The Business Case for Connected Vehicles

Prof David G Michelson
University of British Columbia
Transportations Futures Group | Radio Science Lab
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Introduction

• If connected vehicle technology has such great potential to:
  • improve road safety,
  • ease traffic congestion,
  • enhance the efficiency of commercial vehicle operations,
  • support the adoption of renewable energy and
  • enable automated vehicle technologies...

• Why aren’t we there yet?
Or, more specifically...

- Why has the rate at which connected vehicle technology has been adopted and deployed been so slow?
- What are the missing pieces that remain to be filled?
- Will it merely take an additional round of cost reductions to open the field?
- Is something more fundamental required?
Agenda

I. Technology
II. Use Cases
III. Human Factors
IV. Systems and Scalability
V. Next Steps
I - Technology

• Vehicles have always devoted a great deal of infrastructure to signaling!

• The *incremental cost* of adding CV devices is low.

• Many vehicles provide ready access to sensor data via CANBUS and similar.
Many CV Technology Options!

<table>
<thead>
<tr>
<th>Technology</th>
<th>Frequency</th>
<th>Range</th>
<th>Data Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellular</td>
<td>0.8 – 2.5 GHz</td>
<td>Wide Area</td>
<td>$O(10$ Mb/s)</td>
</tr>
<tr>
<td>RFID</td>
<td>VHF/UHF</td>
<td>$O(10$ m)</td>
<td>$O(0.1$ Mb/s)</td>
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<tr>
<td>Bluetooth</td>
<td>2.4 GHz</td>
<td>$O(10$ m)</td>
<td>$O(1$ Mb/s)</td>
</tr>
<tr>
<td>ZigBee</td>
<td>2.4 GHz</td>
<td>$O(10$ m)</td>
<td>$O(1$ Mb/s)</td>
</tr>
<tr>
<td>WiFi</td>
<td>2.4, 5.2 GHz</td>
<td>$O(100$ m)</td>
<td>$O(10$ Mb/s)</td>
</tr>
<tr>
<td>DSRC*</td>
<td>5.9 GHz</td>
<td>$O(100$ m)</td>
<td>$O(10$ Mb/s)</td>
</tr>
<tr>
<td>Radar*</td>
<td>77 GHz</td>
<td>Line of Sight</td>
<td>$O(100$ Mb/s)</td>
</tr>
<tr>
<td>Visible Light*</td>
<td>$O(500$ THz)</td>
<td>Line of Sight</td>
<td>$O(100$ Mb/s)</td>
</tr>
</tbody>
</table>
Technology Selection Issues

- Cost and performance,
- Security and privacy,
- Service life and Development life cycle,
- Standards vs Proprietary design,
- Coverage and interference.

- Installation of CV devices *aboard vehicles* is inexpensive* and power is readily available.
- Retrofit installation is more expensive than new design.
- Installation of CV devices *on infrastructure* is an order of magnitude more expensive (power and housing issues).
Further Insights – DSRC Infrastructure Deployment Issues

AASHTO Connected Vehicle Field Infrastructure Footprint Analysis

Preparing to Implement a Connected Vehicle Future

Moving with Technology
II – Use Cases

Connected vehicle technology has great potential to help:

• improve **road safety**,  
• ease **traffic congestion**,  
• enhance the efficiency of **commercial vehicle operations**,  
• support the adoption of **renewable energy**, and  
• enable **automated vehicle** technologies...

But these applications have very different requirements for:

• Latency  
• Range  
• Throughput (and capacity)  
• User (or machine) interface  
• Infrastructure  
• Cost recovery
CV Use Cases – Requirement Cubes

Throughput

Latency

Range

UX Complexity

Funding Source (User – Government)

Local Traffic

Metro Traffic

CVO

AV

Safety

Engineers tend to focus on this!

Planners tend to focus on this!
ITS Architecture for Canada, Release 2.0

- Patterned after and coordinated with the U.S. National ITS Architecture
- Mapping CV technology to the ITS Architecture is a challenge.
Mapping Technology onto the Architecture

• The AASHTO study was an outstanding first effort to consider infrastructure deployment issues associated with specific scenarios.

• Expanding the range of scenarios and examining the tradeoffs associated with alternative CV technologies would help to resolve outstanding issues.
III – Human Factors

• The role of human response time in traffic safety is well studied.

• It isn’t sufficient to exchange data between RSUs and OBUs or OBUs and other OBUs.

• Safety information must be presented to the driver in a clear and unambiguous manner.

• Experience gained during the Ann Arbor Safety Pilot suggests that standardization of User Interface Design and Delivery of Cues and Messages to the driver has received less than adequate attention.
Distracting the Driver?

• US DOT officials report that the possibility of vendor and/or regional diversity in User Interface Design and Delivery of Cues and Messages is a tremendous concern.

• Critics have expressed concern that cues and messages could distract rather than assist the driver.

• Where should the messages be presented? Standardized colours, placement, sounds?
IV - Systems and Scalability

An engineer can do for a dollar what any fool can do for two!

- Arthur M. Wellington

• Cost and cost recovery remains a dominant theme for CV technology.
• It isn’t difficult to stage small-scale demonstrations.
• Planning and executing large-scale deployments in a cost-effective manner is another matter!
Scaling Issues

How does the importance of the following issues scale with the size of the deployment?

- Cost and performance,
- Security and privacy,
- Service life and Development life cycle,
- Standards vs Proprietary design,
- Coverage and interference.

- Software development
Software Development

Software has been the Achilles Heel of most wireless technology rollouts of the last twenty years!

- Are complete reference implementations of the protocol stacks readily available to developers?
- Are complete reference implementations of the servers readily available to developers?
- Have standardized user interfaces been agreed upon?
- Are software development kits available?
- Are network planning and monitoring tools that help predict and identify coverage, interference & performance (i.e., aircell) issues available?
Can we answer these questions now?

• Why has the rate at which connected vehicle technology has been adopted and deployed been so slow?

• What are the missing pieces that remain to be filled?

• Will it merely take an additional round of cost reductions to open the field?

• Is something more fundamental required?
Answers

• The business case for connected vehicle technology is not yet well enough understood.
  • Cost-benefit analysis for various scenarios and use cases
  • Cost reduction techniques
  • Funding model
• System-level support for CV deployment is inadequate.
  • Network planning and monitoring tools that help to predict, identify and resolve airlink issues.
• Software support for CV deployment is inadequate.
  • Reference implementations of protocol stacks
  • Reference implementations of servers
  • Software development kits
V – Next Steps

• Most of these issues can be resolved – given the right focus and effort.

• The multidisciplinary UBC Transportation Futures Group and the AURORA Connected Vehicle Testbed aims to take a leading role.