COLLABORATIVE CONNECTED VEHICLE RESEARCH UPDATE

ITS America Annual Meeting
April 24, 2013

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Collaborative Research Overview

- Collaborative effort between Crash Avoidance Metrics Partnership Vehicle Safety Communications 3 (CAMP VSC3) Consortium US DOT
- Seven active projects
APPLICATION DEVELOPMENT PROJECTS (2)

• Goals:
  • Characterize system performance of mature prototype applications (OEM proprietary) that may combine V2V communications with other on-board safety sensors
  • Use the characterization in the Safety Benefits analysis

• Forward Collision Avoidance Applications
  • Five OEMs participating
  • Testing completed: achieved good results from initial test session

• Intersection Collision Avoidance Applications
  • Three OEMs participating
  • Testing is scheduled to begin in May 2013

• No final project report
Objectives:

- Obtain feedback on connected vehicle technology and safety applications from a representative sample of drivers

- Assess the performance and reliability of 5.9 GHz DSRC communications and GPS in diverse geographic locations and environmental conditions… and

- Promote V2V-based safety technology and potential safety benefits
USER ACCEPTANCE – DRIVER CLINICS

- 6 locations across the U.S. - began in August 2011
- Over 100 drivers per location
- Crash Warning Applications
  - Forward Crash Warning
  - Emergency Brake Light
  - Blind Spot Warning
  - Lane Change Warning
  - Intersection Assist
  - Do Not Pass Warning
DRIVER ACCEPTANCE CLINICS CONCLUSIONS

• About 700 participants experienced V2V safety across 10 scenarios (over 7,000 warnings issued) without a single adverse event.

• More than 45,000 individual responses were solicited
  • 100% of the participants were exposed to FCW, BSW, LCW, EEBL, and IMA
  • 37% experienced the DNPW, and
  • 25% experienced LTA.

• Analysis indicates that drivers are accepting of the V2V technology.
  • Drivers had very high acceptance and indeed a desire to have the technology deployed
  • 91% of the drivers felt the V2V technology was either “absolutely necessary” or “nice to have” after training, but prior to exposure
  • Post-exposure desirability increased to 93%

• Final report is under USDOT review
System Performance Testing Conclusions

- Current production automotive navigational-grade (low cost) GPS receivers can perform very well for V2V safety applications.

- Good relative positioning performance:
  - Lane-level in most environments
  - Road-level achievable in all environments
  - Deep urban most challenging

- **Applications can be designed to have graceful degradation** (e.g. road level to lane level) during GPS degradation periods based on feedback from GPS receiver (via the error ellipse, residual errors, etc).

- Wireless communications are reliable for V2V safety communications in all environments.

- Application performance shows improvements over the lower positioning layer, made possible through the use of path history & path prediction. Further tuning, filtering, and heuristics can improve the V2V safety applications.

- Final report is under USDOT review.
V2V Interoperability Phase 1

- Project Goals
  - Address 5.9 GHz DSRC technical issues related to interoperability, scalability, security, and data integrity / reliability
  - Provide necessary inputs into the relevant standards development and related efforts, as required, in order to ensure a deployable standards-based system

- Project ended in Aug 2012
- Final Report is under USDOT review
V2V Interoperability Phase 1

• Major Accomplishments
  • Achieved device level Vehicle-to-Vehicle (V2V) safety communications and security interoperability between OBEs from different manufacturers
  • Designed, prototyped and demonstrated a V2V security system. Demonstrated that V2V OBEs from multiple suppliers were able to request and receive security credentials received from a server remotely located in the CAMP VSC3 lab and verify credentials from other devices for the following channel configurations:
    - Channel 174 (adjacent channel to the other 196 units)
    - Channel 172 (same as 196 unite)
    - Cellular 3G
  • Developed the SP BSM Minimum Performance Requirements
  • Participated in US-EU standards harmonization
SCALABILITY TESTING

…and in reality
V2V Interoperability Phase 1

- Channel Scalability Accomplishments
  - Implemented two transmission control protocols for scalable V2V safety communications
    - Algorithm X – Adaptive transmission rate and power
    - Algorithm Y – Adaptive transmission rate
  - Defined metrics for analyzing protocol performance
  - Validated protocol effectiveness in real-world driving scenarios involving 50 to 200 vehicles
  - Developed a Proof-of-Concept NS-2 simulator for IEEE 802.11p DSRC which:
    - Accepts real mobility traces obtained from the field testing
    - Enabled evaluation of the simulation results with respect to the field testing results
V2V Interoperability Phase 1

- Scalability Research Conclusions
  - With congestion from 200 vehicles, V2V safety application scenario warnings were provided within the nominal warning range for all transmit protocols.
  - Both algorithms show promising communication performance for up to at least 200 vehicles while reducing the channel utilization below 10Hz transmit levels.
  - Due to the congestion level never reaching the point of saturation, a recommendation on a V2V safety communication congestion control approach could not be made.
V2V INTEROPERABILITY PHASE 2
SCALABILITY EFFORTS

• Goal: Finalize V2V safety communication technique(s) that will support large-scale deployment level of vehicles while preserving the performance of V2V safety applications

• Activities:
  • Calibration of communication simulation environments
  • Algorithm refinement and, if necessary, development of alternate approaches
  • Field testing
  • Incorporate recommendations into standards
V2V Interoperability Phase 2 Simulation Update

• Contracted two universities to work independently to calibrate simulation to real-world field test results
• Will move beyond field data and provide simulation results for full-deployment levels of vehicles
  • Algorithm refinements through simulation
  • Channel break-point determination
• Results will be verified through field tests
V2V Interoperability Phase 2 Field Testing

• Field testing will rely primarily on static On-Board Equipment (OBEs) mounted on carts
• Up to 400 OBEs will ultimately be used for testing
• Fewer moving vehicles will be used relative to Phase 1 testing
• Increased focus on safety application performance with channel congestion
V2V MODEL DEPLOYMENT PROJECT

- Build and maintain sixty-four integrated light vehicles for Safety Pilot Model Deployment
- Harvest data monthly for the independent evaluation of safety benefits
- Establish BSM minimum performance requirements based upon Safety Pilot data analysis
INTEGRATED VEHICLE BUILDS
V2V Key Components and Example Installations

- Power, IGN sense, RS-232, GPS Serial Ethernet, 2xUSB1.1, GPIO (3 in, 1 out), Ground, 2xCAN – 38 pin automotive
- 5.9 GHz DSRC (RX diversity)
- FAKRA Z – coaxial RF bulkhead
**Security Framework Access Device (SFAD) Phase 2 of Model Deployment**

- Sixteen SFAD equipped vehicles (2 per OEM)
  - Perform over-the-air security credential management
  - Eight communicate via DSRC
  - Eight communicate via 3G cellular
  - Automatically perform monthly updates of short term certificates
    - Initial batch loaded at initialization
    - Subsequent batches automatically loaded over-the-air
    - Fallback mechanisms (down to Phase I configuration) are still in place
  - Introduced into Model Deployment March 2013

- Forty-eight non-SFAD equipped vehicles
  - Use short term certificates preloaded on USB drives
DAS Components Camera & Radar Views

- Left Fender Mount: 120°H, 80°V
- Left Side View
- Rear View
- Package Shelf Mount: 105°H, 78°V
- Forward View
- Windshield Mount: 120°H, 80°V
- Right Fender Mount
- Right Side View
- Side Radar View
- Face View: 55°H, 45°V
- Dome View: 105°H, 78°V
- Sunroof Lip Mount
- Side Radar View
- Forward Radar View: ±18° Azimuth, ±6° Elevation

U.S. Department of Transportation
MAINTAINING THE FLEET
Remote Monitoring

- All vehicles are remotely monitored via cell link
- Study parameters are tracked to ensure exposure is sufficient
- Systems are scheduled for repair when anomalies detected
Data Harvesting and Fleet Status

- **Harvest**
  - Performed Monthly
  - Data is harvested via removable HD
  - Vehicle systems verified

- **Status @~6 Months**
  - Miles Driven: 446,919
  - Trips: 67,962
  - V2V Comms: 536,608
  - Comms < 30m: 34,445
Data Sharing – Volpe, UMTRI, & TFHRC

Volpe
- CAMP and VTTI providing a set of numerical and video data to Volpe
- Volpe serves as the Independent Evaluator
- Performs the analysis for the DOT

UMTRI (PCAP Files)
- CAMP and VTTI providing PCAP files
- UMTRI compiling V2V BSM database from PCAP

TFHRC
- CAMP and VTTI providing a subset of numerical data for the Real-time Data Capture Management Program.

CAMP & VTTI
- Performing a series analyses on system performance
Event Examples

FCW
Event Examples

BSW
V2V Security
Why do we need it?

• The receiver of a message is not able to determine, without additional mechanisms, whether
  • a message originates from a trustworthy and legitimate device, and whether
  • the message was modified between the sender and the receiver.

• Public Key Infrastructure is necessary for a system that relies upon vehicles trusting messages broadcasted by other vehicles
V2V Security Communications

Three types of communications
• Basic safety message broadcasts from vehicles
• Communication Channel from Vehicles to SCMS
  • Send misbehavior reports (messages flagged by local misbehavior detection)
• Communication Channel from SCMS to Vehicles
  • Issue New Certificates
  • Update Vehicles with Certificate Revocation List
High Level SCMS Technical Structure

Main Operations:

1. Device Initialization
2. Certificate Provisioning
3. Misbehavior Detection and Revocation
COMMUNICATIONS SECURITY RESEARCH
RECENT ACCOMPLISHMENTS

- Defined a deployment model for connected vehicle security for a vehicle-to-vehicle warning system, including an initial deployment model, an end-state model and the transition between the two
- Identified potential design simplifications using risk assessment techniques
- Refined SCMS design for functions such as device initialization, certificate provisioning, and misbehavior detection and revocation
- Identified restriction for operating different SCMS components
- Documented the technical considerations for OEMs for potential involvement in the operation of SCMS components
**Title:** Design Optimization and Cost Analysis of Connected Vehicle Security System

**Period of Performance:** April 3, 2013 – January 3, 2014

**Activities:**
- Define baseline security model and baseline OBE requirements
- Develop security system cost model
- Perform cost analysis on baseline security model
- Analyze potential simplifications to the deployment model
- Analyze alternative device-SCMS connectivity approaches
- Identify technical approaches to linking enrollment certificates to batches of devices to aid defect investigations
- Provide design recommendations for V2V Security System
COMMUNICATIONS SECURITY RESEARCH
UPCOMING RESEARCH ACTIVITY

- Misbehavior Detection and Reporting
  - Consider both Local and Global Misbehavior Detection
  - Explore one or more detection schemes that could potentially be suitable for initial deployment
  - Consider communication protocol and/or data elements
Questions?
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