Wireless Networking Architecture for Driverless Car – An Impossible Possibility

Dr. Suresh Borkar
Department of ECE
Illinois Instt. of Techn., Chicago
borkar@iit.edu

Dr. Vivek Deshpande
Department of Computer Engineering
Vishwakarma Instt. of Tech, Pune
vsd.deshpande@gmail.com

IIT Real-Time Computing Conference
Oct 15-17, 2018
Chicago
Car Theory of Evolution

1769 Steam Engine Based
1885 Gas (Petrol) Engine Based
1906 Mass production

1930’s Modern cars
2010’s Electric cars
2020’s Driverless cars

Major Innovations

<table>
<thead>
<tr>
<th>Rear View Mirror</th>
<th>Wind Shield</th>
<th>CD Players</th>
<th>Sun roof</th>
<th>GPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seat Belts</td>
<td>Turn Signals</td>
<td>Cruise control</td>
<td>Airbags</td>
<td>Electric Windows</td>
</tr>
<tr>
<td>Speedometer</td>
<td>Air conditioning</td>
<td>Power Steering</td>
<td>Heated Seats</td>
<td>Electric Doors</td>
</tr>
<tr>
<td>1900</td>
<td>1920</td>
<td>1940</td>
<td>1960</td>
<td>1980</td>
</tr>
</tbody>
</table>
Driverless Features

Automatic Emergency Braking  Adaptive Cruise Control  Lane Detection

Traffic Jam Assist  Autonomous Parking  Autonomous Driving

Key Requirements:
• Safety Critical Operations
• Ultra Reliable Low latency Communications
• Bursty Machine to Machine (M2M) Broadband ”Inherently Intelligent” Traffic

Flight of a Bumblebee
Self Driving Car Sensor Technologies

Internet of Vehicles (IoV)
- Vehicle to Everything (V2X)
Flood of Data in Autonomous Vehicles

1 Driverless car = 2,666 Internet Users
Driverless Car Communications Network

Key Issues: Data Orchestration and Multimodal Wireless Connectivity

*: Dedicated Short Range Communications
Wireless Network Constituents

- **Proximity Area Network (PAN)**
  - Bluetooth/RFID inside the vehicle

- **Wide Area Network (WAN) (C-V2X)**
  - 4G LTE Rel14 (50 Mbps; 10 ms latency) / 5G Rel 15/16 (20 Gbps; 1 ms latency) Cellular
  - Wireless Access by itself – low latency and secure
  - Ford, BMW, Daimler, Qualcomm, Intel

- **Local Area Network (LAN) / Vehicular Ad Hoc Network (VANET)**
  - Spanning vehicles and RSUs within 300m of each other
  - Dedicated Short Range Communications (DSRC)
    - IEEE 802.11p (5.850-5.925 MHz) WiFi for secure and reliable use
      - Wireless Access in Vehicular Environments (WAVE)
    - IEEE 802.11ac (5725-5850 MHz) WiFi for non-safety related use
    - Toyota, General Motors

- **Other Potential Candidates**
  - IEEE 802.16 WiMAX

**Cellular &/or DSRC – That is the Question**
## Human Driven Car versus Driverless Car

<table>
<thead>
<tr>
<th></th>
<th>Human Driven Car</th>
<th>Driverless Car</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time to react</strong></td>
<td>2 secs.</td>
<td>300 ms</td>
</tr>
<tr>
<td><strong>Distance to Stop @ 30 mph</strong></td>
<td>100 ft.</td>
<td>50 ft.</td>
</tr>
<tr>
<td><strong>@ 60 mph</strong></td>
<td>300 ft.</td>
<td>200 ft.</td>
</tr>
<tr>
<td><strong>Time to Parallel Park</strong></td>
<td>60 secs.</td>
<td>20 secs</td>
</tr>
<tr>
<td><strong>Probability of Fatal Accident in lifetime in US</strong></td>
<td>0.2%</td>
<td>0.02%</td>
</tr>
<tr>
<td><strong>Distracted while Driving</strong></td>
<td>Human nature</td>
<td>Machines have no nature</td>
</tr>
<tr>
<td><strong>Driving Experience</strong></td>
<td>Alert and Tense</td>
<td>Relaxed and Entertaining</td>
</tr>
</tbody>
</table>
Potentially Competing Network Architectures

Cellular – V2X (C-V2X)

Cloud Computing

4G/5G

Data Generation

(RSUs)

VNET/DSRC Based

Centralized Information

Edge Computing

Extreme Edge Computing

Data Generation

(RSUs) (DSRC)
## Architectural Extremes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Cellular – C2X &amp; Cloud Computing</th>
<th>VNET/DSRC Based &amp; Edge Computing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car Processor</td>
<td>Limited processing capabilities; Low power</td>
<td>Integrate data from sensors &amp; cloud and process</td>
</tr>
<tr>
<td>Cost Effectiveness</td>
<td>Shared Centralized Resource</td>
<td>High cost of car device(s) and maintenance</td>
</tr>
<tr>
<td>Time to React</td>
<td>Delay Infrastructure; Longer Reaction Time</td>
<td>Fast Link Establishment; Low Local Latencies; Short Reaction Time</td>
</tr>
<tr>
<td>Overall Reliability</td>
<td>99.99% (53 mins DT/year)</td>
<td>99.999% (2 mins DT/year Duplexed)</td>
</tr>
<tr>
<td>Est Prob of Fatal Accident over lifetime</td>
<td>0.02%</td>
<td>0.001%</td>
</tr>
<tr>
<td>Est Min. Dist to avoid accidents at 60 mph</td>
<td>225 ft.</td>
<td>210 ft.</td>
</tr>
<tr>
<td>Primary Concerns</td>
<td>Network Delay and Reliability</td>
<td>Weight, Cost, and Power Consumption; Needs RSU</td>
</tr>
</tbody>
</table>
### Need New Paradigm for Wireless Network Architecture

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Cellular – C2X + Cloud Computing</th>
<th>VNET/DSRC Based + Edge Computing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight of Computing System</td>
<td>Acceptable</td>
<td>Significant</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>Acceptable</td>
<td>Concern</td>
</tr>
<tr>
<td>Prob of Fatal Accident</td>
<td>High</td>
<td>Acceptable ?</td>
</tr>
<tr>
<td>Cost</td>
<td>Concern</td>
<td>Significant</td>
</tr>
<tr>
<td>Distance to Avoid Accident (incl Reliability)</td>
<td>High</td>
<td>Acceptable ?</td>
</tr>
</tbody>
</table>

**Need More Study for a Possible Convergence Between two Impossible Alternatives**

-  (Leaner Cellular wireless connectivity & Centralized scalable Processing Advantages of 4G/5G Cellular system) + (Low Latency and lower accident probability of VNET/DSRC & Distributed Edge computing network) = Nirvana
Concluding Remarks

• Driverless Car
  – 90% Reduction in Fatal Accidents Compared to Human Drivers

• Major Wireless Architecture Alternatives
  – Cellular 4G/5G & Centralized Cloud Based
    • Centralized and Scalable
    • Higher Probability of Accidents
  – VNET/DSRC Based & Edge computing
    • Low Latency and Reliable
    • Weight, Cost, and Power Consumption
  – Need Re-thinking

• Making Impossible Possible – A “Hybrid” Solution
  – Emphasis on mesh networking with other Cars and Road Side units
  – Significantly reduce weight and cost of on-board computer
  – Improve reliability and Latency of cellular wireless and Cloud Network
“Speeding, officer? You’ll have to ask the self-driving car.”
Key References


