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V2X Deployment: Safety and Beyond

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June 12, 2015

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Questions

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- 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

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CENTER, U.S.A., INC.

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

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32,719 US Traffic Fatalities in 2013

Google

32719 2013

Web | Images | Maps | Shopping | Videos | More | Search tools

About 437,000 results (0.37 seconds)

Images for 32719 2013 — Report images

More images for 32719 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-yea...
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 …

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Connected Vehicle Applications

V2I Safety
- Red Light Violation Warning
- Curve Speed Warning
- Stop Sign Gap Assist
- Spot Weather Impact Warning
- Reduced Speed/Work Zone Warning
- Pedestrian in Signalized Crosswalk Warning (Transit)

V2V Safety
- Emergency Electronic Brake Lights (EEBL)
- Forward Collision Warning (FCW)
- Intersection Movement Assist (IMA)
- Left Turn Assist (LTA)
- Blind Spot/Lane Change Warning (BSW/LCW)
- Do Not Pass Warning (DNPW)
- Vehicle Turning Right in Front of Bus Warning (Transit)

Agency Data
- Probe-based Pavement Maintenance
- Probe-enabled Traffic Monitoring
- Vehicle Classification-based Traffic Studies
- CV-enabled Turning Movement & Intersection Analysis
- CV-enabled Origin-Destination Studies
- Work Zone Traveler Information

Environment
- Eco-Approach and Departure at Signalized Intersections
- Eco-Traffic Signal Timing
- Eco-Traffic Signal Priority
- Connected Eco-Driving
- Wireless Inductive/Resonance Charging
- Eco-Lanes Management
- Eco-Speed Harmonization
- Eco-Cooperative Adaptive Cruise Control
- Eco-Traveler Information
- Eco-Ramp Metering
- Low Emissions Zone Management
- AFV Charging / Fueling Information
- Eco-Smart Parking
- Dynamic Eco-Routing (light vehicle, transit, freight)
- Eco-ICM Decision Support System

Road Weather
- Motorist Advisories and Warnings (MAW)
- Enhanced MDSS
- Vehicle Data Translator (VDT)
- Weather Response Traffic Information (WxTINFO)

Mobility
- Advanced Traveler Information System
- Intelligent Traffic Signal System (I-SIG)
- Signal Priority (transit, freight)
- Mobile Accessible Pedestrian Signal System (PED-SIG)
- Emergency Vehicle Preemption (PREEMPT)
- Dynamic Speed Harmonization (SPD-HARM)
- Queue Warning (Q-WARN)
- Cooperative Adaptive Cruise Control (CACC)
- Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG)
- Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE)
- Emergency Communications and Evacuation (EVAC)
- Connection Protection (T-CONNECT)
- Dynamic Transit Operations (T-DISP)
- Dynamic Ridesharing (D-RIDE)
- Freight-Specific Dynamic Travel Planning and Performance
- Drayage Optimization

Smart Roadside
- Wireless Inspection
- Smart Truck Parking

Source: US Department of Transportation

DSRC V2V Safety Concept

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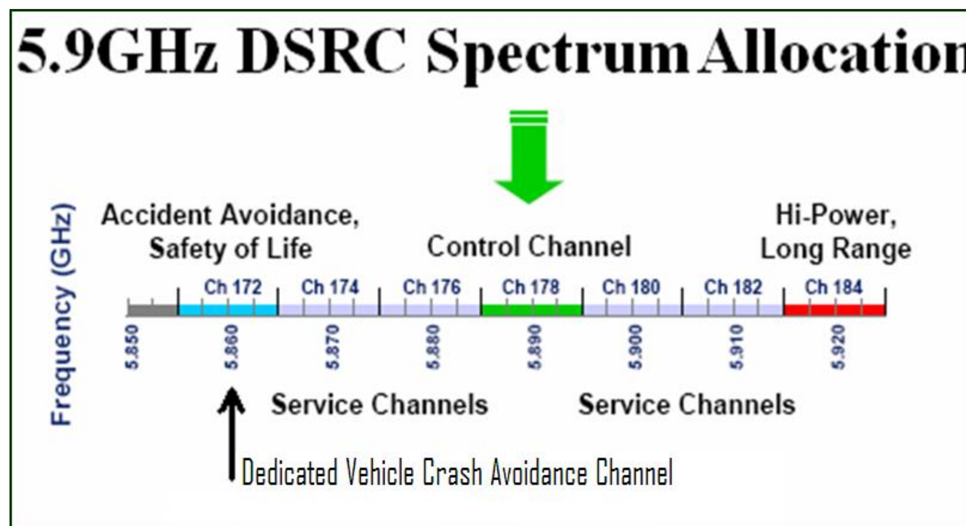
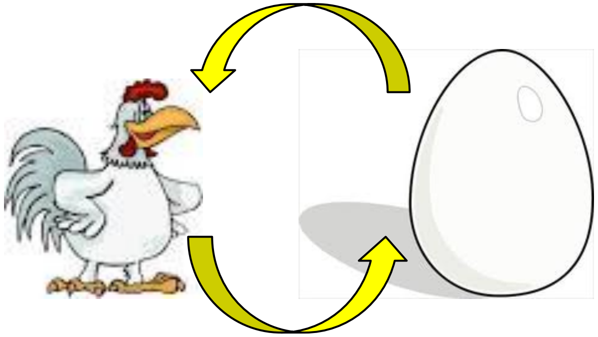
- Concept: each vehicle sends <u>Basic Safety Messages</u> frequently.
- Receiving vehicles assess collision threats
- Threat: Warn driver or take control of car

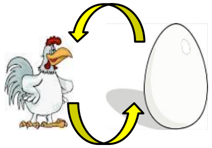
	SAE J2735 Basic Safety Message
Part I	**Basic Vehicle State** **(Temp ID, Seq. #, Time, Position Motion, Control, Vehicle Size)** ***Mandatory in Basic Safety Message***
Part II	**Vehicle Safety Extension** **Event Flags** **Path History** **Path Prediction** ***Required for V2V Safety Applications***
	Other optional safety-related data



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

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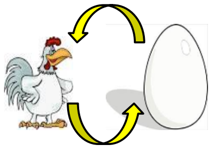
2014	2016-17	2019-20
Start Regulatory Process	Propose and finalize specific regulation	Deployment in new car fleet begins

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

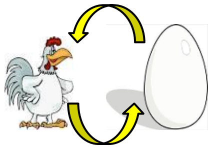
10th October 2012

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

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Nov. 26, 2014

TOYOTA LEXUS

Toyota to Bring Vehicle-Infrastructure Cooperative Systems to New Models in 2015

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.

Right-turn Collision Caution
(using road-to-vehicle communication)

Communicating Radar Cruise Control
(using vehicle-to-vehicle communication)

Implications of Deployment Models

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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 $(\text{Penetration})^2$

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?

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- 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?

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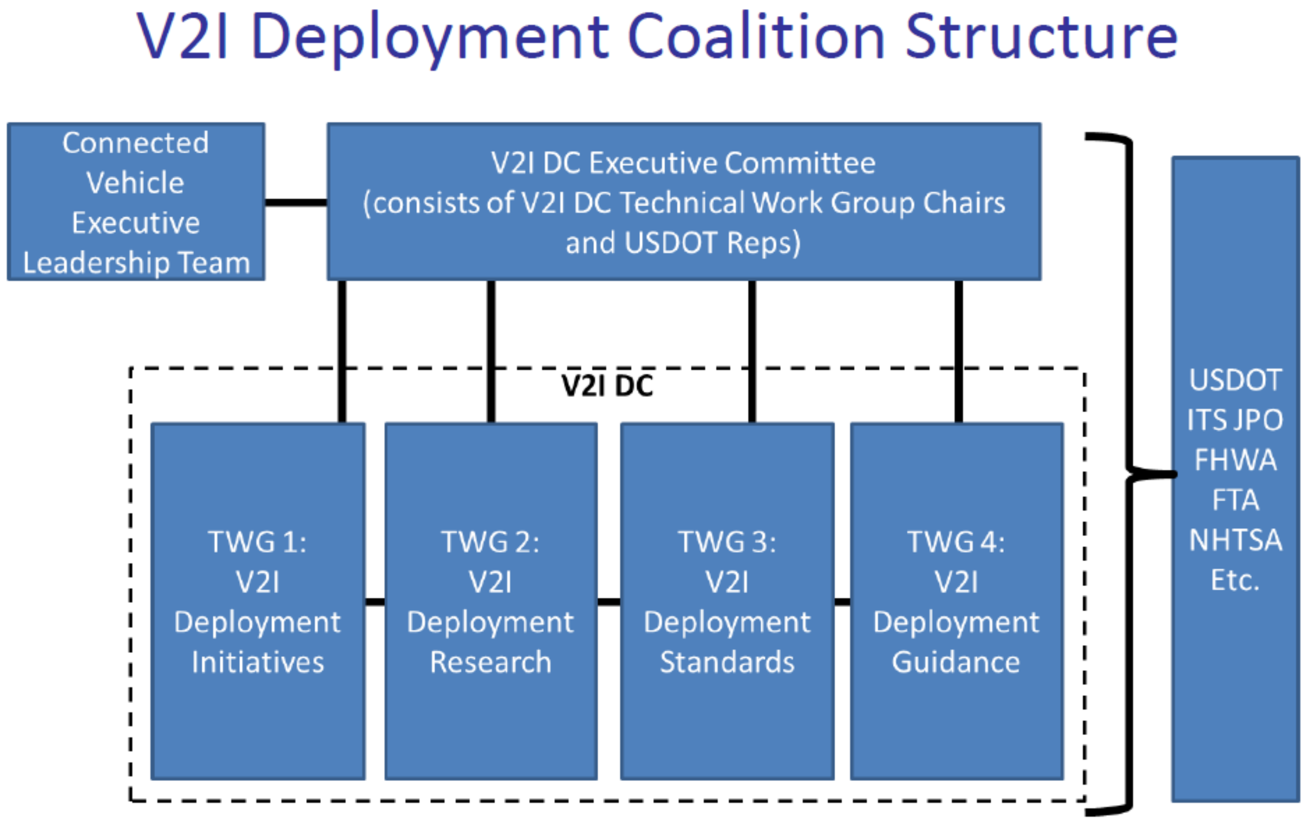

Source: ITS America, 4/16/15

- 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

We've come a long way

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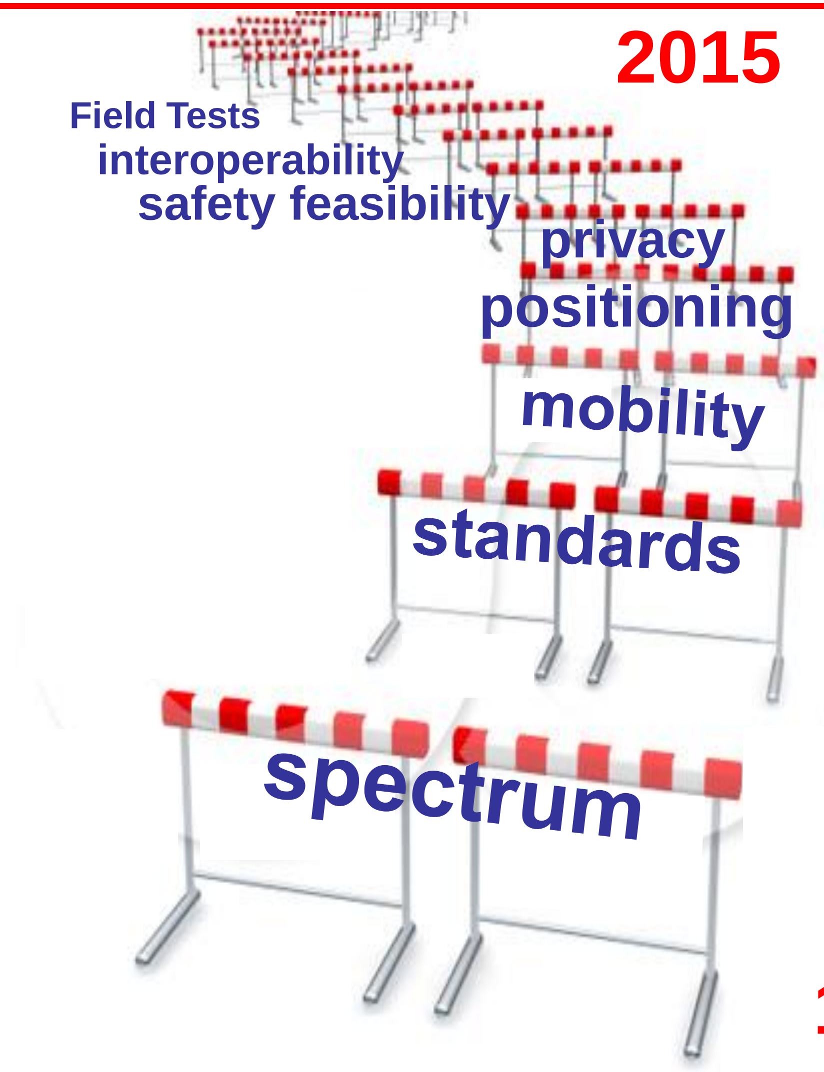
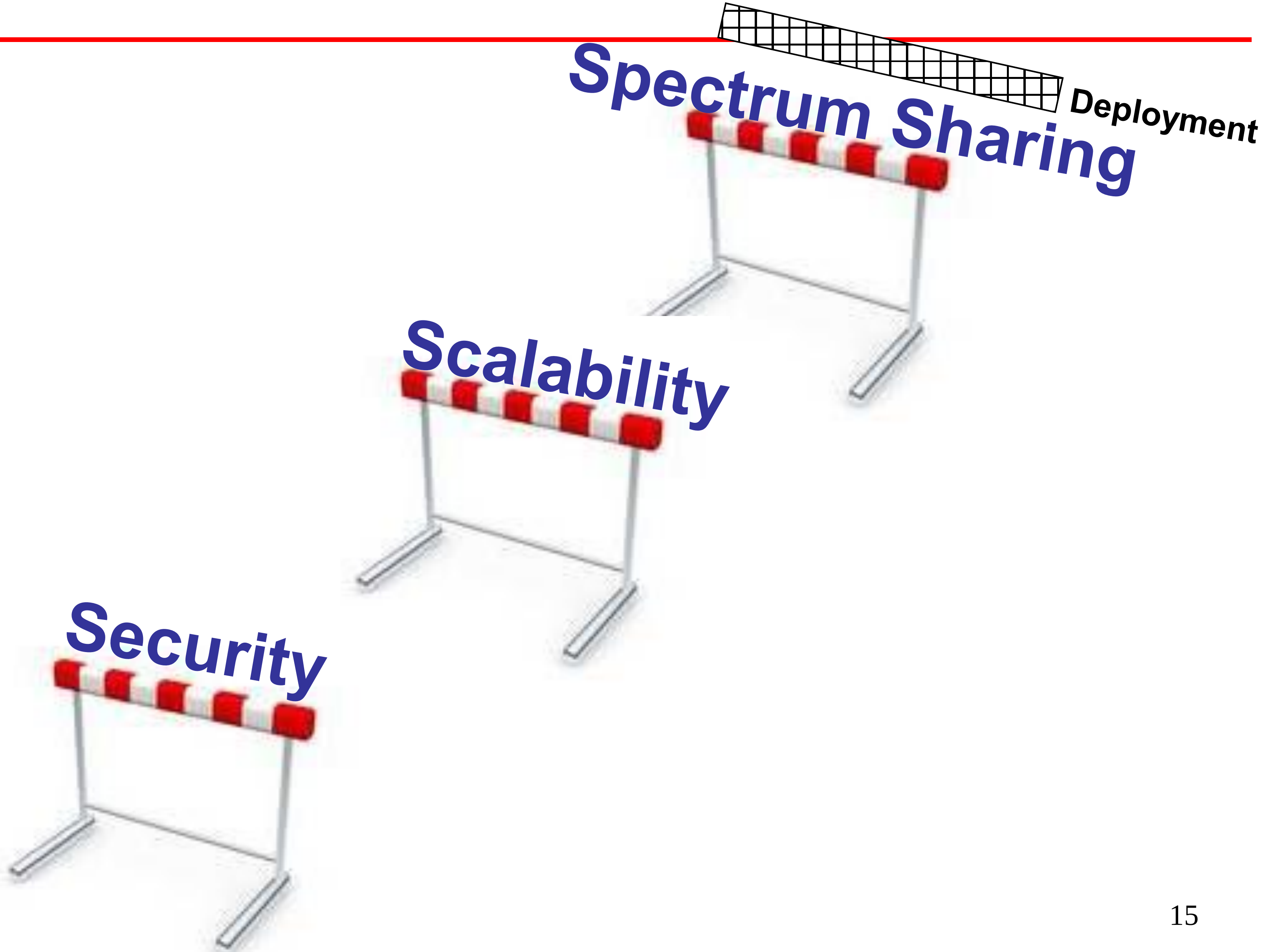


Still to go … near term



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

CAMP

Vehicle Safety Communications 3

Mercedes-Benz Research & Development North America, Inc.
GM
TOYOTA
HONDA Honda R&D Americas
Ford
NISSAN
HYUNDAI·KIA MOTORS Hyundai · Kia America Technical Center, Inc.
VOLKSWAGEN GROUP OF AMERICA

Intelligent Transportation Systems

DEPARTMENT OF TRANSPORTATION · UNITED STATES OF AMERICA

Distributed Reactive Control

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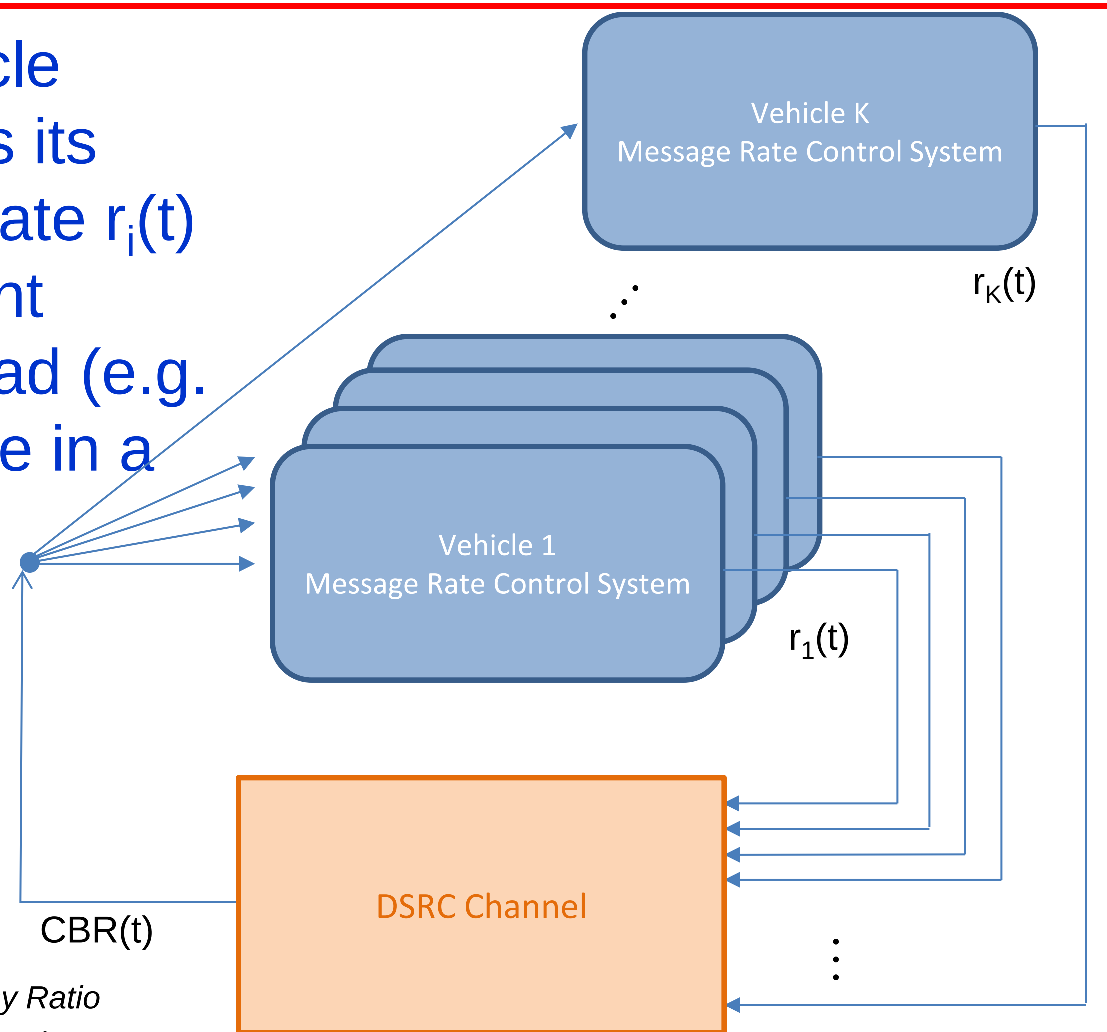
Each vehicle determines its message rate $r_i(t)$ from current channel load (e.g. look up rate in a table)



CBR = Channel Busy Ratio
A channel loading metric

Can equivalently control power, or both power & rate

Distributed Adaptive Control

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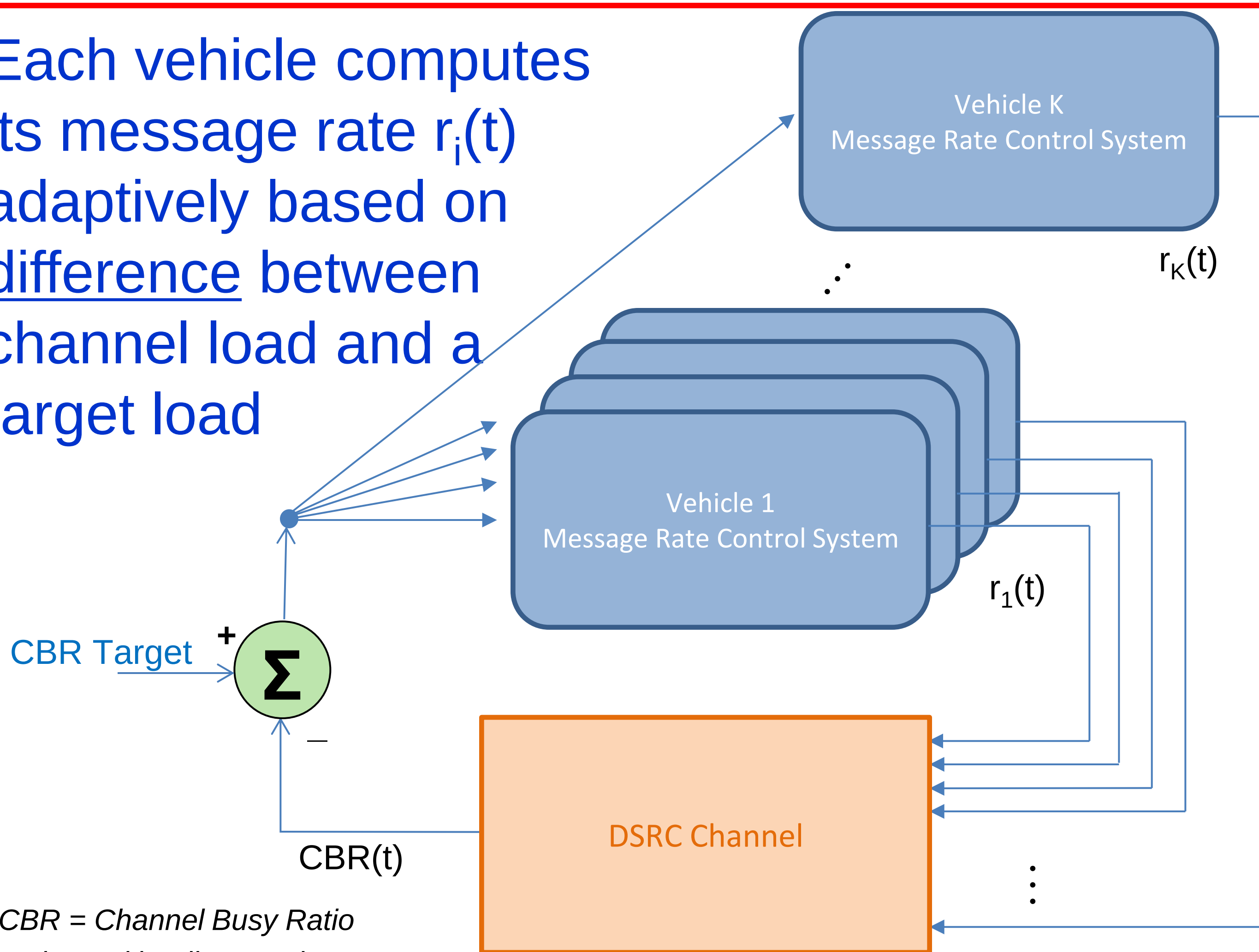
Each vehicle computes its message rate $r_i(t)$ adaptively based on difference between channel load and a target load

CBR Target is associated with high channel throughput

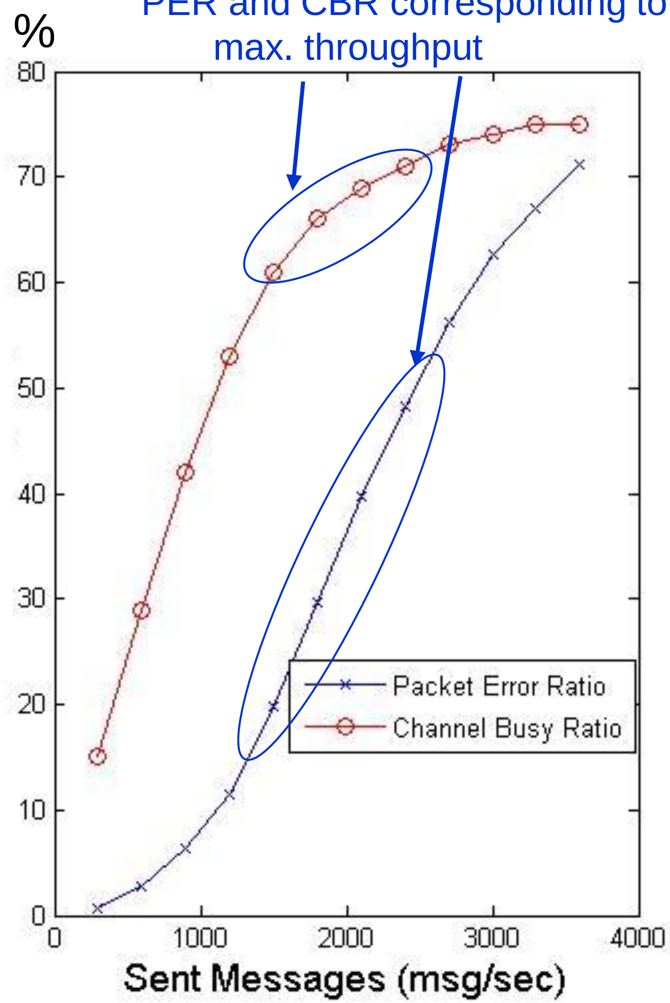


CBR = Channel Busy Ratio
A channel loading metric

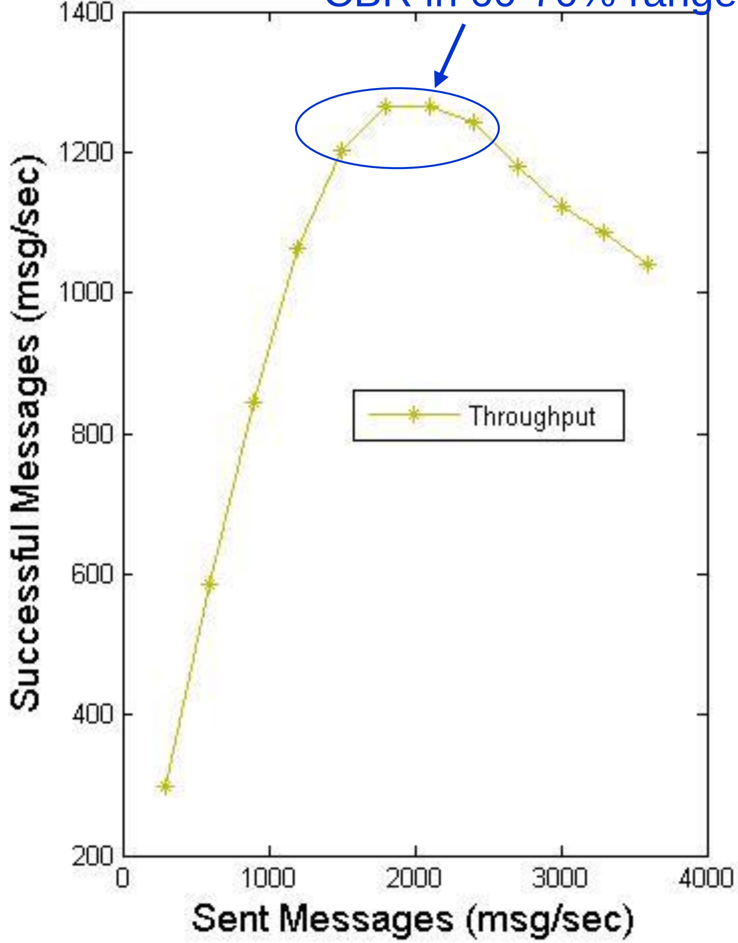
Algorithm Goals: controlled load, convergence, fairness

Why drive CBR to target?

PER and CBR corresponding to max. throughput



Throughput maximized when CBR in 60-70% range



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

- *An Adaptive DSRC Message Transmission Rate Control Algorithm*, Weinfield, Kenney, Bansal, ITS World Congress, October 2011
- *Cross-Validation of DSRC Radio Testbed and NS-2 Simulation Platform for Vehicular Safety Communications,* Bansal, Kenney, Weinfield, IEEE WiVec Symposium, September 2011

LIMERIC

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

Rate for node j

CBR Target

Current CBR

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

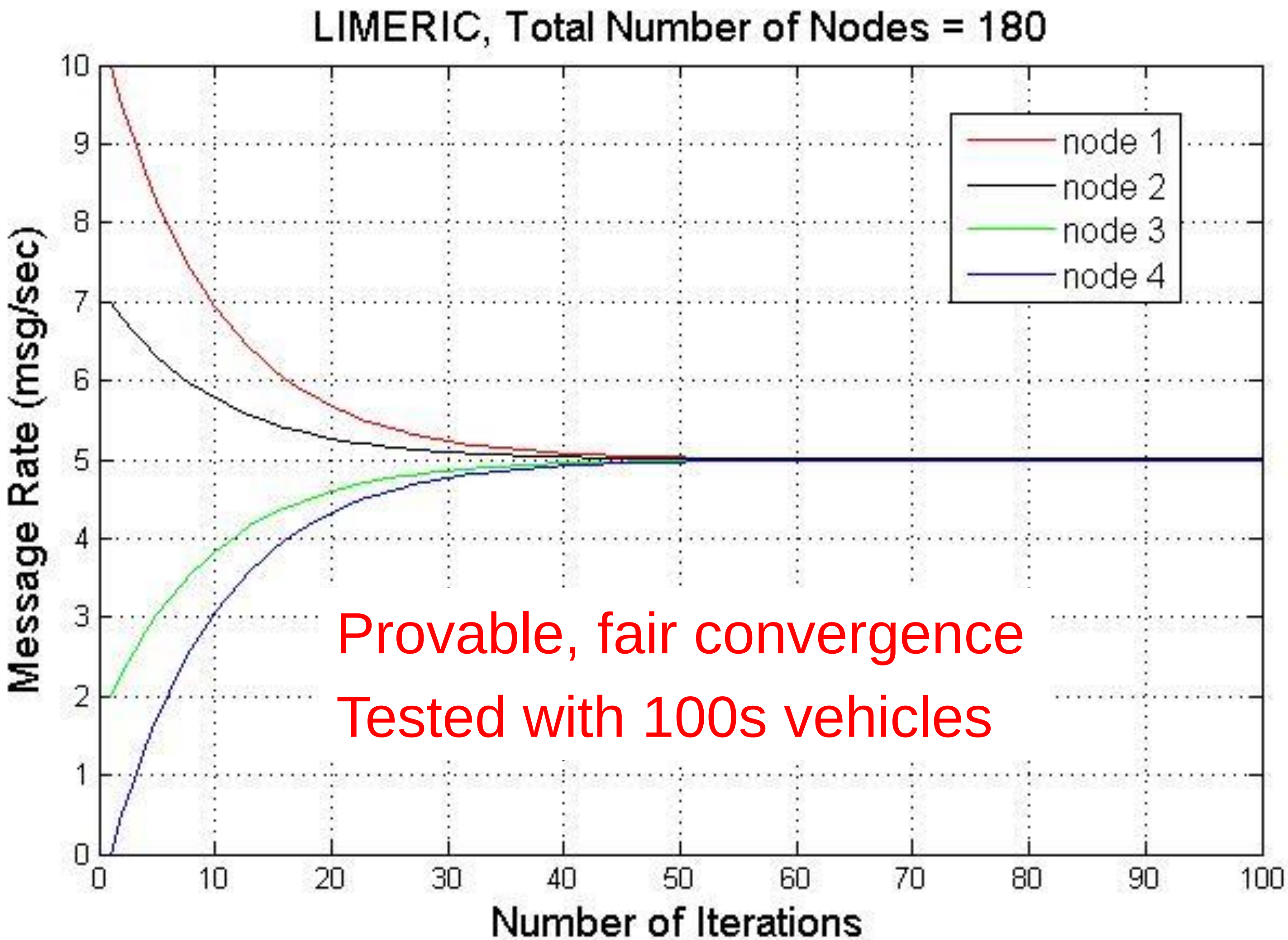
e(t - 1)

β>0: linear gain adaptive parameter,
Impacts stability, convergence speed

0 < α < 1 :
contraction parameter,
Impacts fairness, convergence speed

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

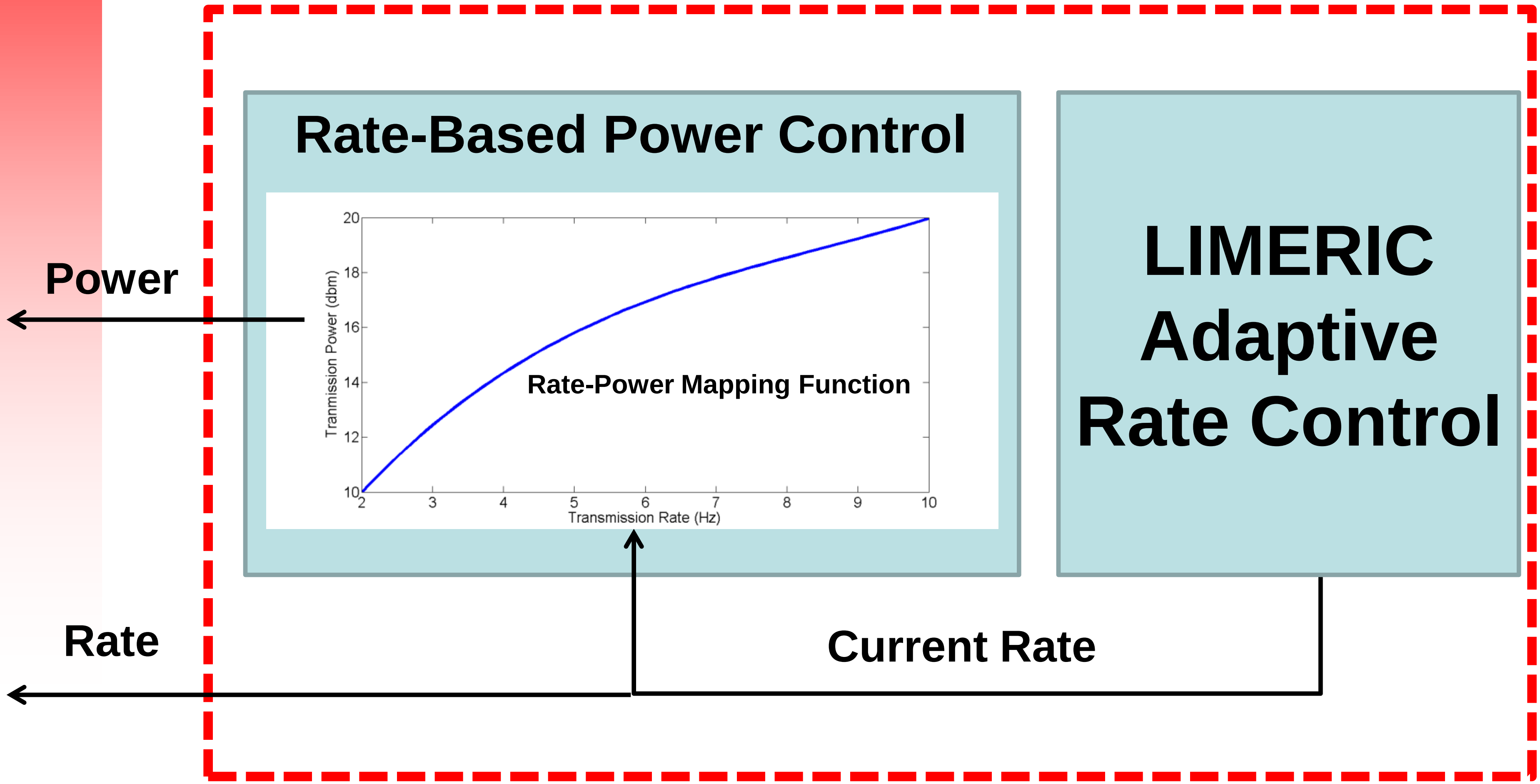
Example fair convergence



Provable, fair convergence

Tested with 100s vehicles

LIMERIC Joint Rate-Power Control



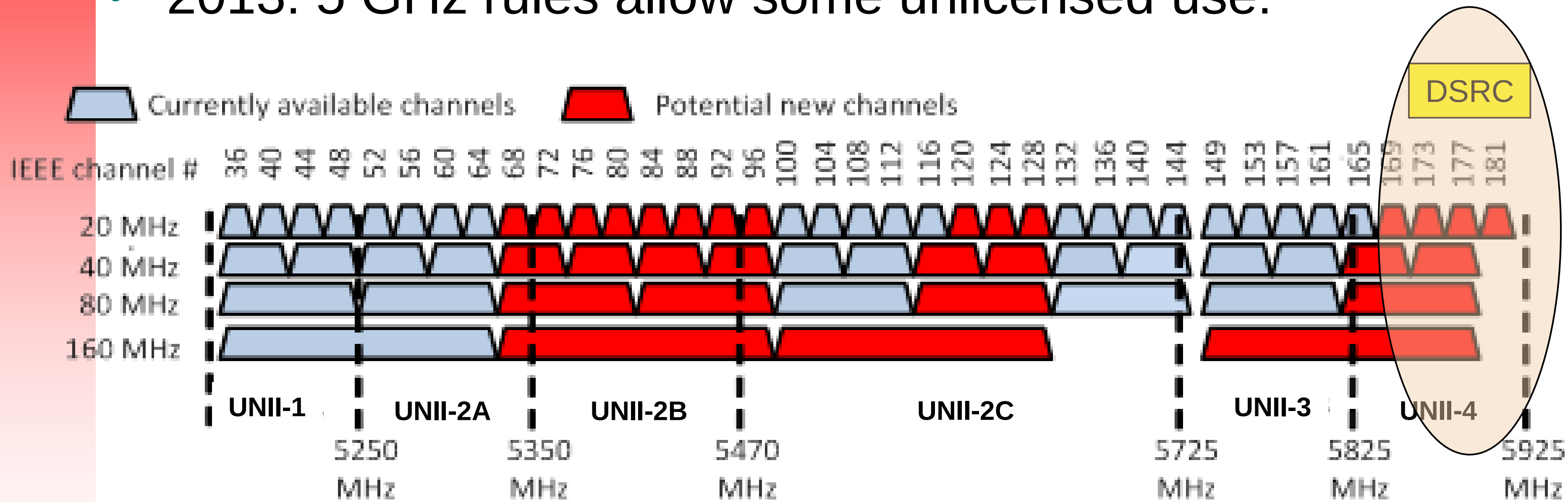
Paper will be presented at ITS World Congress 2015, Bordeaux

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:



Source: Cisco

- 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

Zoom in to 5.9 GHz band

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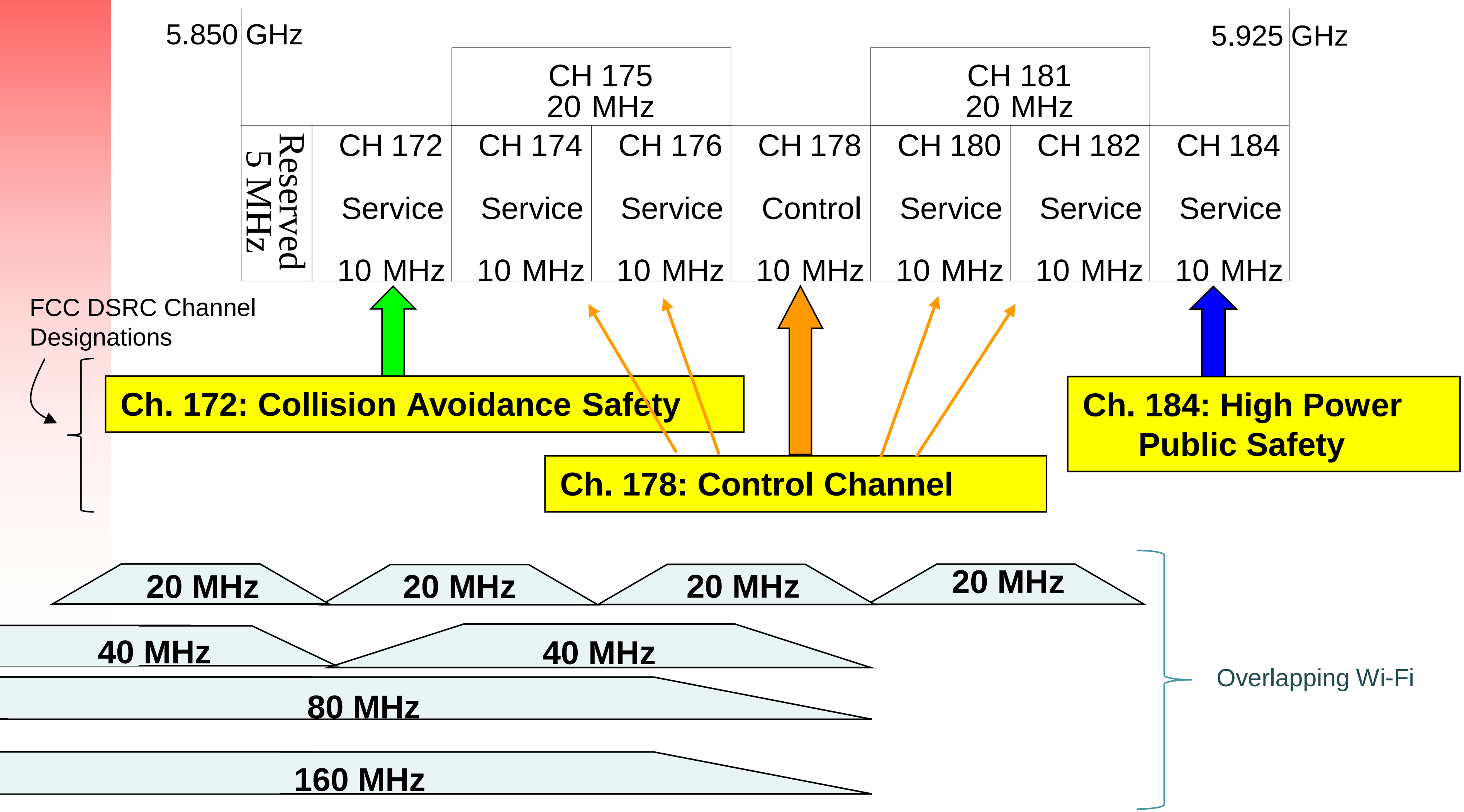

Major Stakeholders

Rechannelization Proposal

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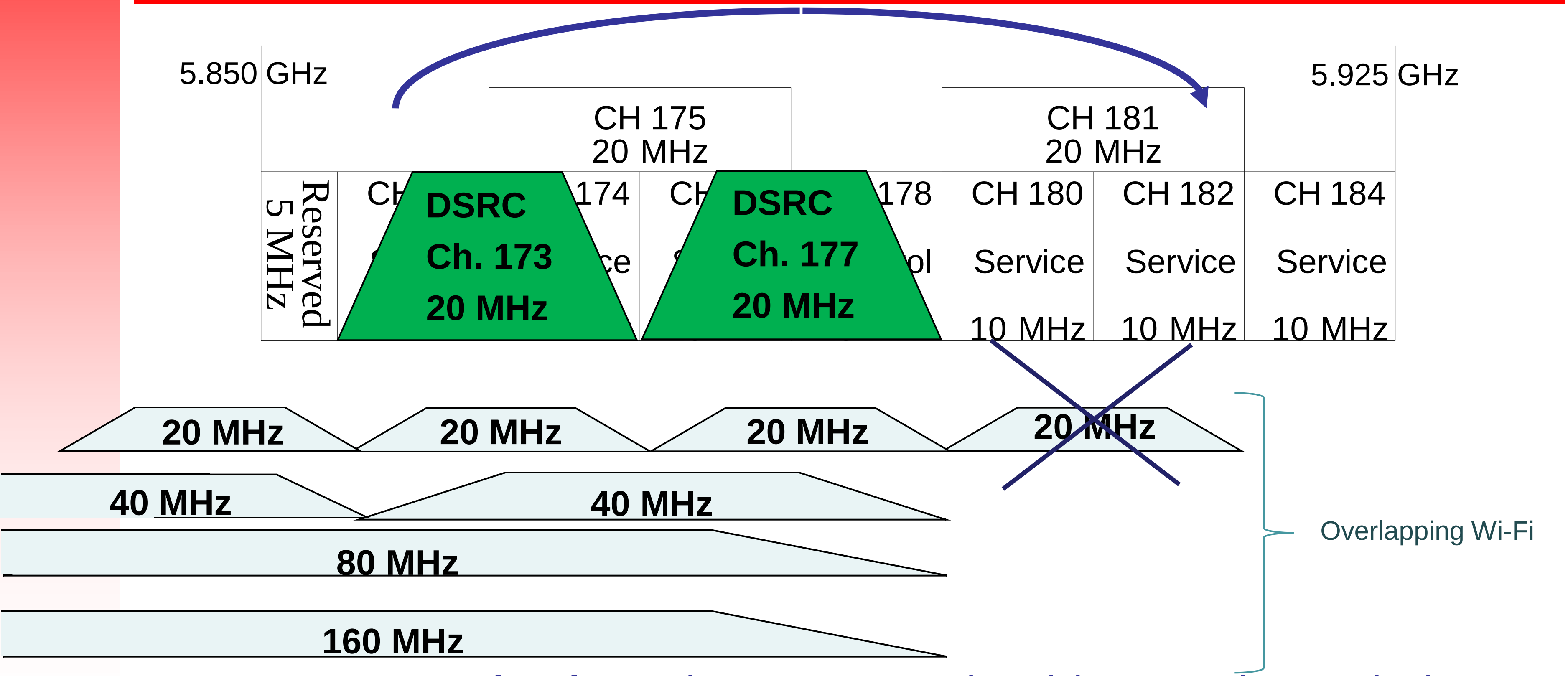

- Move DSRC safety from Ch. 172 to upper band (non-overlap portion)
- Cancel highest 20 MHz Wi-Fi (Ch. 181)
- DSRC use 20 MHz channels in overlap portion instead of 10 MHz
- Problems include: Safety in non-Ch. 172 not protected, Interference in upper channels, 20 MHz is sub-optimal, …
  - See https://mentor.ieee.org/802.11/dcn/14/11-14-1101-01-0reg-a-response-to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

Detect-and-vacate Proposal

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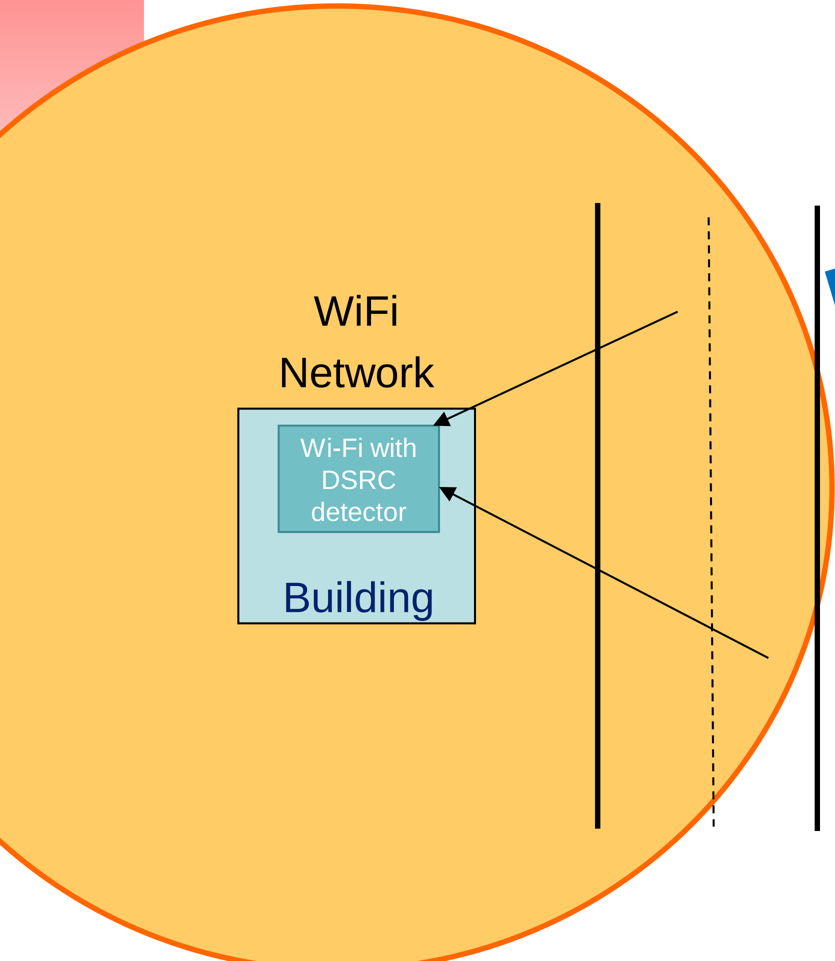
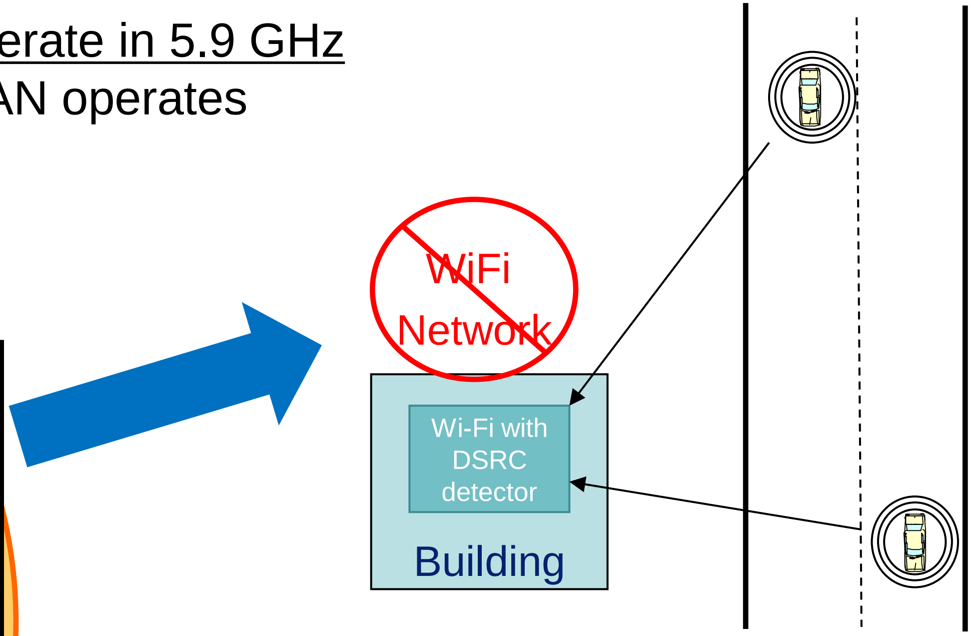
- Wi-Fi devices listen for DSRC
- If no DSRC ➔ <u>Wi-Fi ok to operate in 5.9 GHz</u>
- Continues to listen while WLAN operates





- 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

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- 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?

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- Challenge: Technology evolution?
- Opportunity: New applications?
- Other communication options: 5G V2X?

Post-deployment challenge: Protocol evolution

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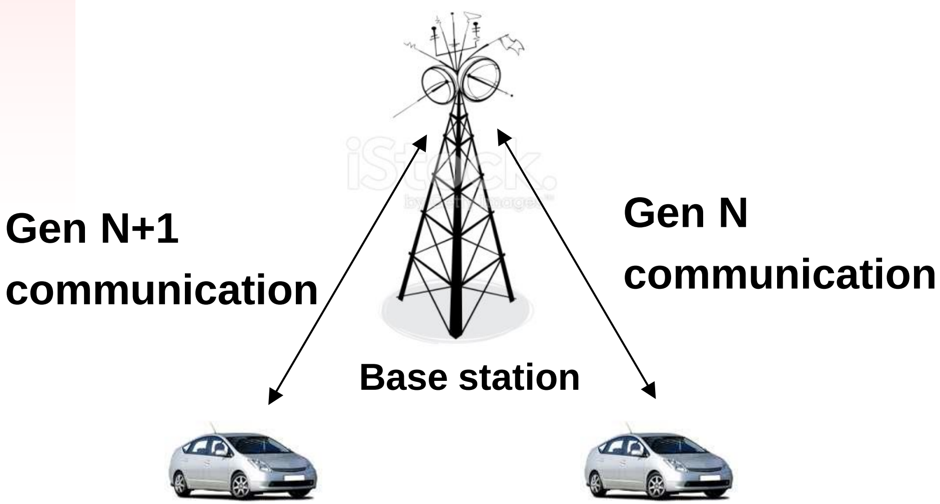
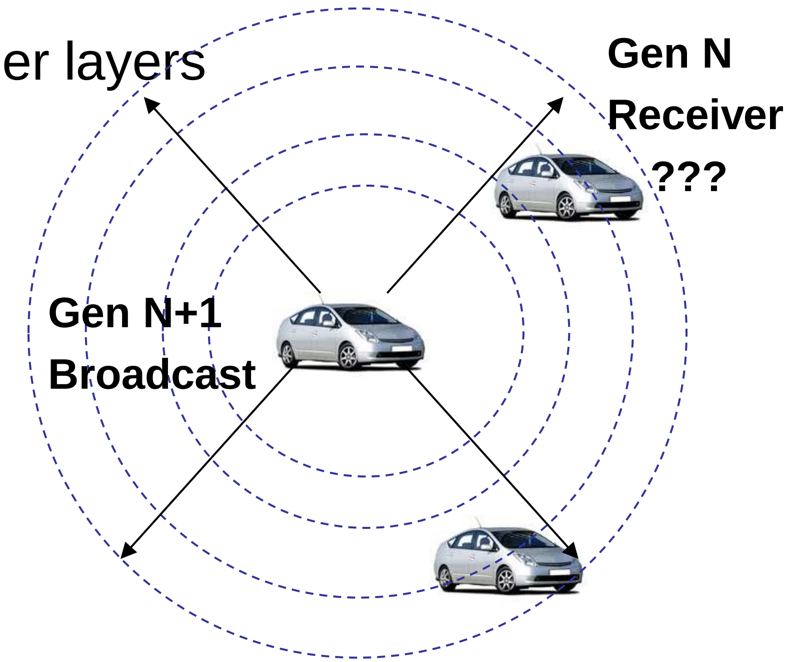
- How to update technology without disenfranchising legacy vehicles?
- Contrast master-slave network with ad hoc
- Master (Base station, Access Point) can manage multiple generations of clients
- Ad hoc:
  - Unicast or small group: Negotiation to common protocol generation
  - Broadcast: ???
- Lower layers more difficult than higher layers





Post-deployment Opportunity:
Remote sensing for automated driving

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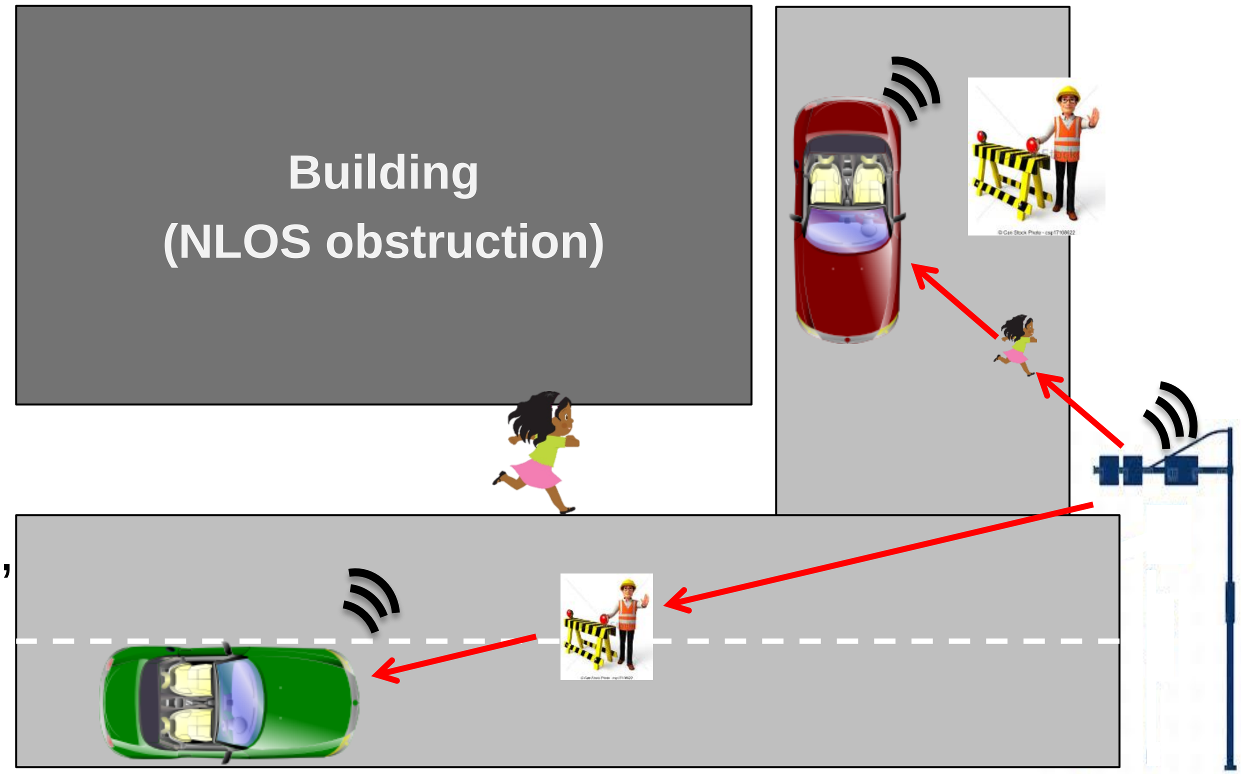
Non-line-of-sight (NLOS) obstacles are a major challenge for automated vehicles, especially at intersections



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

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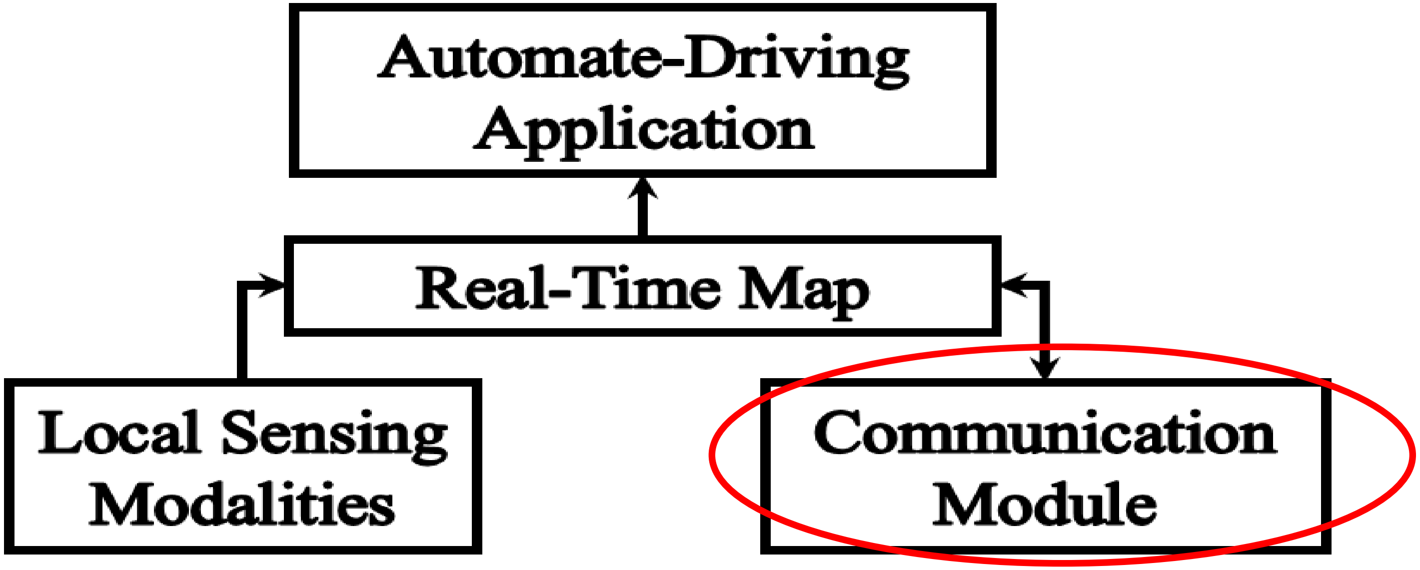

- Scalability is a concern
- Need adaptive content management
- ***"Connected, automated vehicles that can sense the environment around them and communicate with other vehicles and with infrastructure have the potential to revolutionize road safety and save thousands of lives." – US DOT Sec. Foxx 5/13/15***

"Adaptive Content Control for Communication amongst Cooperative Automated Vehicles," M. Fanaei, A. Tahmasbi-Sarvestani, Y. Fallah, G. Bansal, M. Valent, and J. Kenney, *IEEE WiVEC 2014*

What about 5G for V2X?

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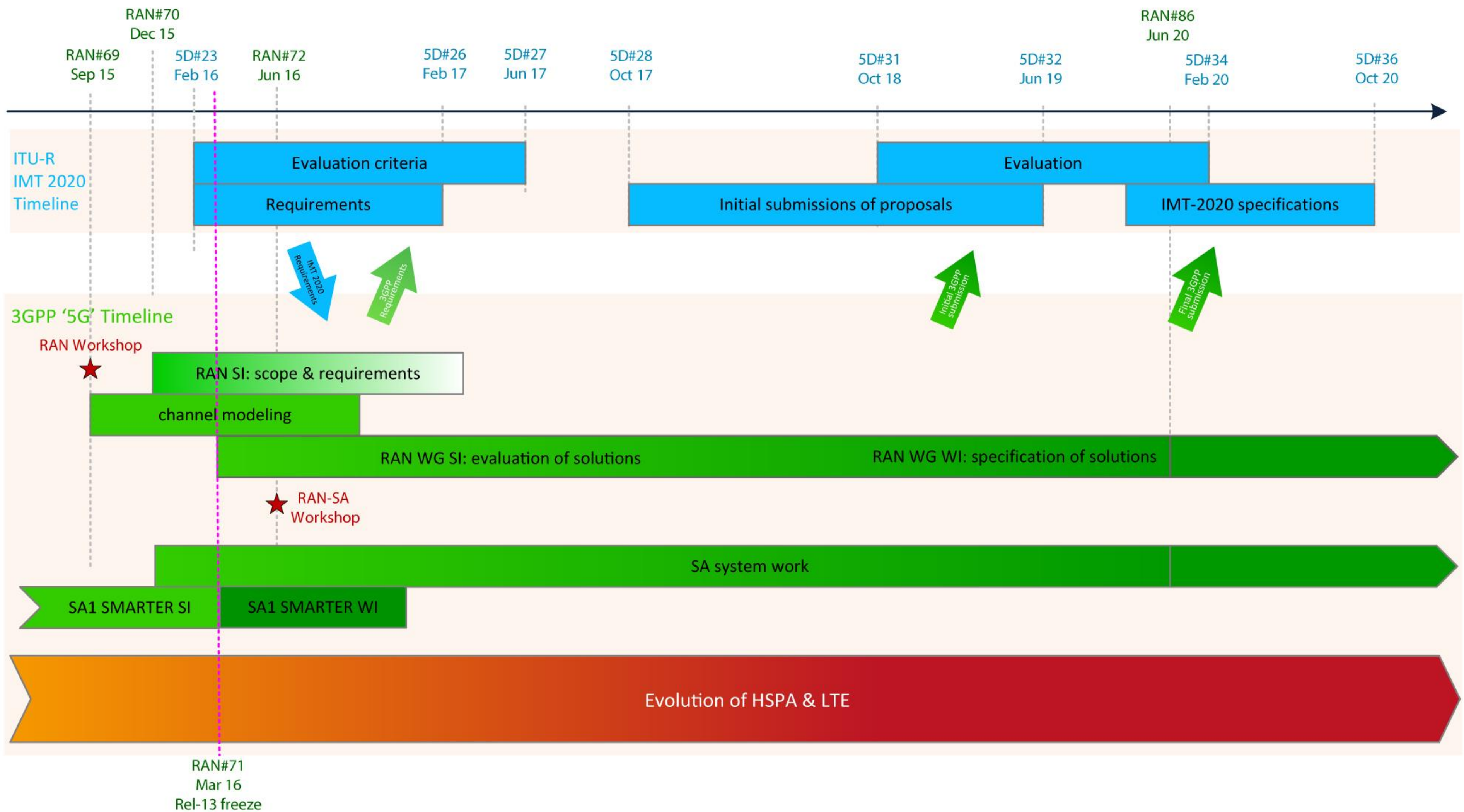
3GPP/ITU-R Timeline for 5G (3/17/15)



3GPP New Work on V2X

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- 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

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- 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?

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Thank You

jkenney@us.toyota-itc.com