DAIMLERCHRYSLER

Research and Technology North America, Inc.

Vehicle IT and Services Research

driving connectivity

Wireless Communication
The next logical step in Vehicle Safety

IEEE Communications Society Joint Meeting
Oakland-East Bay and Santa Clara Valley Chapter

Dr. Wieland Holfelder, VP & CTO

May 18, 2006

A Company of the DaimlerChrysler Group

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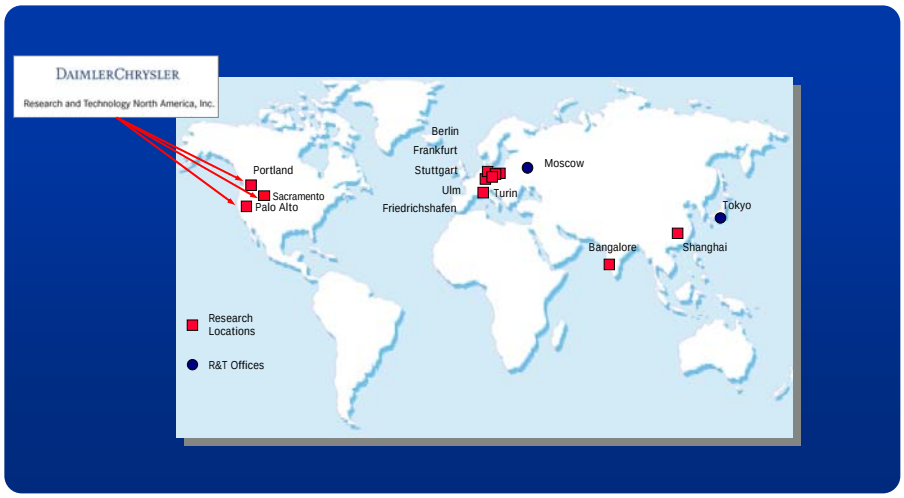
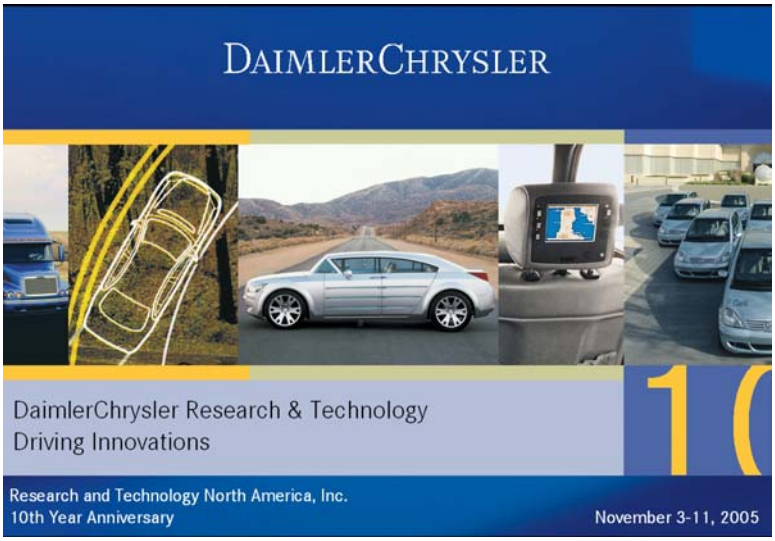
- Introduction
- Telematics & Safety
- Wireless Communication - The next logical step in Vehicle Safety
- Vehicle Infrastructure Integration (VII)
- Recent examples of VII demonstrations
- Current DSRC Research
- Summary and Conclusion

Introduction

DaimlerChrysler Group Research Locations



10 Years of DaimlerChrysler RTNA, Inc.



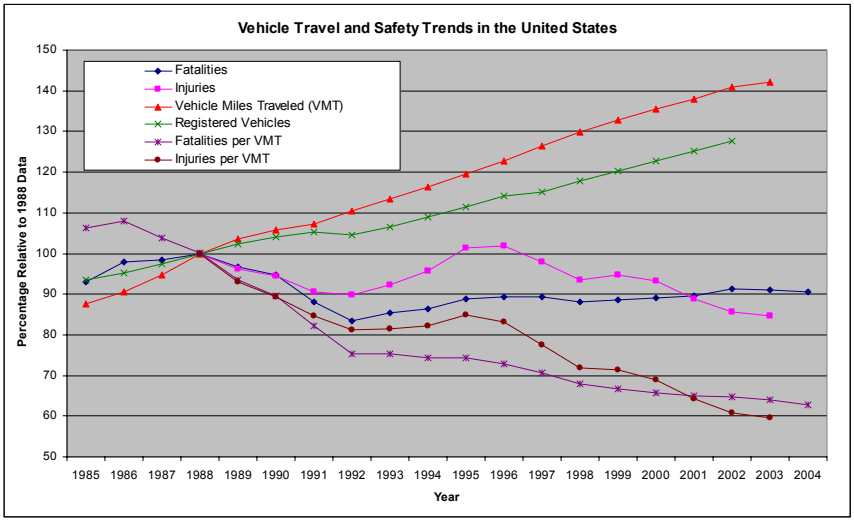
DaimlerChrysler Group Research Strategy and Challenges

Focus of today's talk

DaimlerChrysler's Vision of Accident Free Driving

Telematics & Safety

Safety Trends: Very encouraging, but always room for improvement



Source: Compiled from published data from National Highway Traffic Safety Administration, U.S. Department of Transportation

Intelligent Transport Systems = Autonomous + Telematics Systems

Telematics Systems

The World
(*Information Push*)


Service Centers


People


Other Vehicles & Drivers

Autonomous Systems

The Immediate Vehicle Surroundings
(Information Pull)


Programming

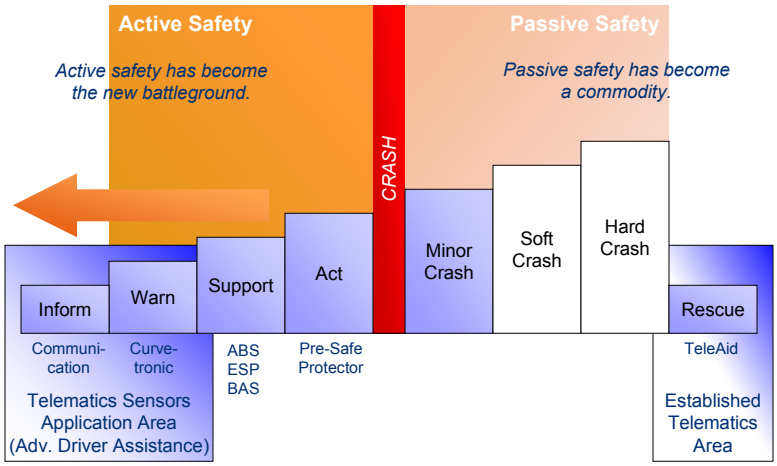

Vehicle & Driver


Infrastructure

Short Range
Long Haul

Safety Application Areas

Focus in safety shifts towards accident avoidance and collision mitigation.

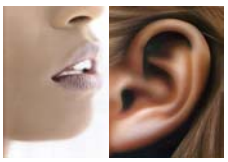


The Next Logical Step in Vehicle Safety

So far: „Feel“
- Sensing a critical situation by assessing vehicle state and driver actions
- PRE-SAFE® (since 2002)

Today: „See“
- Watching for obstacles on the road with radar
- PRE-SAFE® and Brake Assist PLUS (from 2005)

In the Future: „Speak“ / „Listen“ = Communication
- Inform drivers about dangerous situations further down the road
- Warn others (to protect them and yourself)



Wireless Communication
The next logical step in Vehicle Safety

DSRC is *THE* Enabler for Wireless Communication

Prerequisite No. 1:

Radio Frequency

FCC Federal Communications Commission

Prerequisite No. 2:

Communication Protocol

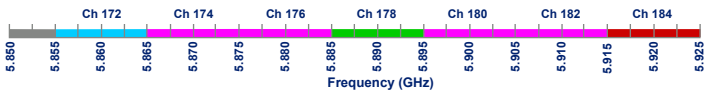
IEEE

FCC Rulings:

- Allocated exclusive spectrum for DSRC (5.850 – 5.925 GHz)
- Established licensing rules for the operation of roadside units (RSUs) and onboard units (OBUs)

IEEE Standardization:

- Future part of the IEEE 802.11 family of WiFi standards
- IEEE 802.11p a.k.a. WAVE (Wireless Access for the Vehicular Environment)



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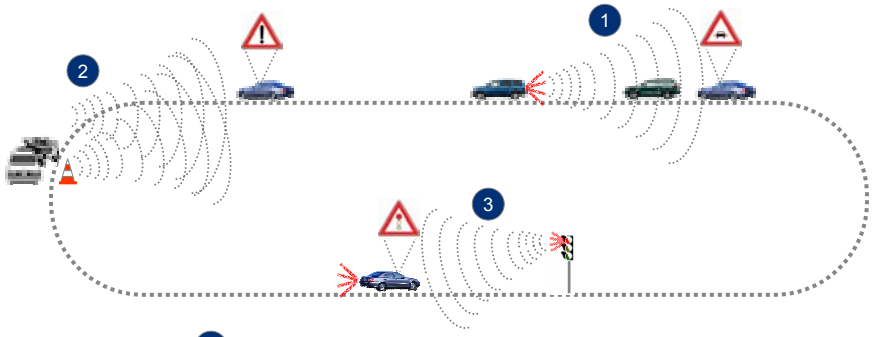
DSRC Examples

DSRC allows vehicles to communicate with each other and with infrastructure.



1. V2V: Extended Electronic Brake light
2. V2V (V2I): Hazard Warning
3. V2I: Traffic Signal Violation Warning

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More DSRC-based Safety Applications

Between Vehicles:

- Approaching Emergency Vehicle Warning
- Blind Spot Warning
- Cooperative Adaptive Cruise Control
- Cooperative Collision Warning
- Cooperative Forward Collision Warning
- Emergency Electronic Brake Lights
- Highway Merge Assistant
- Lane Change Warning
- Post-Crash Warning
- Pre-Crash Sensing
- Vehicle-Based Road Condition Warning
- Vehicle-to-Vehicle Road Feature Notification
- Visibility Enhancer
- Wrong Way Driver Warning

Source:
Vehicle Safety Communications Consortium

Between Vehicles and Infrastructure:

- Blind Merge Warning
- Curve Speed Warning
- Emergency Vehicle Signal Preemption
- Highway/Rail Collision Warning
- Intersection Collision Warning
- In-Vehicle Amber Alert
- In-Vehicle Signage
- Just-In-Time Repair Notification
- Left Turn Assistant
- Low Bridge Warning
- Low Parking Structure Warning
- Pedestrian Crossing Information at Intersection
- Road Condition Warning
- Safety Recall Notice
- SOS Services
- Stop Sign Movement Assistance
- Stop Sign Violation Warning
- Traffic Signal Violation Warning
- Work Zone Warning

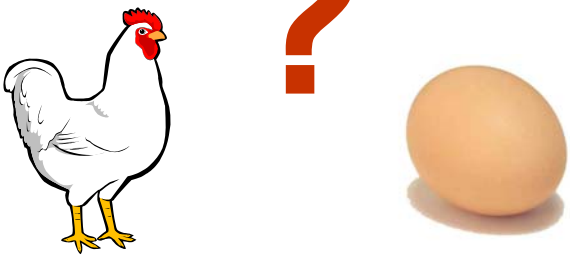
DSRC Introduction Strategy

For communication you always need at least two parties to communicate…

… and to make matters worse, for wireless communication, the other party needs to be within the range of the wireless communication system.

A classical Chicken and Egg problem…

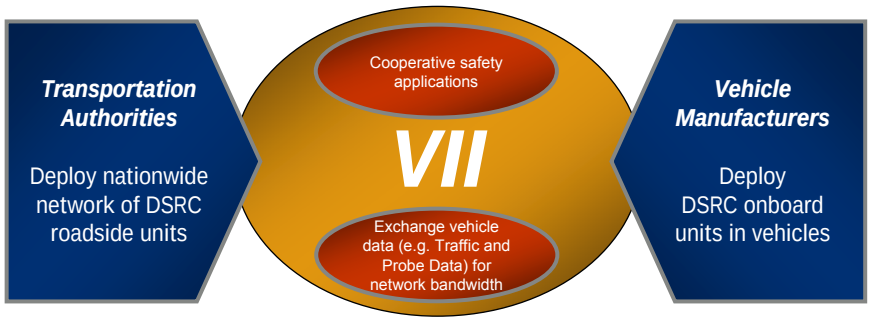
Install DSRC first in the infrastructure or first in the vehicles?



Vehicle Infrastructure Integration (VII)

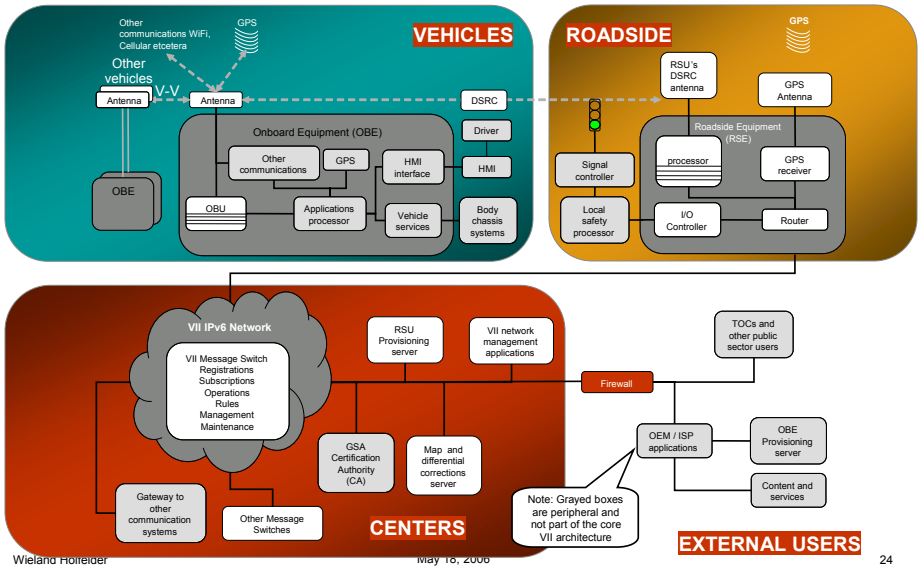
The Vehicle Infrastructure Integration (VII) Initiative

Transportation authorities and vehicle manufacturers will need to join forces to deploy DSRC. The VII Initiative forms the platform for this cooperation.

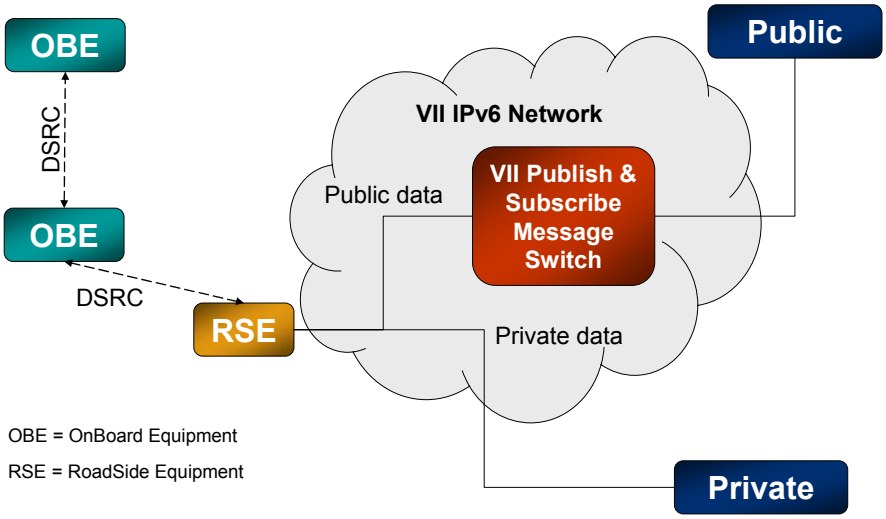


DaimlerChrysler actively participates in the upcoming VII pilots over the next 4 years to prepare for a DSRC deployment decision before the end of the decade.

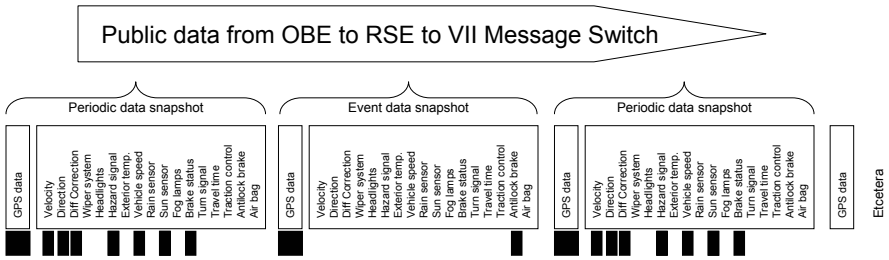
VII Architecture Framework (DRAFT)



Simplified VII Architecture (DRAFT)



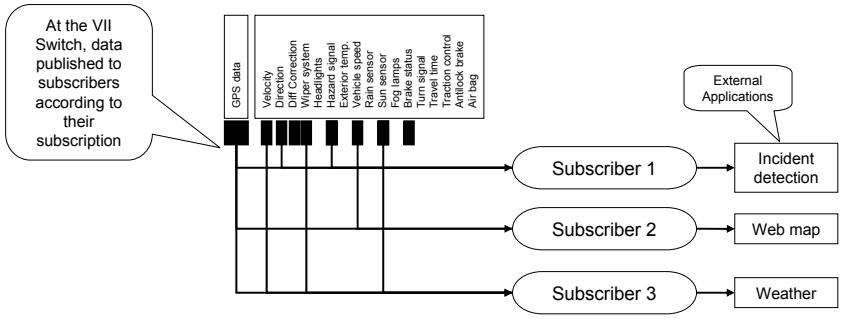
VII Collects Probe Data from DSRC-equipped Fleet, …



When the vehicle comes within range of a roadside unit (RSU) that is designed to accept such data, selected stored probe data are sent to the RSU from the vehicle and immediately forwarded to a VII Message Switch for subsequent dissemination.

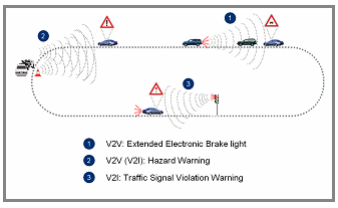
…, and Distribute Them to Data Subscribers

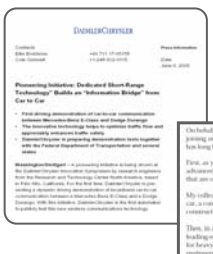
The design of VII architecture allows for detailed publish and subscribe schemes to allow for information distribution according to the types of data needed by various applications



Recent Examples of VII Demonstrations

DaimlerChrysler Innovation Symposium, Washington, DC (June 2005)





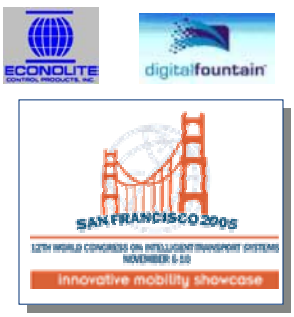
DaimlerChrysler Innovation Symposium, Washington, DC (June 2005)

Fox News Sunday June 12th 2005

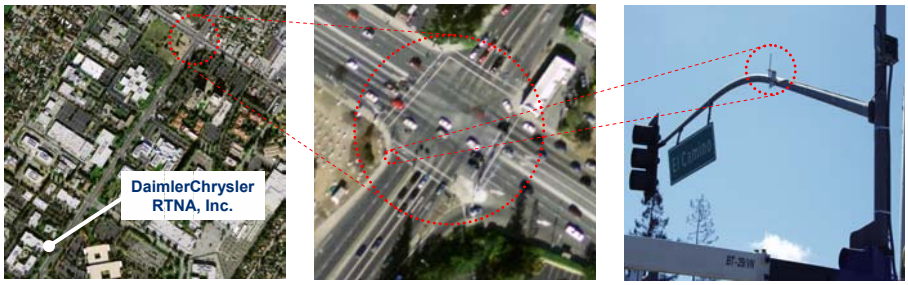
ITS World Congress (November 2005)

DC RTNA participated with 4 demonstrations at the Innovative Mobility Showcase (IMS) at the 12th ITS World Congress in San Francisco, CA.

- Traffic Signal Violation Warning at a instrumented intelligent intersection (with Econolite)
- Wireless Digital Map Update using DSRC (with Navteq and Digital Fountain)
- In-vehicle Signage with UC Berkeley PATH using the VII California DSRC Infrastructure
- Traffic Probe Data Collection with Metropolitan Traffic Center (MTC) using the VII California DSRC Infrastructure



VII California Infrastructure operational (operational since 10/05)



Example Intersection: Page Mill Road and El Camino
DSRC Access Point installed by Caltrans in 2005

Current DSRC Research

DSRC Research Activities (from an automotive OEM perspective)

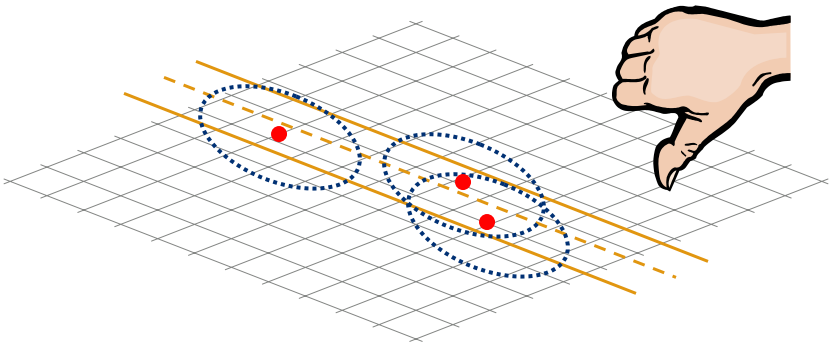
- DSRC research and design is most valuable, when grounded in real physics
  - RF Models based on the real world (communication range, interference range, variable power, multi-channel architecture, etc.)
  - Mindful of real traffic flow and traffic behavior patterns (speed, density, etc.)
  - Mindful of real deployment scenarios (initially very low penetration rates, later scalability, event-based vs. routine messaging, etc.)

- It is furthermore important to understand and embrace automotive requirements and implications of vehicle safety communications:
  - Security, Anonymity, Privacy
  - Trust (immediate, resilient)
  - Safety (absolute priority)
  - Cost (one radio design)
  - Long Vehicle Lifecycles
  - And many more…

Real World Example (1/3)

Obvious but often overlooked facts about wireless communication:

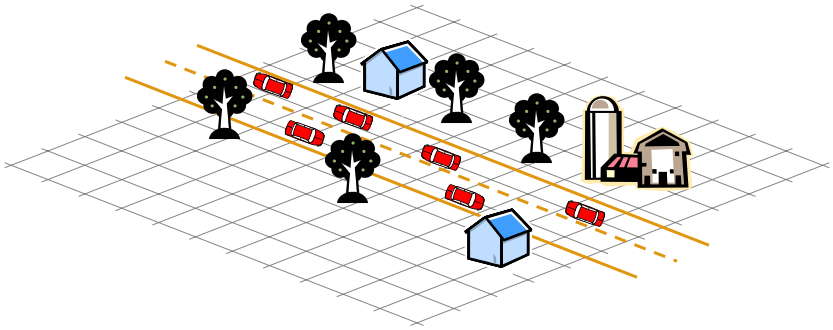
- Reception does not happen in some nice round circles with sharp boundaries, nor does interference



Real World Example (2/3)

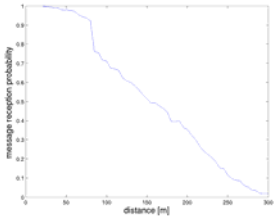
The “unfortunate” reality:

- DSRC is to be used in a real world, and therefore its research and design should be grounded in real physics
- Instead of being in an abstract and flat 2 dimensional space, DSRC is used in vehicular environments with cars, trees, buildings, bridges, and hills around, all affecting the RF propagation

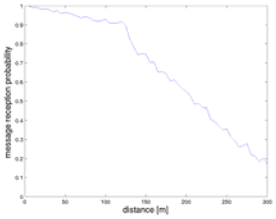


Real World Example (3/3)

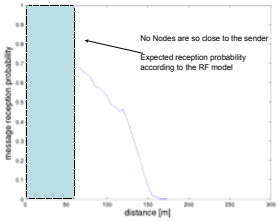
Preliminary DSRC test results in real world environments



Freeway Broadcast Reception



Urban Canyon Broadcast Reception



Urban Corner Broadcast Reception

Vehicle to vehicle communication quality was measured on freeways and in typical urban intersection

- The test equipment was based on the 1st generation VSC DSRC prototype radio and antenna
- The transmission power was restricted to only 100mW (up to 2W allowed)

There are significant deviations in DSRC communication behavior in real world environments

The presence of large tails (beyond the “reception range”) creates complex and interesting interference implications

Safety Communications Scaling

Scaling at low penetration:
Meaningful benefits of vehicle safety communication for the early adaptors are important for the introduction of the DSRC technology

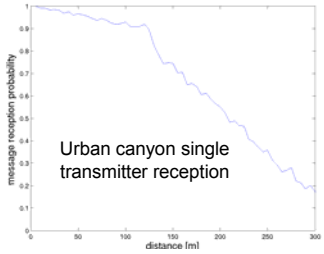
- Primarily an issue of equipping the roadway infrastructure and public safety vehicles to deliver tangible value to initial fleet with DSRC installations

Scaling at high penetration:
The safety communication design must also look forward and prepare for the future in which a significant portion of the vehicles are DSRC equipped

- The capacity of the 10Mhz DSRC channels is large but not so large as to support naïve design for safety communication
  - It is not feasible to have frequent (e.g. 10 Hz) messaging among all vehicles to long ranges (e.g. 300 meter) with highly reliable receptions in any realistically stressful traffic environment

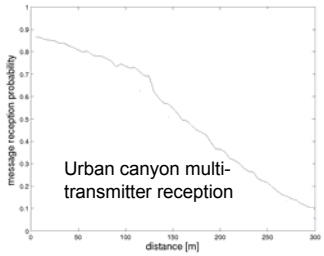
Safety Communication Scalability Observations

Communication quality in roadways is not optimal even in non-stressful context



Urban canyon single transmitter reception

Scalability concerns will make the result worse as messages compete with each other over the air



Urban canyon multi-transmitter reception

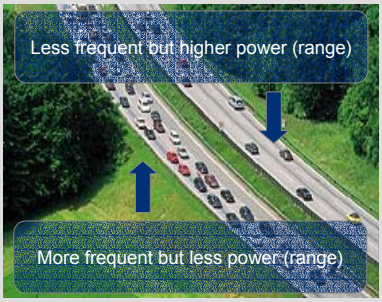
Addressing Scalability Step 1: Regulating Channel Access

Channel capacity is limited. Every vehicle must adjust its usage of the channel by restricting its messaging frequency and transmission power according to the channel load

- Channel load should be managed to allow for acceptable communication quality for high priority messages when they are needed
- It is important to allow for different control strategies depending on the traffic context

We have advanced the mathematical analysis method for evaluating IEEE 802.11p performance on roadways using realistic RF channel models

Resulting insight on “communication density” provides guidance on how to design channel access control with adequate strategies

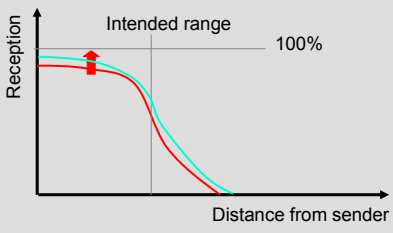


Addressing Scalability Step 2: Preventing Broadcast Failures

Safety broadcast reception generally does not have to be “perfect”; but a total failure due to a strong nearby transmission collision should be avoided

Piggybacked acknowledgement helps a sender to detect “catastrophic collisions”

- Each sender is required to include a list of most recent *n* (e.g. 5) message IDs it successfully received
- Each sender monitors the incoming messages for a short while for its ID
  - If such an ID is found, then there is no catastrophic collision in that direction
  - If no acknowledgement is found after a few messages, it should resend the message since the original one probably failed to reach its audience in general



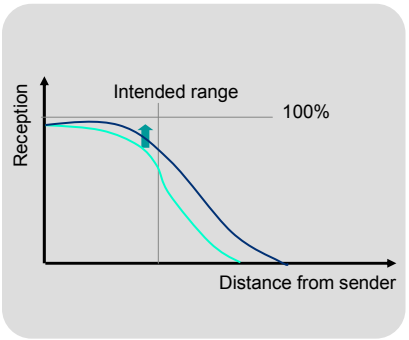
Addressing Scalability Step 3: Improving Routine Safety Broadcast

While channel access control limits the number of frames to be sent over the air, each frame does not have to contain only one safety message

- Piggybacking the content of another safety message (on the order of 50 byte according to SAE) within one's own safety message is unlikely to significantly cost the overall safety communication quality since the actual safety message size is dominated by the security overhead (on the order of 150 byte) in addition to the MAC/PHY overhead

Proactive "echoing" others' messages improves the safety broadcast quality in general

- Each sender is further required to "echo" a recently heard routine safety message content in its own packet
- If done right, each message will be sent twice

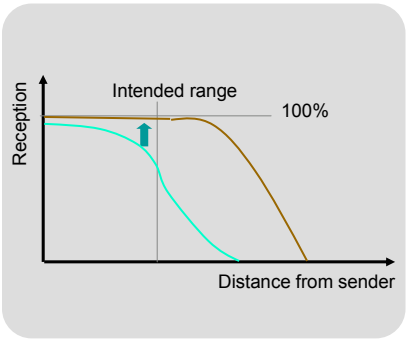


Addressing Scalability Step 4: Ensuring Priority Message Reception

High priority safety messages happen relatively rarely but require much higher reception rate within a short time

Echoing high priority message creates a controlled flooding effect

- Each sender is required to echo a recent and nearby event message
- Each high priority message would have been echoed multiple times, improving its reception probability dramatically



Summary and Conclusion

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Summary and Conclusion

- DaimlerChrysler is committed to Safety and its Vision of Accident Free Driving.
- Communicating vehicles and roadways will bring cost effective, large scale gains in safety and convenience and we are among a large group of public, private and academia partners in a substantial effort to bring this vision into reality
- DSRC (IEEE 802.11p) is the enabling technology DSRC for turning this vision into reality
- We believe that the remaining technical challenges can and will be solved, and we have shown you a survey of some of the most relevant activities
- VII (Vehicle Infrastructure Integration) will provide the necessary business and deployment framework over the next few years.
- There are many exciting opportunities for other industry participants to make contributions and to benefit from a DSRC/WAVE and VII deployment.