The value of communication and infrastructure for automated cars

Professor Robert W. Heath Jr., PhD, PE

Wireless Networking and Communications Group
Department of Electrical and Computer Engineering
The University of Texas at Austin

Thanks to sponsors including the U.S. Department of Transportation through the Data-Supported Transportation Operations and Planning (D-STOP) Tier 1 University Transportation Center, the Texas Department of Transportation under Project 0-6877 entitled “Communications and Radar-Supported Transportation Operations and Planning (CAR-STOP)”, National Instruments, and Toyota IDC

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Automated vehicles

**LEVEL 0**
- No automation

**LEVEL 1**
- Function specific automation
  - Driver can cede control over a primary function (e.g., ACC)
  - Responsible for safe operation

**LEVEL 2**
- Combined function automation
  - Driver can cede control on at least two primary functions

**LEVEL 3**
- Limited self-driving automation
  - Driver does not have to monitor the roadway at all times

**LEVEL 4**
- Fully self-driving automation
  - Driver not available for control
  - Driver provides destination

NHTSA, “Preliminary Statement of Policy Concerning Automated Vehicles”, 2013
Myths surrounding automated vehicles

MYTH 1
Automated vehicles can be fully autonomous, no communication is required

MYTH 2
Infrastructure has no value for automated vehicles
Limited range of vehicular sensing (ideal)

Drivers can see 3000 meters

Radar can see 200 meters

Cameras can see 30 meters

Lidar can see 100 meters
Limited range of vehicular sensing (in traffic)

Drivers can see 3-5 meters

Radar can see 3-5 meters

Cameras can see 3-5 meters

Lidar can see 3-5 meters
How is this solved in aviation?

Air traffic control tower
Radar tower
Air-to-air commun.
Transponder
A2A

Combination of communication, sensing, and infrastructure
Benefits of communication and sensing

- Fly through weather with limited or no visibility
- Separation between aircraft for collision avoidance
- Access to restricted airspace, faster routes, more flight options
- Full automation is not required, though automated flying using 2D and 3D autopilots using inertial guidance or GPS is common

Image source: http://www.dailymail.co.uk/news/article-2548628/
Do all aircraft really exploit comm. and sensing?

No!

**Flies under visual flight rules (VFR)**
- Less flexible travel, limited airspace
- Need to carefully monitor weather
- Recreational form of travel

**Flies instrument flight rules (IFR)**
- Access to restricted airspace
- Faster routes and more flight options
- Ground based radar can track VFR and IFR aircraft
Takeaway #1: Communication is useful

- Expand the sensing range of the vehicle
- Higher levels of traffic coordination like platooning
- More informed safety decisions
- Allows interactions between vehicles with different automation levels
Takeaway #2: Infrastructure is valuable

Supports sensing of the environment, does not require all cars to have complete sensing equipment.

Can be used for other functions, for example more precise navigation.

Effective with non-connected cars, bicycles, and pedestrians.

Helps coordinate traffic through intersections, eliminating lights.
Ex: Passing on rural roads

Both communication and radar are useful for collision avoidance.

82% of head-on fatal collisions take place in rural areas.

Radar requires line-of-sight.

What if the bus or oncoming car do not have communication capability?
Ex: Passing on rural roads

Infrastructure w/ sensing can broadcast position, velocity, and acceleration of vehicles.

Infrastructure has enhanced sensing, better communication range.
Benefits of comm. and sensing at infrastructure

<table>
<thead>
<tr>
<th></th>
<th># of collisions with correct warning</th>
<th># of safe maneuvers with incorrect warning</th>
<th># of safe maneuvers with received warning message</th>
</tr>
</thead>
<tbody>
<tr>
<td>V2V - DSRC</td>
<td>2,545</td>
<td>113</td>
<td>349</td>
</tr>
<tr>
<td>V2I with 200m spacing</td>
<td>3,482</td>
<td>322</td>
<td>1097</td>
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<tr>
<td>V2I with 500m spacing</td>
<td>3,436</td>
<td>288</td>
<td>985</td>
</tr>
</tbody>
</table>

Infrastructure can provide much better collision warning capability

Other benefits of sensing & infrastructure

Radar operating in another band

BS supporting V2X

Radar at the infrastructure can help predict blockages

Improves communication link efficiency and reduces overheads


** N. Gonzalez-Prelcic, Roi Mendez-Rial, and R. W. Heath Jr., "Radar aided beamforming in mmWave V2I communications support antenna diversity," ITA 2016.
What can we expect of smart cities in the future?

**DENSE URBAN AREA**
Class B Road Space
Level 4 automation and full communication only

**DENSE SUBURBAN AREA**
Class C Road Space
Level 3 automation and full communication only

**RESTRICTED LANES**
Automated-only lane

**RURAL AREA**
Class G Road Space
No automation or communication requirement
Must use communication equipment if available
Backup slides