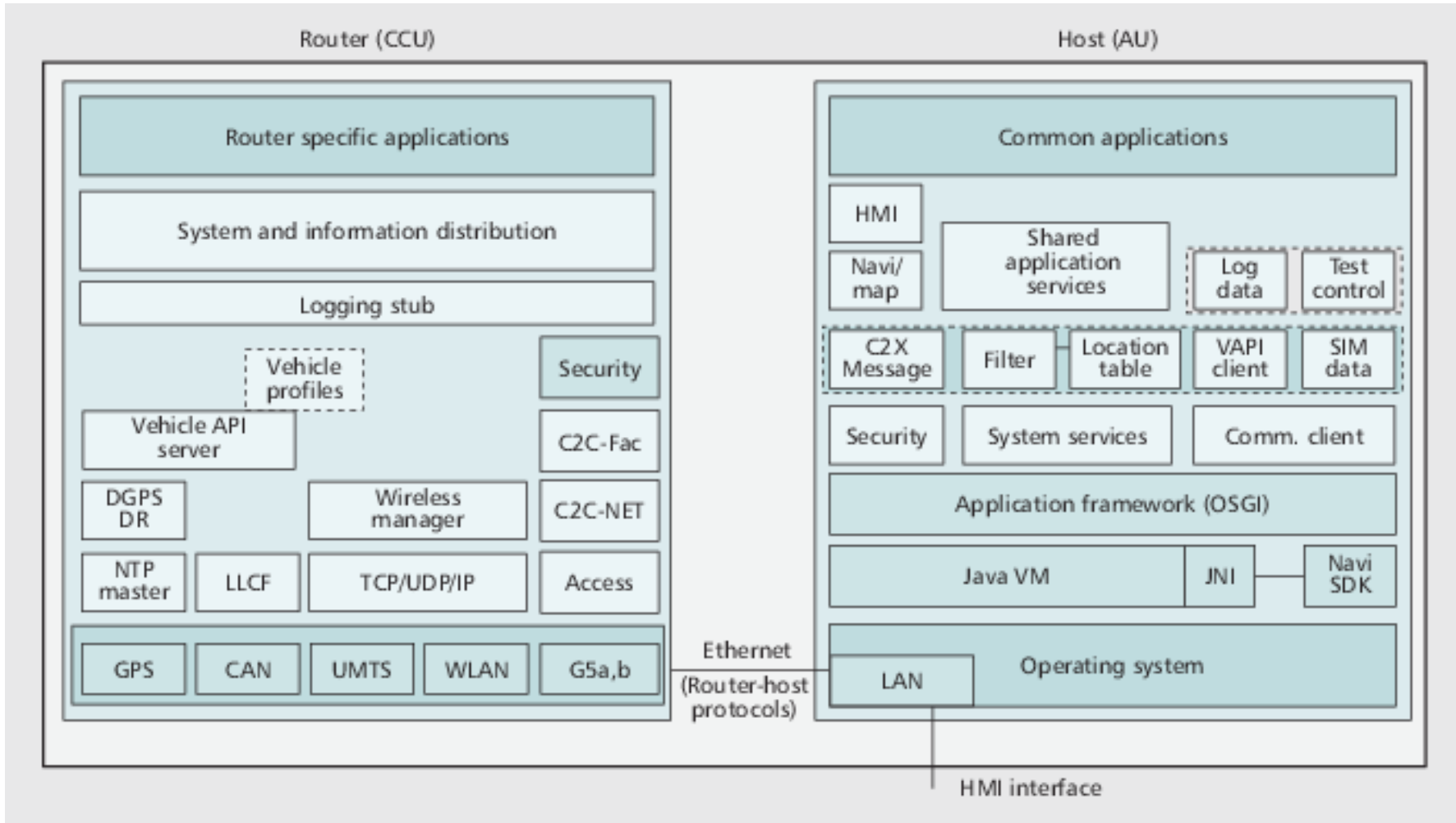


From Automotive Internetworking, courtesy M. Bechler, BMW.



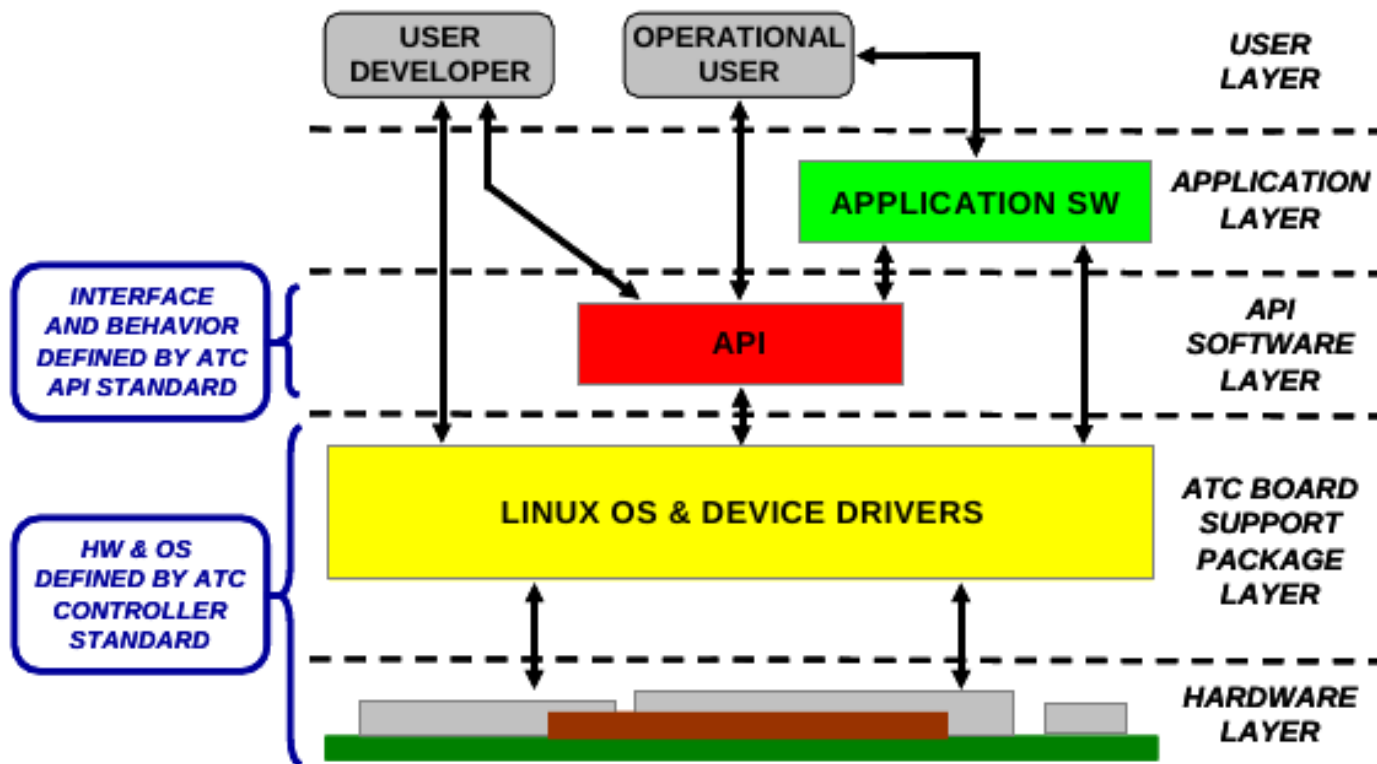
# simTD's “vehicle stations”

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

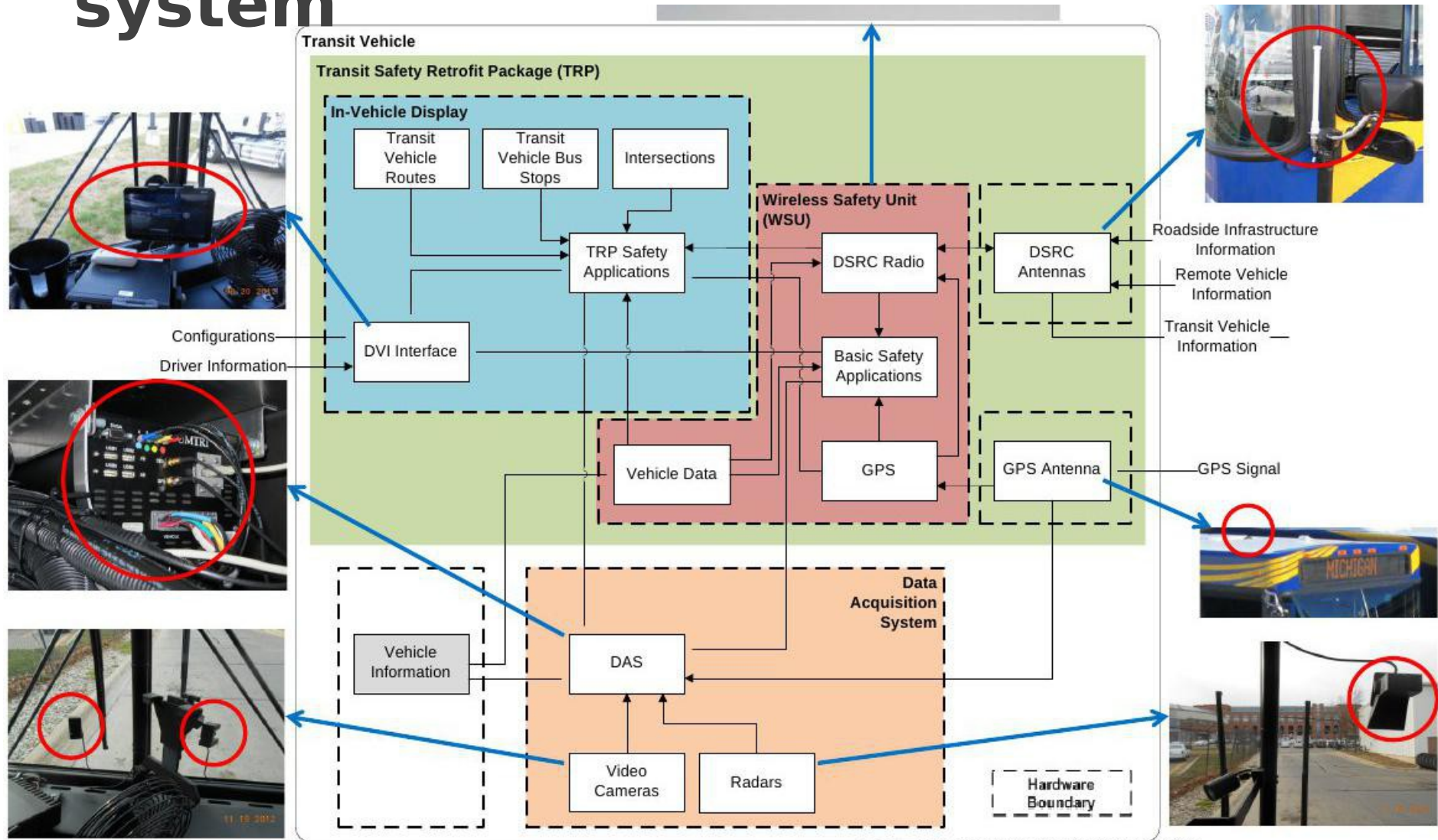
- 3 draft standards in preparation
  - Geonetworking (submitted)
  - 'Scenarios and Requirements for IP in Intelligent Transportation Systems' (submitted)
  - IPv6 over 802.11p (particular GENIVI interest)
  - V2X (with MANET working group of IETF?)
- Info: <https://www.ietf.org/mailman/listinfo/its>
- 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



U.S. Department of Transportation

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 Heijen  
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

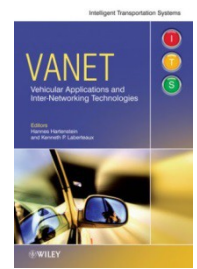
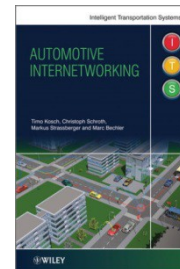
## Automakers:

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/>
- simTD
- Safety Pilot  
<http://www.its.dot.gov/presentations.htm>
- Smart In-Car  
<http://www.etsi.org/smart-in-car-trial-car-data-real-time-accessible-to-improve-traffic-flow-and-increase-traffic-safety/>
- ETSI ISO C-ITS  
<http://www.etsi.org/index.php/technologies-clusters/technologies/intelligent-transport>
- 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/>  
<http://componentality.com/flexroad/>  
<http://componentality.com/drivity/>
- Telematics News  
<http://telematicsnews.info/>
- Wired Autopia  
<http://wired.com/autopia/>
- slideshare.net/chaiken  
<http://slideshare.net/chaiken>



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