V2V Communications Security Project Update

USDOT ITS Connected Vehicle Workshop

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V2V Safety Framework

Maturing the V2V Research
- Initial Crash Problems
- Performance Measures
- Testing Procedures
- Interoperability Requirements
- Initial Security Models
- Driver Vehicle Interface Guidance

Model Deployment
- Benefits Framework
- Driver Clinics
- Performance Testing
- Model Deployment
- Experimental Design

Evaluation
- Evaluation Plan
- Data
- Conduct Evaluation
- Run Simulations

Supporting Policy Elements
- Implementation
- Technical
- Legal

Moving Towards a Decision
- Safety Benefits
- Performance Requirements
- Test Procedures
- Driver Acceptance

Moving Towards an Operation Model

Data Collection

Data Evaluation & Analysis

Establishing an Operational Environment

Results
Key Messages

A team of OEMs, US DOT personnel, automotive suppliers and security experts have examined the technical feasibility and risks associated with a security system for V2V warning-only applications, under a certain set of assumptions.

The proposed security model developed needs to be built and tested to validate the conclusions from this study.
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5. OEMs believe that privacy and tracking risks will likely require a combination of technical and policy solutions.
Vehicle Communications + GPS: A New Safety Sensor

- Lower cost enables deployment to all market segments, not just luxury
- Offers new features not possible with existing obstacle detection-based driver assistance systems
- Enhances existing obstacle detection-based driver assistance systems
Opportunity for Safer Driving

- Greater situational awareness
  Your vehicle can “see” nearby vehicles

Reduce or even eliminate crashes thru:
Driver Advisories
Driver Warnings

V2V systems have the potential to address 81% of light vehicle crash scenarios involving unimpaired drivers
## Safety Applications vs. Crash Scenarios Mapping

<table>
<thead>
<tr>
<th>Crash Scenarios</th>
<th>V2V Safety Applications</th>
<th>EEBL</th>
<th>FCW</th>
<th>BSW</th>
<th>LCW</th>
<th>DNPW</th>
<th>IMA</th>
<th>CLW</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Lead Vehicle Stopped</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Control Loss without Prior Vehicle Action</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Vehicle(s) Turning at Non-Signalized Junctions</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Straight Crossing Paths at Non-Signalized Junctions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Lead Vehicle Decelerating</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Vehicle(s) Not Making a Maneuver – Opposite Direction</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Vehicle(s) Changing Lanes – Same Direction</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 LTAP/OD at Non-Signalized Junctions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
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</table>


**Legend:**
- **EEBL:** Emergency Electronic Brake Lights
- **FCW:** Forward Collision Warning
- **BSW:** Blind Spot Warning
- **LCW:** Lane Change Warning
- **DNPW:** Do Not Pass Warning
- **IMA:** Intersection Movement Assist
- **CLW:** Control Loss Warning
Interoperable Communication: SAE J2735 Message Set

- Periodic safety message broadcast (10 times per second)
- Event-driven safety message broadcast (immediate on event occurrence)

![Diagram showing the J2735 Basic Safety Message]

**Part I**
- Basic Vehicle State
  
  (Veh. ID, Seq. #, time, position, motion, control, veh. size)

  *Part I is mandatory in the Basic Safety message*

**Vehicle Safety Extension**
- Event Flags
- Path History
- Path Prediction
- RTCM Corrections

*Required for V-V safety applications, but not in every message*

**Other optional safety-related data**
Why we need security

• The receiver of a message is not able to determine, without additional mechanisms, whether

1. a message originates from a trustworthy and legitimate device, and whether

2. the message was modified between sender and receiver.
What is a PKI?

1. Issue certificate and private key

Vehicle A

Public Key
Validity Date

CA Signature

2. Sign message (using private key) and send message, signature & certificate

Vehicle A

Public Key
Validity Date

CA Signature

Message
Signature

3. Verify certificate (using CA’s public key) and verify message (using certificate’s public key)
V2V Security Communications

- Communication Channel from Vehicles to SCMS
  - Send misbehavior reports (messages that led to warnings, messages flagged by local misbehavior detection and casual reports)

- Communication Channel from SCMS to Vehicles
  - Issue New Certificates
  - Update Vehicles with Certificate Revocation List
Assumptions and Goals

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• DSRC and/or other communications technologies may be used to provide communications between vehicles and off-board security functions, without any subscription fees for mandatory services
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- User acceptance is important for the V2V crash avoidance system in order to realize the potential safety benefits.
- The system should be designed so that a vehicle is not able to be tracked in order to gain user acceptance.
- DSRC and/or other communications technologies may be used to provide communications between vehicles and off-board security functions, without any subscription fees for mandatory services.
- The system should be able to withstand attacks and effectively recover from the effects of attacks.
## Initial Deployment Model

<table>
<thead>
<tr>
<th>Security Credential Management System (SCMS)</th>
<th>On-Board Elements (OBE)</th>
<th>Communications between OBE &amp; SCMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>• SCMS structure with:</td>
<td>• OBE requirements:</td>
<td>• Communications required after 3 years for:</td>
</tr>
<tr>
<td>• Certificate Authority (CA)</td>
<td>• FIPS 140 Level 2 or equivalent security processor</td>
<td>• New certificate request</td>
</tr>
<tr>
<td>• Registration Authority (RA)</td>
<td>• Encrypted storage of certificates on-board</td>
<td>• Certificate Revocation List</td>
</tr>
<tr>
<td>• 2 Linkage Authorities (LAs)</td>
<td>• Capability to:</td>
<td>• Misbehavior reporting</td>
</tr>
<tr>
<td>• Preliminary Misbehavior Authority, etc.</td>
<td>• Option 1: initially load 3000 non-overlapping certificates, re-use for 3 years, 5 minute duration each use – 300kB certificate storage</td>
<td>• Also possible more frequently, if supported by opt-in connections</td>
</tr>
<tr>
<td>• Capability to generate and provide certificates valid for use for three (3) years from initial deployment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Option 1: re-useable, non-overlapping, 5 minute certificates valid for 3 years</td>
<td>• Option 2: initially load 7 - 40 overlapping certificates per week, sufficient for 3 years (~6000), re-use during week if necessary, change at OEM discretion – max. 600kB certificate storage</td>
<td></td>
</tr>
<tr>
<td>• Option 2: re-useable, overlapping certificates valid for 1 week for each week for 3 years</td>
<td>• SCMS risk mitigation techniques are well-known from similar implementations</td>
<td>• Connectivity not required for the first 3 years</td>
</tr>
</tbody>
</table>

• OBE requirements are technically feasible
• Security portion < 20% of total OBE cost
# Full Deployment Model

## Security Credential Management System (SCMS)

- SCMS structure with:
  - Certificate Authority (CA)
  - Registration Authority (RA)
  - 2 Linkage Authorities (LAs)
  - Misbehavior Authority, etc.
- Capability to generate and provide certificates valid for use for <3 years from certificate request:
  - **Option 1**: re-useable, non-overlapping, 5 minute certificates valid for <3 years
  - **Option 2**: re-useable, overlapping certificates valid for 1 week for each week for <3 years

## On-Board Elements (OBE)

- OBE requirements:
  - FIPS 140 Level 2 or equivalent security processor
  - Encrypted storage of certificates on-board
- Capability to:
  - **Option 1**: request and load 3000 non-overlapping certificates, re-use for <3 years, 5 minute duration each use – 300kB certificate storage
  - **Option 2**: request and load 7 - 80 overlapping certificates per week, sufficient for <3 years (~6000), re-use during week if necessary, change at OEM discretion – max. 600kB certificate storage

## Communications between OBE & SCMS

- Communications required for:
  - New certificate request
  - Certificate Revocation List
  - Misbehavior reports
- Connectivity required:
  - Likely more frequently than every 3 years
  - Depends upon:
    - number of attackers
    - magnitude of the attacks
  - Difficult to estimate without actual operational experience

## Graceful evolution from initial deployment model

- OBE full deployment requirements supported by initial deployment vehicles

- Connectivity options, both default and opt-in, must expand by full deployment
Risk Analysis

• Risk analysis was performed for various attack/attacker combinations and scenarios. Analysis done for 24 attacks, 11 attackers, and 3 scenarios, so overall a total of 792 risk assessments.

• Expert judgment and a NIST-like model were used to find likelihood and impact levels, and finally risk levels.
  • Risk levels are low, medium and high. A high risk level may, for example, mean frequent false warnings that may deter user acceptance.

• Assuming connectivity only every 3 years, Sybil attacks on the OBEs in the full deployment model showed up as high risk.
  • This risk can be mitigated by having more frequent connectivity. Connectivity requirements analysis results are on the next slide.
Connectivity Requirements
For Different Penetration Levels and Attack Rates

<table>
<thead>
<tr>
<th>Attack Rate Penetration Levels</th>
<th>Benign Case: up to 100 devices/year cert extraction</th>
<th>Severe Case: up to 1000 devices/year cert extraction</th>
<th>Extreme Case: up to 10,000 devices/year cert extraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1%</td>
<td>3 years</td>
<td>3 years</td>
<td>1 year</td>
</tr>
<tr>
<td>10%</td>
<td>3 years</td>
<td>3 years</td>
<td>4 months</td>
</tr>
<tr>
<td>50%</td>
<td>3 years</td>
<td>1 year</td>
<td>6 weeks</td>
</tr>
<tr>
<td>100%</td>
<td>3 years</td>
<td>6 months</td>
<td>3 weeks</td>
</tr>
</tbody>
</table>

Modeling target is less than one false alarm per week per equipped vehicle from intentional attacks. This may change as system matures and there is a better understanding about user acceptance of false alarms.
Summary of Highest Risk Levels for SCMS-Directed Attacks

<table>
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<tr>
<th>Type of Attack</th>
<th>Initial</th>
<th>Full</th>
<th>Mitigation</th>
<th>After Mitigation</th>
</tr>
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<tbody>
<tr>
<td>SCMS - Root CA Compromise</td>
<td>High</td>
<td>High</td>
<td>Policy (see below)</td>
<td>High (Very Low Probability)</td>
</tr>
<tr>
<td>SCMS - Intermediate CA Compromise</td>
<td>High</td>
<td>High</td>
<td>Policy (see below)</td>
<td>High (Very Low Probability)</td>
</tr>
<tr>
<td>Trust Management Compromise</td>
<td>High</td>
<td>High</td>
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- The likelihood of each attack can be reduced by implementing appropriate policy, process and procedures, as is done with similar systems. This would include separation of duties and multiple layers of security.
# Summary of Highest Risk Levels for Privacy and Tracking Attacks

<table>
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<th>Full</th>
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<tr>
<td><strong>Tracking</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tracking Vehicles using 1-Day Certificates by Funded Private Organizations</td>
<td>* - US DOT technical team rankings are lower</td>
<td>Medium to High</td>
<td>Medium to High</td>
<td>Use shorter duration for certificates, to make this attack more difficult, such as 5-minute certificates which are now assumed for initial and full CAMP models</td>
</tr>
</tbody>
</table>
| Find and Track Vehicles by Government Organizations  
Assumptions: certificates are linked to VIN, a subpoena/warrant is not required & full RSE network deployed | Low | High* | Public SCMS: Do not link certificates to VIN and/or require legal process  
Private SCMS: Require legal process | Medium |
| **Law Enforcement** |         |      |            |                 |
| Traffic Law Enforcement. Assumptions: using BSM information is advantageous as compared to current automated traffic enforcement systems and data would hold up in a court of law* | High* | High* | Under these assumptions, a technical mitigation for this risk has not yet been identified. Further technical and policy study is required. | TBD |
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Next Step: Analyze alternative connectivity options
Next Step: Analyze SCMS architectures and potential OEM roles