Is 5G the Future of Autonomous Vehicles?
Tim Talty  
Collegiate Professor and MEng Director of Admissions  
Virginia Tech  
Bradley Department of Electrical and Computer Engineering  
Blacksburg Virginia  
talty@vt.edu  
540.231.7778  
linkedin.com/in/timtalty  

Industrial and Governmental Experience  

General Motors  
Product Line Manager, Laboratory Group Manager and Technical Fellow  

Ford Motor Company  
Design and Release Engineering, and Section Supervisor  

US Navy  
Combat Systems Engineer  

Academic Experience  

Virginia Tech  
Collegiate Professor and MEng Director of Admissions  

Fairfield University  
Department Chair, Electrical Engineering  

United States Military Academy  
Associate Professor, Electrical and Computer Science Department
Overview of our discussion

- Autonomous Vehicles
- Conventional Role of Connectivity in Vehicle Safety
- Functional blocks of Autonomous Vehicles
- Role of 5G in Autonomous Driving
- Discussion
Autonomous Vehicles

What are Autonomous Vehicles?
What is ADAS (Advanced Driver Assistance Systems)
ADAS in the market place
How to distinguish ADAS from AV
ADAS Advanced Driver Assistance Systems

- ADAS are systems that help the driver to safely navigate the vehicle
- Over 90% of vehicle accidents have some degree of driver error
  - >36,000 death in US
  - >$850 Billion in cost related to accidents
ADAS are systems that help the driver to safely navigate the vehicle.

https://news.jardinemotors.co.uk/lifestyle/the-history-of-car-technology
ADAS are systems that help the driver to safely navigate the vehicle

★ADAS Features <1970

https://news.jardinemotors.co.uk/lifestyle/the-history-of-car-technology
# Recent ADAS Features

<table>
<thead>
<tr>
<th>Passive Features</th>
<th>Alert the driver of dangerous situations</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACC</td>
<td>Adaptive Cruise Control</td>
</tr>
<tr>
<td>LDW</td>
<td>Lane Departure Warning</td>
</tr>
<tr>
<td>NVS</td>
<td>Night Vision System</td>
</tr>
<tr>
<td>BSD</td>
<td>Blind Spot Detection</td>
</tr>
<tr>
<td>AVM</td>
<td>Around View Monitoring</td>
</tr>
<tr>
<td>RCW</td>
<td>Rear Collision Warning</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Active Features</th>
<th>Collision Avoidance Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACC</td>
<td>Automatic Emergency Braking</td>
</tr>
<tr>
<td>LDW</td>
<td>Lane Keeping Assist</td>
</tr>
<tr>
<td>NVS</td>
<td>Adaptive Front Lighting</td>
</tr>
<tr>
<td>BSD</td>
<td>Blind Spot Intervention</td>
</tr>
<tr>
<td>AVM</td>
<td>Pedestrian Protection System</td>
</tr>
<tr>
<td>RCW</td>
<td>Automatic Parking</td>
</tr>
</tbody>
</table>

https://www.german-autos.co.uk/radar-lidar-and-camera-calibration/
DRIVER ASSISTANCE

HANDS OFF THE WHEEL. EYES ON THE ROAD.
Available Cadillac Super Cruise offers the ease and convenience of hands-free driving.

ADAPTIVE CRUISE CONTROL – ADVANCED
Maintains a selected following gap between you and the detected vehicle ahead.

LANE CENTERING
Multiple cameras and sensors work in tandem to help keep you traveling in your lane.

How to define AVs

https://www.sae.org/
Conventional Role of Connectivity in Vehicle Safety

Peer to Peer Networks (DSRC and C-V2X)
Vehicle Peer-to-Peer Networks

- Vehicle P2P networks are interconnected vehicles ("peers") that share the connection channel (wireless channel) and coordinate access to the channel without the use of centralized control.
- DSRC (Dedicated Short Range Communications)
  - In ~2000, the FCC dedicated 75 MHz of spectrum in the 5.9 GHz for Automotive Intelligent Transportation Systems (ITS); which includes vehicles safety applications
DSRC: V2V, V2P, V2I,.... V2X

https://www.auto-talks.com/technology/dsrc-technology/
C-V2X

Rel 14/15 C-V2X established basic safety
Rel 16 NR C-V2X saw continued evolution for advanced use cases

- Release 14/15 C-V2X standards completed
- 5G
  - Broad industry support with 5GAA
  - Global trials started in 2017, first commercial deployment expected in 2020
- Qualcomm® 9150 C-V2X chipset announced in September, 2017
- Integration of C-V2X into the Qualcomm® Snapdragon™ Automotive 4G and 5G Platforms announced in February, 2019

Vehicle Peer-to-Peer Networks

- Augment and Enhance Situation Awareness
  - Where are nearby objects (vehicles, pedestrians, infrastructure)
  - Traffic light phasing and timing
  - Emergency vehicle approaching
  - Vehicle hard braking events
Functional blocks of Autonomous Vehicles
Autonomous Systems

https://spectrum.ieee.org/transportation/self-driving/accelerating-autonomous-vehicle-technology
Functional blocks of Autonomous Vehicles

- Sensing & Connectivity
- Perception/ Situational Awareness
- Planning and Behaviors
- Vehicle Control
Functional blocks of Autonomous Vehicles

1. Sensing & Connectivity
2. Perception/Situational Awareness
3. Planning and Behaviors
4. Vehicle Control
Functional blocks of Autonomous Vehicles

Sensor Data $\rightarrow$ ~20 msec latency $\rightarrow$ ~20 msec latency $\rightarrow$ Vehicle Control

~12 Gbps $\rightarrow$ ~1.4 Mbps $\rightarrow$ ~160 Kbps
Role of 5G in Autonomous Driving
Computing Resources For Autonomous Vehicles

Ultra-Reliable and Low Latency Communications (URLLC):
- less than 5 ms end-to-end system delay.
- maximum block error rate (BLER) of 10^{-5} or 0.001%.

https://broadbandlibrary.com/5g-low-latency-requirements/
Role of 5G in Autonomous Driving

Recall: Functional Block Diagram of AV

Sensor Data \(\rightarrow\) \(~20\) msec latency \(\rightarrow\) \(~20\) msec latency \(\rightarrow\) Vehicle Control

\(~12\) Gbps \(\rightarrow\) \(~1.4\) Mbps \(\rightarrow\) \(~160\) Kbps
Role of 5G in Autonomous Driving

Recall: Functional Block Diagram of AV

Sensor Data \[\rightarrow\] \(~20\text{ msec latency}\) \[\rightarrow\] \(~20\text{ msec latency}\) \[\rightarrow\] Vehicle Control

\(~12\text{ Gbps}\) \[\rightarrow\] \(~1.4\text{ Mbps}\) \[\rightarrow\] \(~160\text{ Kbps}\)
Role of 5G in Autonomous Driving

- Off board rapidly changing AV computational processing
  - Reduce demands on AV embedded hardware
  - Minimize impact on EV range
  - Extent the useful life of the vehicle (avoid obsolesces)

- Enable a high level of coordination of vehicles/vehicle motions and pathways.
Evolution of the Role of 5G in Autonomous Driving
MOBILITY CLASSIFICATIONS

- **Today**
  - Mobility In Isolation

- **Coming**
  - Mobility With Neighborhood Knowledge
    - V2X Enabled
  - Mobility With Community
    - 5G Enabled

Time