Prototypical implementation of CAV features at connected traffic lights

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Agenda

- Motivation
- Use Case 1: Traffic light assistant with automated longitudinal control
- Use Case 2: Priority request for public transport / emergency vehicles
- Remaining Challenges
- Conclusion & Outlook
- Q&A, Discussion

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Motivation:
- Mobility sector is changing rapidly
- Continuously increasing importance of vehicle connectivity and automation (driver assist features, V2X & other connectivity, highly automated driving, OTA)

Consequence:
- Ford wants to increase the level of connectivity and automation in its vehicle line-up continuously over the next years

Need:
- Adoption of algorithms to local market requirements (e.g. to different V2X standards like SAE, ETSI, ...)
- Local testing & validation opportunities are crucial (connected traffic light corridors)
- Simulation based validation gains importance

Source: www.extremetech.com
Use Cases 1 – Traffic Light Assistant

- Traffic light assistant with automated longitudinal control

**Classic ACC:**
- Speed is influenced by leading vehicles speed only
- Speed does not get adopted according to traffic light status
- Reactivation required when resuming from red traffic light

**Traffic Light Assistant:**
- Speed is additionally influenced by traffic light status and timing
- Speed can be adopted early to pass at green or stop smoothly, even without leading vehicle in front
- System stays active all the time while travelling in straight direction
Test Vehicle

- Production line Kuga PHEV

- Modifications:
  - Cohda MK5 OBU (reception and forwarding of V2X messages)
  - Vodafone C-V2X LTE Router
  - u-Blox GPS receiver
  - dSpace MicroAutoBox II (running feature code)
  - Power supply, CAN bus connection, additional antennas on the roof
Testing & Validation

**Goals:**
- Compatibility of transmitted MAPEM/SPATEM message content with developed algorithms
- Benchmarking of all communication technologies available on connected traffic lights (ITS-G5, 4G via MDM/MQTT/TTS)
- Closed loop feature testing

**Facts:**
- >55 days of on-road testing in corridors in Aachen, Kohlscheid & Alsdorf
- >35 h logged data
- > 500 simulated scenarios

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Testing & Validation - Results

Slow down to pass at green scenario:
- Vehicle adopts speed early
- Stop can be avoided
- Improved traffic flow, reduced fuel consumption / emissions
## Testing & Validation - Results

### Communication Benchmarking

<table>
<thead>
<tr>
<th></th>
<th>Range</th>
<th>Latency</th>
<th>Connection stability</th>
<th>Closed Loop Test Findings</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline Requirements:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;=300 m</td>
<td>&lt;500 ms</td>
<td></td>
<td>Minimal Packet loss</td>
<td></td>
</tr>
<tr>
<td><strong>ITS-G5 Road-Side-Units</strong></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Works well within required range</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Cellular Network via MQTT &amp; Vodafone V2X Backend</strong></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Works basically well even with 1Hz SPAT frequency, higher SPAT frequency desired to face potential packet loss and edge cases</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Cellular Network via MDM &amp; Vodafone V2X Backend</strong></td>
<td>✓</td>
<td></td>
<td></td>
<td>Not evaluated for time reasons</td>
<td>?</td>
</tr>
<tr>
<td><strong>C-V2X PC5 Sidelink Direct Communication</strong></td>
<td>✓</td>
<td></td>
<td></td>
<td>Technology not available in test field</td>
<td>?</td>
</tr>
</tbody>
</table>
Use Case 2 – Priority Request

- **Priority Request for**
  - Public Transport
  - Emergency Vehicles

- **Functionality:**
  - Vehicle transmits SREM messages to request green light
  - Traffic light turns green when receiving SREMs
  - Traffic light turns back to normal operation after vehicle passed the intersection

- Robust functionality during testing
Remaining Challenges

Infrastructure related

1) Infrastructure diversity:
   MAPEM + SPATEM msg. content required many iteration loops to achieve the desired content
   → message structures are standardized in ETSI but not the content itself with respect to
   quality factors and optional fields required for automotive applications

2) Robustness:
   All connected traffic light environments and communication paths faced outages.

3) Dynamically timed traffic lights:
   Traffic lights with dynamic timing delivered a non-sufficient prediction quality to use it for
   automation. This caused problems on vehicle side, e.g. phantom braking events for an
   expected red light which finally did not become reality.
Remaining Challenges

Vehicle / feature related

1) Queue detection:
Knowing about the traffic lights queue status and length is essential to provide a seamless experience and avoid accelerations for green light with subsequent braking for the queue.

2) Vehicle behavior:
Irritation of other road users while braking for a green light that will turn red. Other drivers don’t have this information and can become irritated.

3) Conservative vs. progressive system design:
Conservative system = potentially braking for green light vs.
Progressive system = remaining risk to pass at yellow (due to latencies, message drop, GPS inaccuracy etc.)
Conclusion & Outlook

- **Local testing & validation opportunities are crucial** for a fast feature development process
  - Feature tested successfully in different traffic light corridors using different communication technologies
- **A large-scale deployment** of vehicles with traffic light related features would require:
  - Increased operational robustness
  - Standardization of message content ("profiling") + quality control processes
  - Increased timing prediction quality
- **Merging** traffic light based V2X communication and automation:
  - Both direct communication and cellular network-based communication are appropriate if the underlying architecture is designed in the right way
  - High prediction quality is key to get the benefits of the functionality
  - Unsolved challenges with regards to queue detection and informing other drivers

There is a lot of potential but there are also a lot of challenges ahead
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