CAMP

Vehicle Safety Communications Consortium

IVI Light Vehicle Enabling Research Program

Vehicle Safety Communications Project

H. Krishnan (GM R & D Center)

February 15, 2006

Vehicle Safety Communications (VSC) Project

- 2.5 year program started in May 2002
- VSC Consortium Members: BMW, DaimlerChrysler, Ford, GM, Nissan, Toyota, and VW
- Facilitate the advancement of vehicle safety through communication technologies
  - Identify and evaluate the safety benefits of vehicle safety applications enabled or enhanced by communications
  - Assess communication requirements, including vehicle-vehicle and vehicle-infrastructure modes
  - Contribute to DSRC standards and ensure they effectively support safety
  - Develop next generation DSRC testing system
  - Test and evaluate DSRC communications functionalities for potential vehicle safety implementations

VSC Project Summary

- Prepared a comprehensive list of thirty-four potential vehicle safety applications enabled or enhanced by wireless communications
- Estimated potential safety benefits for potential vehicle safety applications and identified eight high-priority applications
- Defined preliminary communications requirements for the high-priority vehicle safety applications
- Evaluated proposed DSRC standards, identified specific technical issues, presented vehicle safety requirements, and secured necessary revisions in eight major areas
- Developed test system based on lower layer DSRC standard and conducted extensive communication field testing

VSC Project Summary (Continued)

- Confirmed viability of DSRC communications for vehicle safety applications at real intersections
- Implemented and demonstrated successful exchange of preliminary SAE common safety message set needed for vehicle-to-vehicle safety applications
- Identified channel capacity in stressing traffic environments as large scale deployment issue
- Determined that 5.9 GHz DSRC wireless technology is potentially best able to support the communications requirements of the majority of vehicle safety applications

Communications-Based Safety Applications

Communications Between Vehicle 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

Communications Between Vehicles

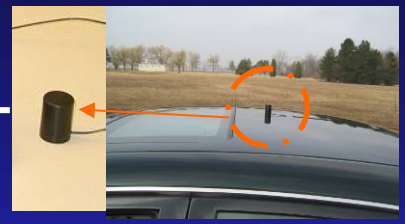
- Approaching Emergency Vehicle Warning
- Blind Spot Warning
- Cooperative Adaptive Cruise Control
- Cooperative Collision Warning
- **Cooperative Forward Collision Warning**
- Cooperative Vehicle-Highway Automation System
- **Emergency Electronic Brake Lights**
- Highway Merge Assistant
- **Lane Change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

Note:
Highest ranking applications based on safety benefit estimates are highlighted in yellow.

VSC DSRC/WAVE Testing System

WAVE Radio Module

SMA RF connection



DSRC prototype antenna magnetically mounted on OBU vehicle

ethernet

RSU configuration

serial

EPAC300 M30
Traffic Signal Controller

serial

DGPS receiver & antenna

usb

OBU configuration

USB to CAN adapter

OBU vehicle

Orchard Lake & Ten Mile Road Intersection

- One RSU in send & receive mode
  - Synchronized traffic signal controller with actual one
  - 500 byte messages including signal state & timing
  - Every 100 msec
- One OBU in send & receive mode
  - Sending 200 byte message including actual v2v common message set using actual data
  - every 100 msec
  - Driving through each lane of intersection, including turn lanes

Orchard Lake & 10 Mile

DSRC outages due to road sign obstruction of antenna

N

100 m

10 Mile Rd

RSU

100.0 m

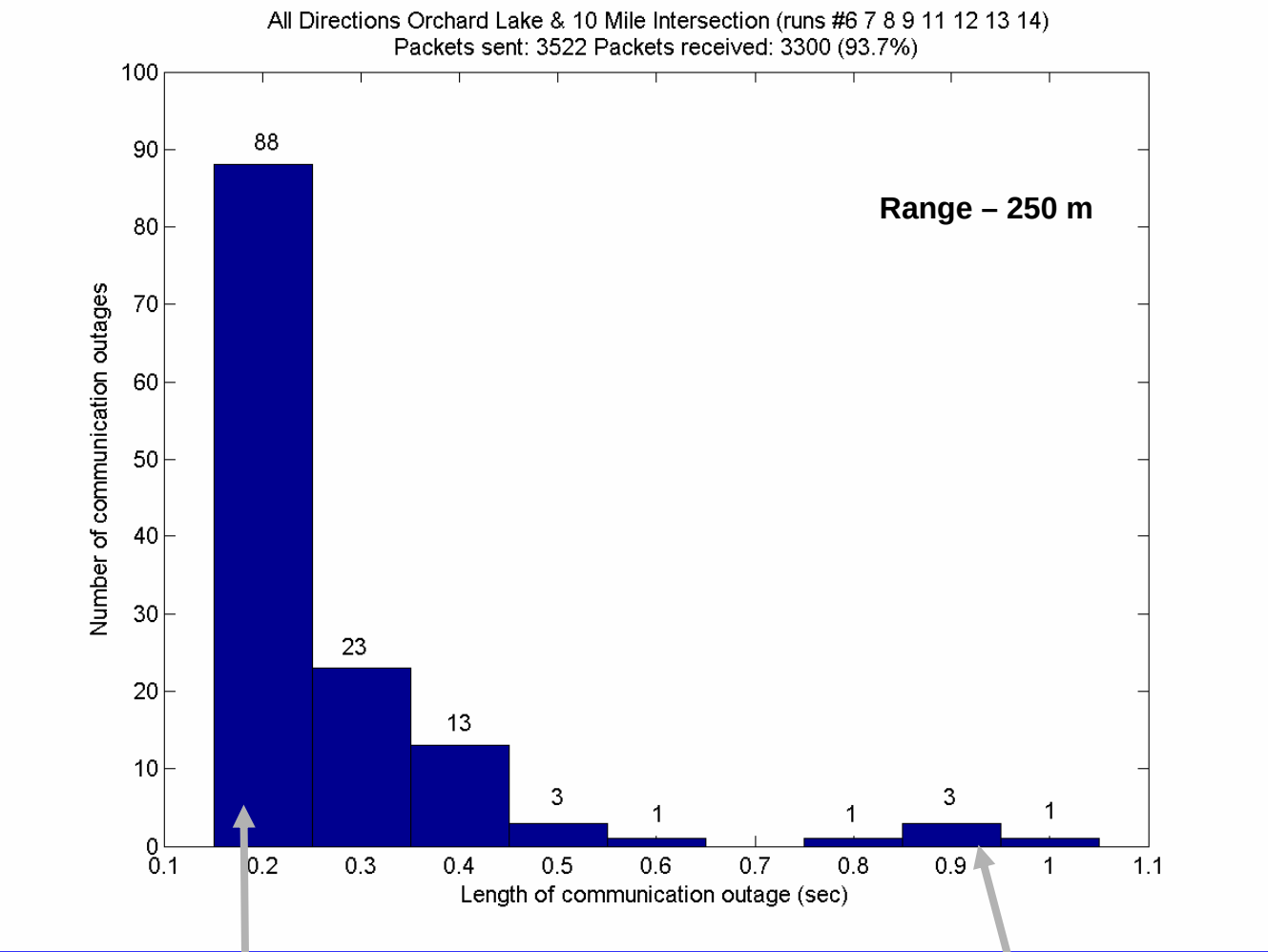
Orchard Lake Rd

RSSI (dBm)
-35.0
-49.5
-64.0
-78.5
-93.0

Orchard Lake & Ten Mile Road Intersection: Signal State & Timing Reception

- Demonstrated end-to-end connectivity between traffic signal controller and vehicle (via a synchronized unit)
- Current serial information from controller has inadequate time resolution and update rate (only 1 second resolution for time remaining in current phase updated only every 200 msec)

DSRC Outage Characterization
An example: Orchard Lake & Ten Mile Rd Intersection



Only 1 packet missed at a time: can be mitigated with data coasting techniques

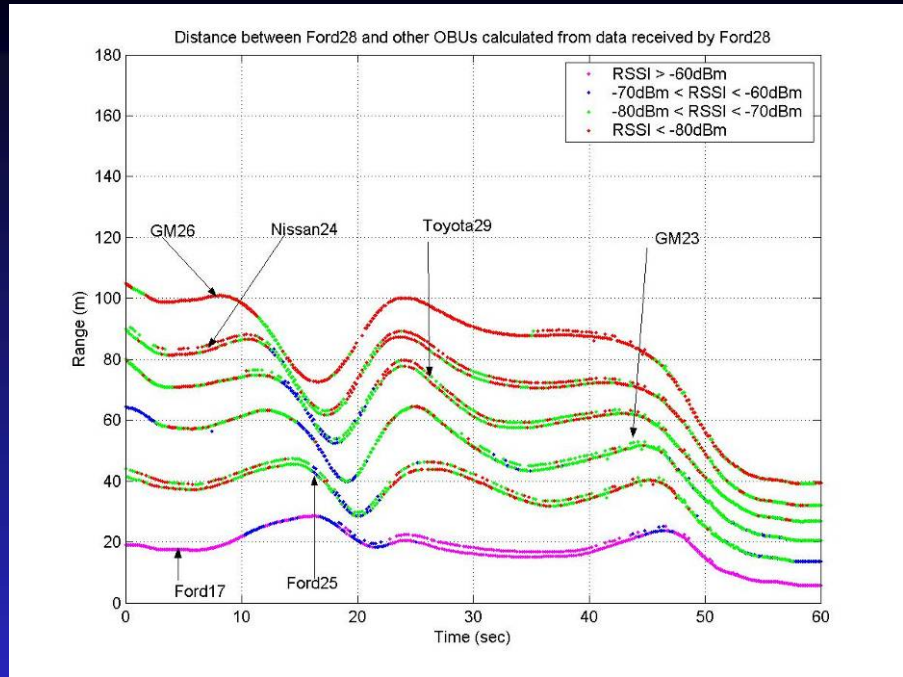
Long outage (~ 1second) due mainly to road sign obstruction of antenna: can be remedied with a more optimal RSU set-up

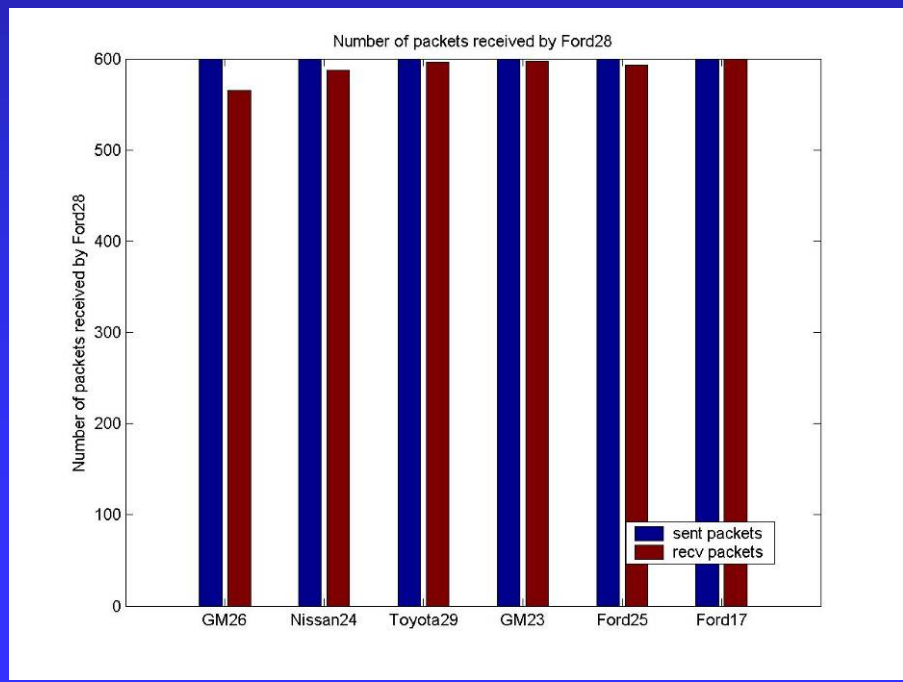
V-V Communication Performance in Real World

- Industry First Safety Communications - CAN information from different vehicle makes were exchanged wirelessly (Sept ’04)
- Seven OBUs (send & receive)
- 200 byte messages (GPS position, speed, yaw-rate, acceleration, brake status, etc)
- Every 100 ms
- Urban roads & freeway setting

V-V Communication with 7 OBU-caravan on freeway ramp

- Packet reception results were better than expected
- Demonstrated communications between vehicles in traffic separated by multiple vehicles





DSRC Security

- Constructed a proposed security architecture and protocol that appears to meet the technical requirements within the constraints identified in the project
- Presented and promoted VSC requirements and solution suggestions into standards development process
- Other stakeholders' requirements presently being integrated with VSC requirements for proposed DSRC security standard
- Drafting group currently preparing updated documents for DSRC security standard IEEE P1609.2

DSRC Standards

- The preliminary SAE common vehicle-to-vehicle DSRC safety message set was implemented in VSC field testing
  - Longitude
  - Latitude
  - Height
  - Time
  - Heading Angle
  - Speed
  - Lateral Acceleration
  - Longitudinal Acceleration
  - Yaw Rate
  - Throttle Position
  - Brake Applied Status
  - Brake Applied Pressure
  - Steering Wheel Angle
  - Headlight Status
  - Turn Signal Status
  - Traction Control State
  - Anti-Lock Brake State
  - Vehicle Length / Width
- Preliminary vehicle safety communications requirements:
  - Supported by FCC Report & Order, current lower layer standards
  - Being considered in development of upper layer and security standards

Current and Future Collaborative Projects

- Cooperative Intersection Collision Avoidance Systems Limited to Stop Sign and Traffic Signal Violations (CICAS-V) project (CAMP + VTTI), under cooperative agreement with USDOT, expected to commence in 2006
- CAMP Emergency Electronic Brake Light (EEBL) project - interoperable EEBL application demonstration conducted successfully at Milford Proving Grounds on January 31, 2006
- Effectiveness of Vehicle Safety Communications Applications, continuation of VSC project focused on V2V safety applications, under cooperative agreement with USDOT, expected to commence in 2006