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TOYOTA TECHNICAL CENTER, USA, INC.

Communication Topics in Information-Rich Vehicular Safety Systems

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Vehicle Safety Consortium—CAMP

Some US Vehicle Collision Facts (US) *

- Auto fatalities: 42,815 per year, or 117 per day (IIHS, 2002)
- 3.2M injuries (2000)
- Cost: $150,000,000 per year
- More health care cost than any other illness or injury
- 53 percent of fatal crashes occur at night or during other degraded visibility conditions
- Driver Error: 90% of police reports

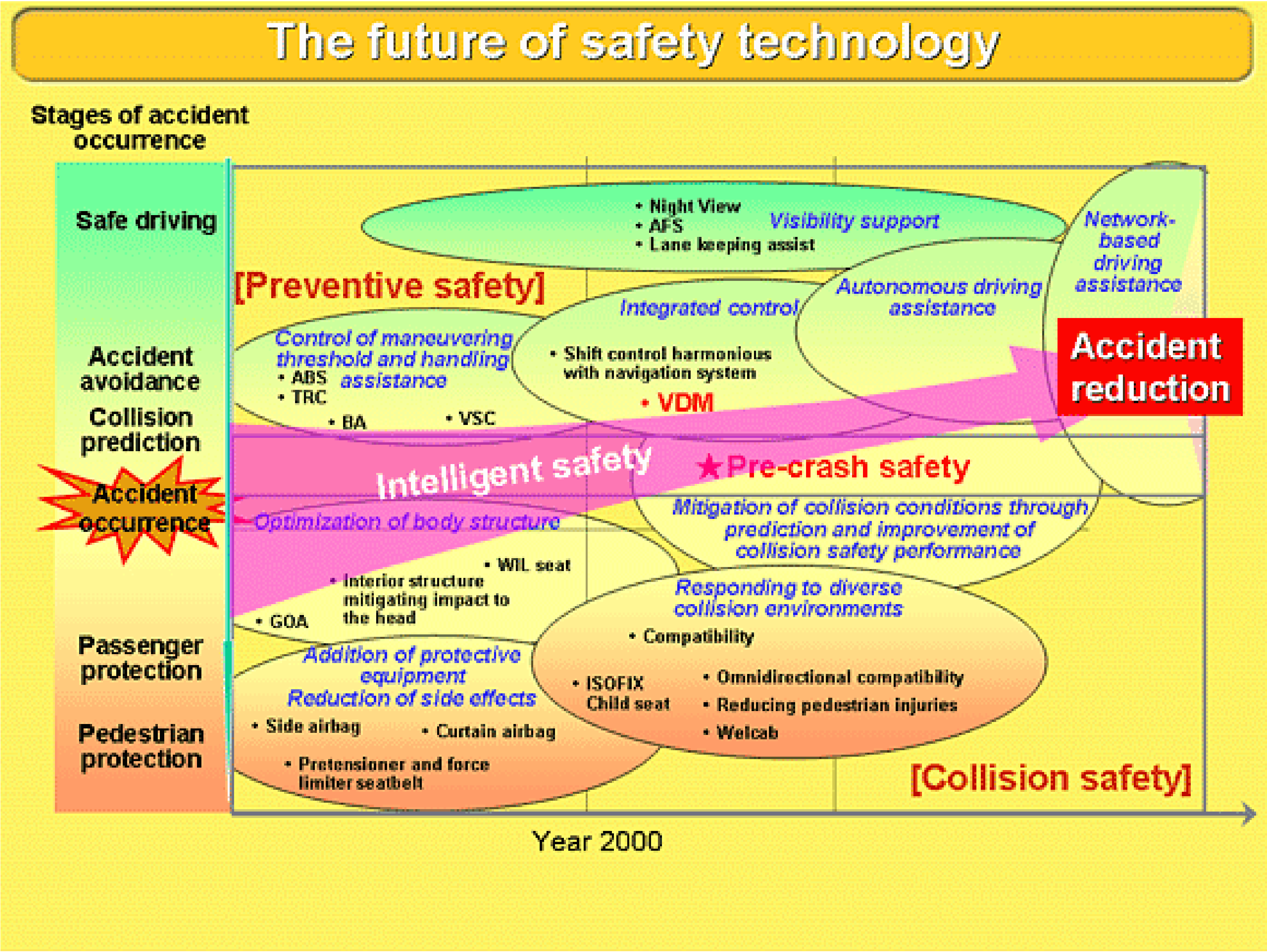
Need Advanced Technology to Aid Safe Driving.

* *Compiled with help from Jeff Cox, U-Mich*

Accidents are predictable and preventable

TRIMARC Auto Incident Recording System (AIRS), Kentucky Transportation Cabinet (KYTC) 2001-2004

Toyota's Safety Technology Plan



CAMP

Vehicle Safety Communications 2 Consortium

DaimlerChrysler
Research and Technology North America, Inc.

GM

TOYOTA

Ford

Intelligent Transportation Systems

Vehicle Safety Communications – Applications

VSC-A

VSC-A Introduction

- 3 year project - December 2006 to November 2009.
- Collaborative effort between 5 OEMs (DCX, Ford, GM, Honda & Toyota) and US DOT (+ Volpe & Mitretek).
- Goal: Determine if DSRC @5.9 GHz & vehicle positioning can improve upon autonomous* vehicle-based safety systems and/or enable new communication-based safety applications.
- Follow-on project to CAMP/DOT VSC (2002-2004) project and CAMP internal EEBL** project.
- Strong emphasis on resolving current communication and vehicle positioning issues so that interoperable future deployment of DSRC+Positioning based safety systems will be enabled.

* The word 'autonomous' is used to indicate that no cooperation from other vehicles or the infrastructure is required .
** Emergency Electronic Brake Lights

VSC-A Objectives

1. Assess how previously identified critical safety scenarios in autonomous systems could be addressed and improved by DSRC+Positioning systems.

2. Define set of DSRC+Positioning based vehicle safety applications and application specifications including minimum system performance requirements.

3. In coordination with NHTSA and VOLPE, develop a well understood and agreed upon benefits versus market penetration analysis, and potential deployment models for a selected set of communication-based vehicle safety systems.

VSC-A Objectives - continued

4. Develop scalable, common vehicle safety communication architecture, protocols and messaging framework (interfaces) necessary to achieve interoperability and cohesiveness among different vehicle manufacturers. Standardize this messaging framework and the communication protocols (including message sets) to facilitate future deployment.

5. Develop accurate and affordable vehicle positioning technology needed, in conjunction with the 5.9 GHz DSRC, to support most of the safety applications with high potential benefits.

6. Develop and verify set of objective test procedures for the vehicle safety communications applications.

VSC-A Communications Activities

- Develop system architecture, communication architecture, standardized messages and protocols:
  - Messaging scheme.
  - V-V Security:
    - *Privacy verses Authentication.*
    - Security Overhead.
    - Certificate Authority (coordination of best practices with VIIC, IEEE 1609.2, etc.).
    - Certificate Revocation (coordination of best practices with VIIC, IEEE 1609.2, etc.).
  - Characterizing reception performance as a function of transmission power.
  - Message dissemination strategies.
  - DSRC WAVE Standards Validation for Safety Applications.
  - Channel 172 usage.
  - International Trends.

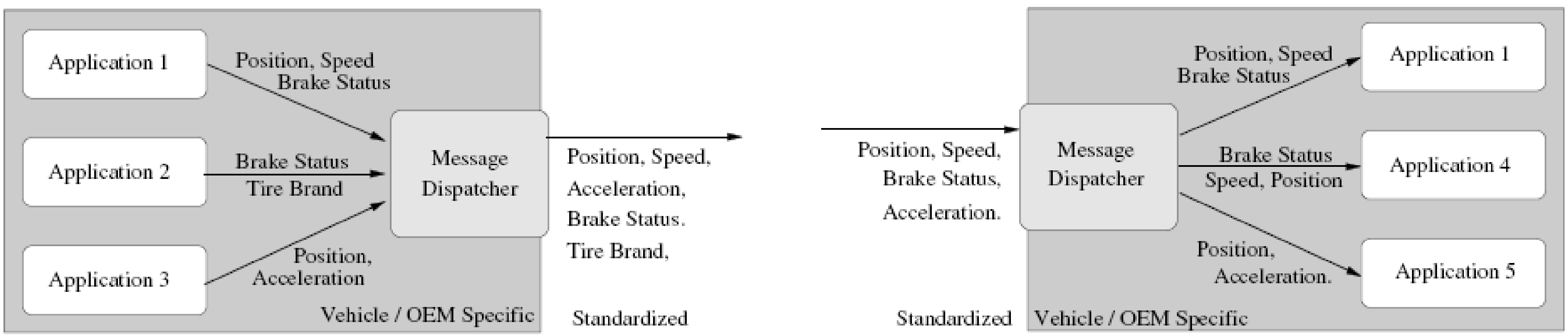
DSRC Research Topics for 07-09

Ken Laberteaux

Standard Message Composition

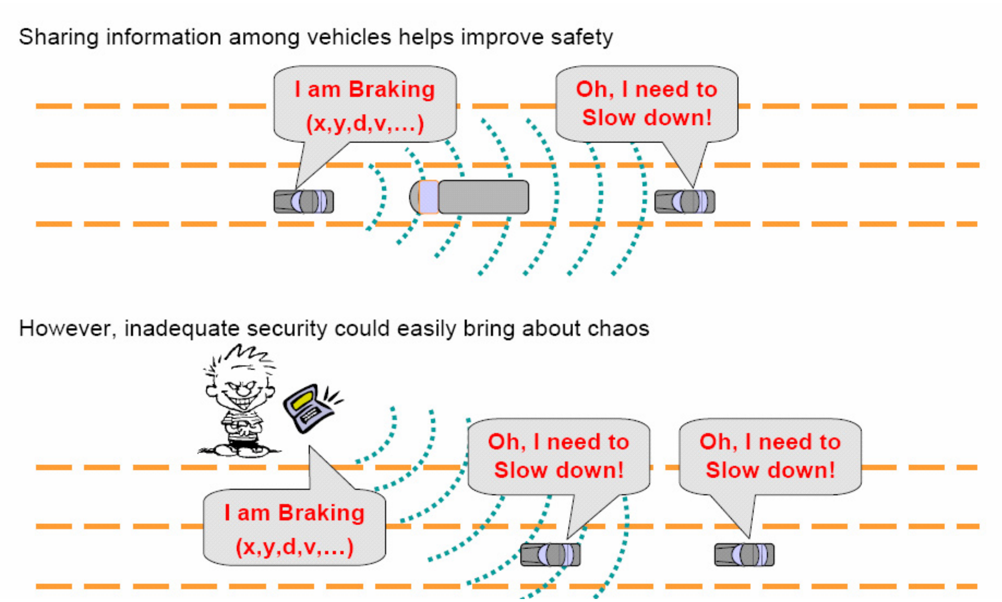
Goal: Explore, Test, Adopt standard method for safety message composition

<u>Proposed Solution</u> Message Dispatcher



Included in SAE Standard J2735. Also VANET06 Paper *Efficient Coordination and Transmission of Data for Cooperative Vehicular Safety Applications*, Robinson et al.

VANET Wireless Security



Message	Security Signature

- Safety applications are much more important than commercial applications.
- Authentication is paramount
- Encryption is likely only for transactions with road-side service providers.

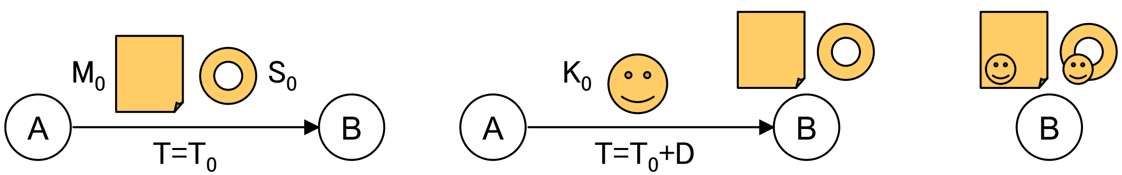
Minimize:

- Signature size
- computation (avoid Public/Private validation on EACH message)

Security-Message Authentication

Goal: Reduce overhead, “Improve” privacy, Propose certificate dissemination/revocation

Proposed Solution Consider reducing security overhead. One candidate: TESLA authentication with periodic PKI certificate broadcasts. Infrastructure-based revocation



TESLA (Time Efficient Stream Loss-Tolerant Authentication) A “Key” will be transmitted immediately after “message” and “signature” transmission: high-reliability with low communication budget.

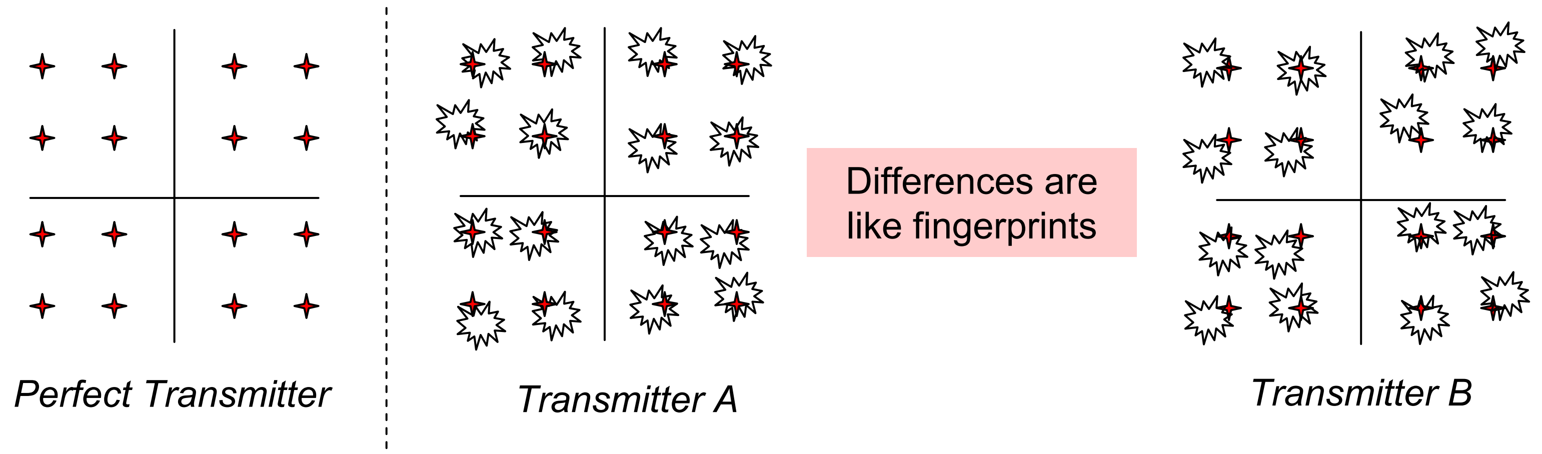
Privacy

Complete privacy **conflicts** with complete accountability.

Acceptable trade-off must be found.

If there is to be accountability, someone (e.g. government) can link a pseudonym to actual identity.

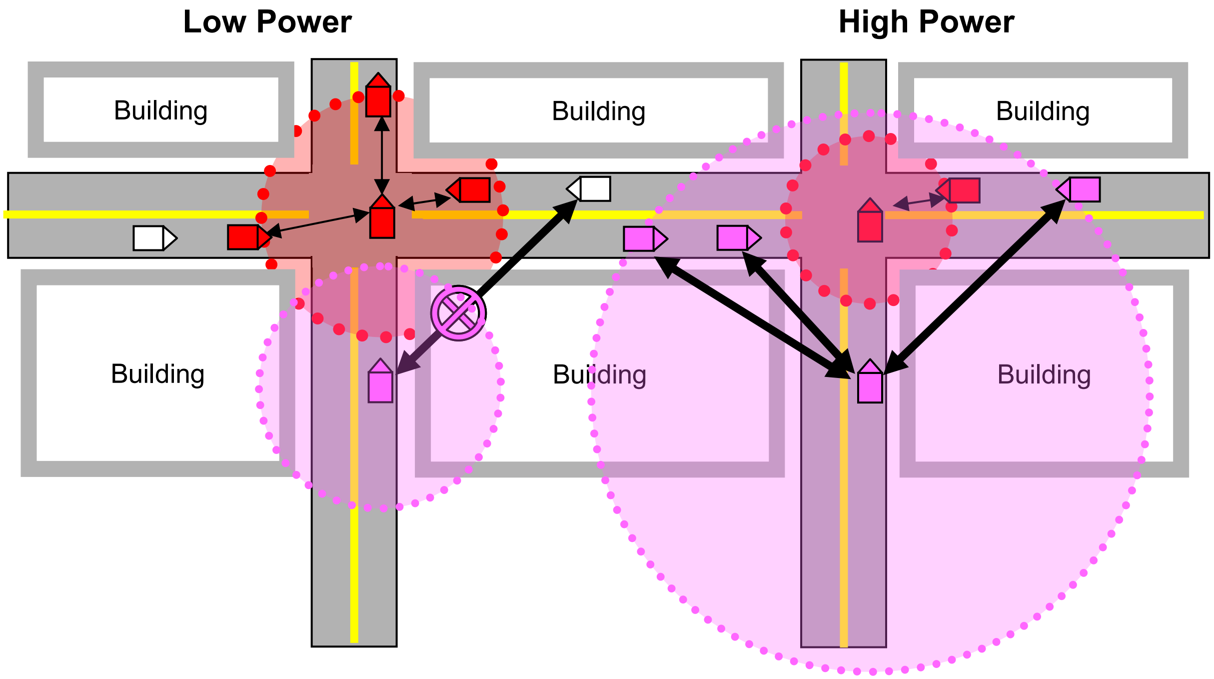
Also, Wireless Fingerprinting will be possible (except with very high cost parts)



Privacy solutions should be proportional to realistic threat model.

High Power Testing

Goal: Reduce need for infrastructure by using higher power DSRC



High Power Testing (cont)

DSRC mostly tested at medium power (0.1 watt=20 dBm). High power (4 watt=36 dBm) not tested

Power	*Example*	*Comment*
10 watts	Cell Phone Tower (10 km)	Max DSRC focused antenna output (approx)**
4 watts	CB Radio (5-8 km)	Max DSRC antenna output (approx)*
3 watts	Cell Phone (10 km)	Lower power due to battery
0.8 watts		Max DSRC antenna input (approx)
0.1 watts	WiFi (0.1 km)	Level for past DSRC testing

* DSRC omni-directional antennas often have 3-9 dB of gain. **Max directional antenna output in US is 44 dBm=25 watts (EIRP)

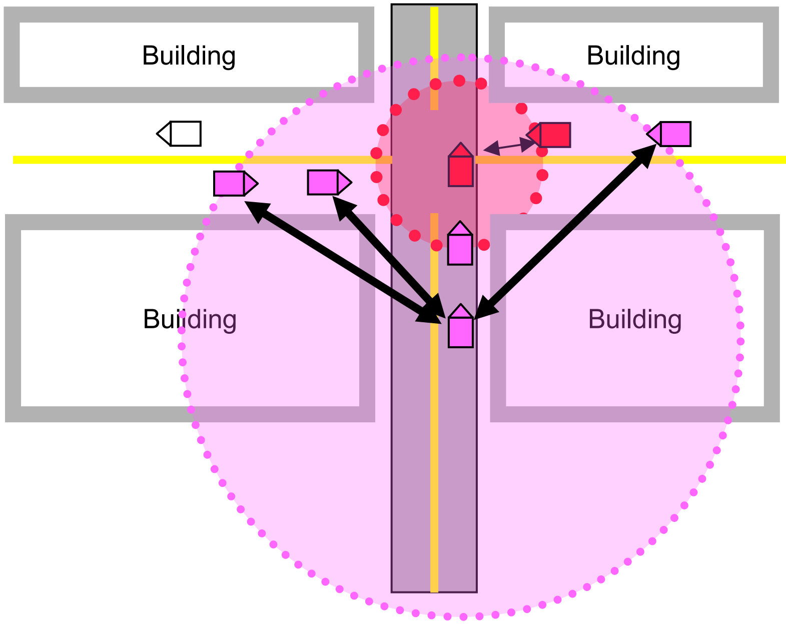
However, DSRC (5.9 GHz) band will not penetrate as well as lower band cell phone and CB

Expected outcome: Full testing of high-power DSRC.
Answer to question: What will it go through?

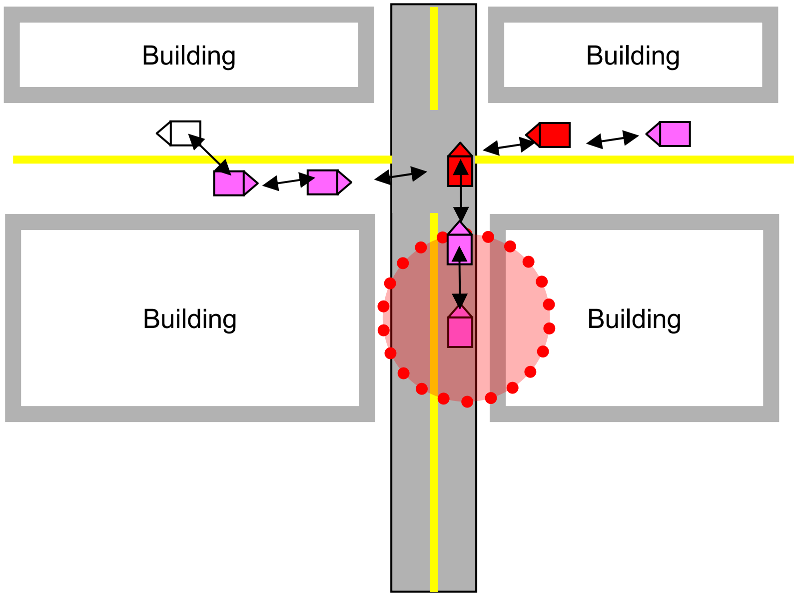
Message Dissemination

Goal: Find Optimal Balance between multi-hop and power control

High Power with Power control



Multi-Hop



DSRC Standards Validation

Goal: Validate and Optimize 802.11p(a) for Vehicular Environment

802.11p (PHY for DSRC) is very similar to 802.11a (See UC-Berkeley analysis on right*)

However 802.11a was designed for fixed, indoor usage

**Comparison of Physical Layer between DSRC and IEEE 802.11a,* Wanbin Tang, UC-Berkeley Report, Oct 2006.

PLAN: Verify current 802.11p performance. If needed, investigate small modifications to current 802.11 chipsets to allow best performance for DSRC.

Parameter	**DSRC**	**IEEE 802.11a**
Information Date Rate	3, 4.5, 6, 9, 12, 18, 24 and 27Mbits/s (3,6, and 12Mbits/s are mandatory)	6, 9, 12, 18, 24, 36, 48, and 54Mbit/s.
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error Correction Coding	K=7 (64 states) Convolutional Code	K=7 (64 states) Convolutional Code
Coding Rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of Subcarriers	52	52
OFDM Symbol Duration	8.0us	4.0us
Guard Interval	1.6us	0.8us
Occupied bandwidth	8.3MHz	16.6MHz
Frequency	5.850~5.925 GHz	5.15~5.25GHz, 5.25~5.35GHz, 5.725~5.850GHz

Channel 172-Multi Channel Behavior

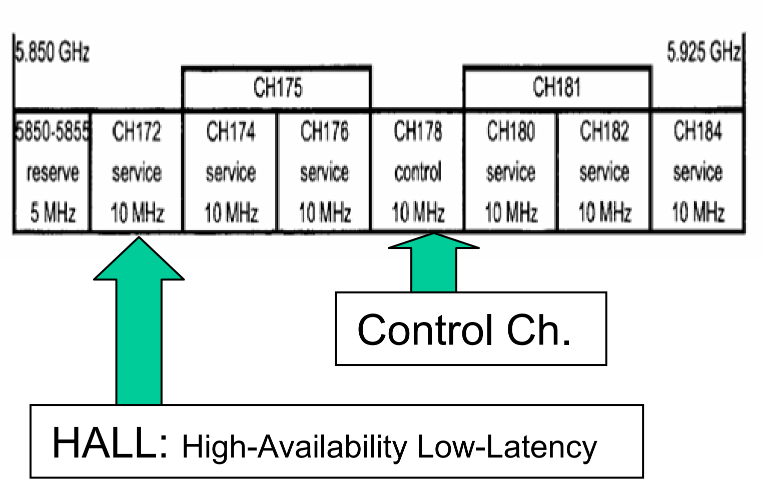
Goal: Find Optimal use of new HALL channel for V2V Safety

New FCC ruling for DSRC Ch 172:

Dedicated V-V Safety for Accident Avoidance and mitigation

However, DSRC requires monitoring Control Channel.

Previously, V-V safety performed in Control Channel.



New FCC rule for 172 channel for safety application

Expected outcome: Recommendation on multi-channel behavior. Multi-channel radio evaluated.

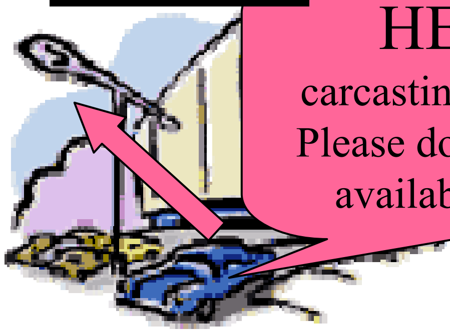
NON-SAFETY
Ubiquitous Internet will reach car

- San Francisco
  - Google will provide free service city-wide (Reuters)
- Philadelphia
  - 135-square-mile network
  - As low as $10/month (Washington Post)
  - Similar plan in Minneapolis
- Washtenaw County, MI (Ann Arbor)
  - Free service by 2007 (Detroit Free Press)
  - 720-square-miles
  - http://wireless.ewashtenaw.org/

Internet will reach car (most hours per day)

CarCasting

Every 2 hrs



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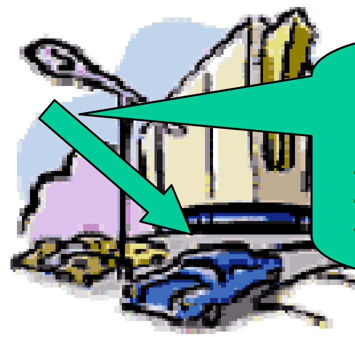

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Q&A

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