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# 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**

# Motivation

- **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**

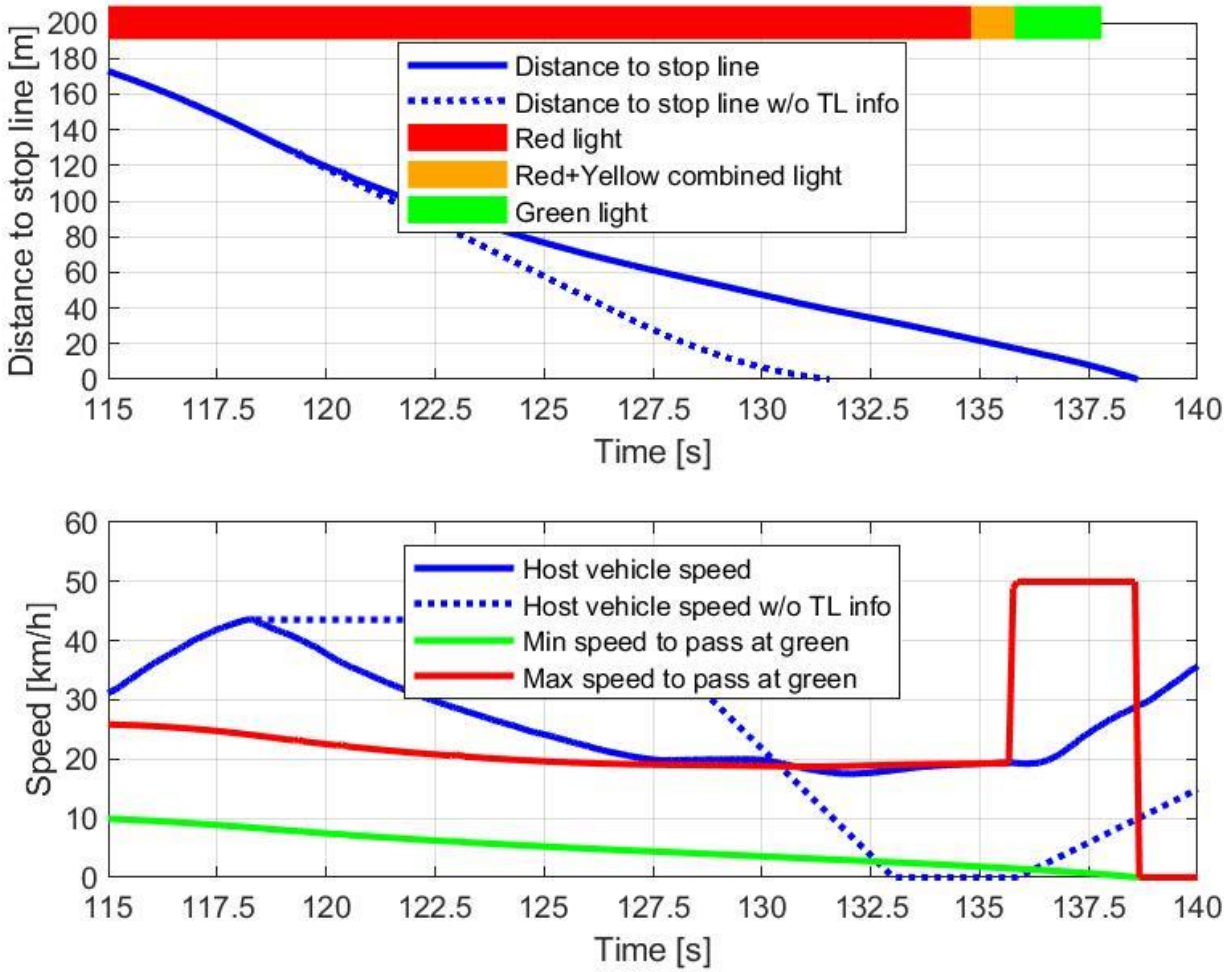
- **Modifications:**
  - Cohda MK5 OBU (reception and forwarding of V2X messages)
  - Vodafone C-V2X LTE Router
  - u-Blox GPS receiver
  - dSpace MicroAutoBox II (running feature code)
  - Power supply, CAN bus connection, additional antennas on the roof

# 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

# 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

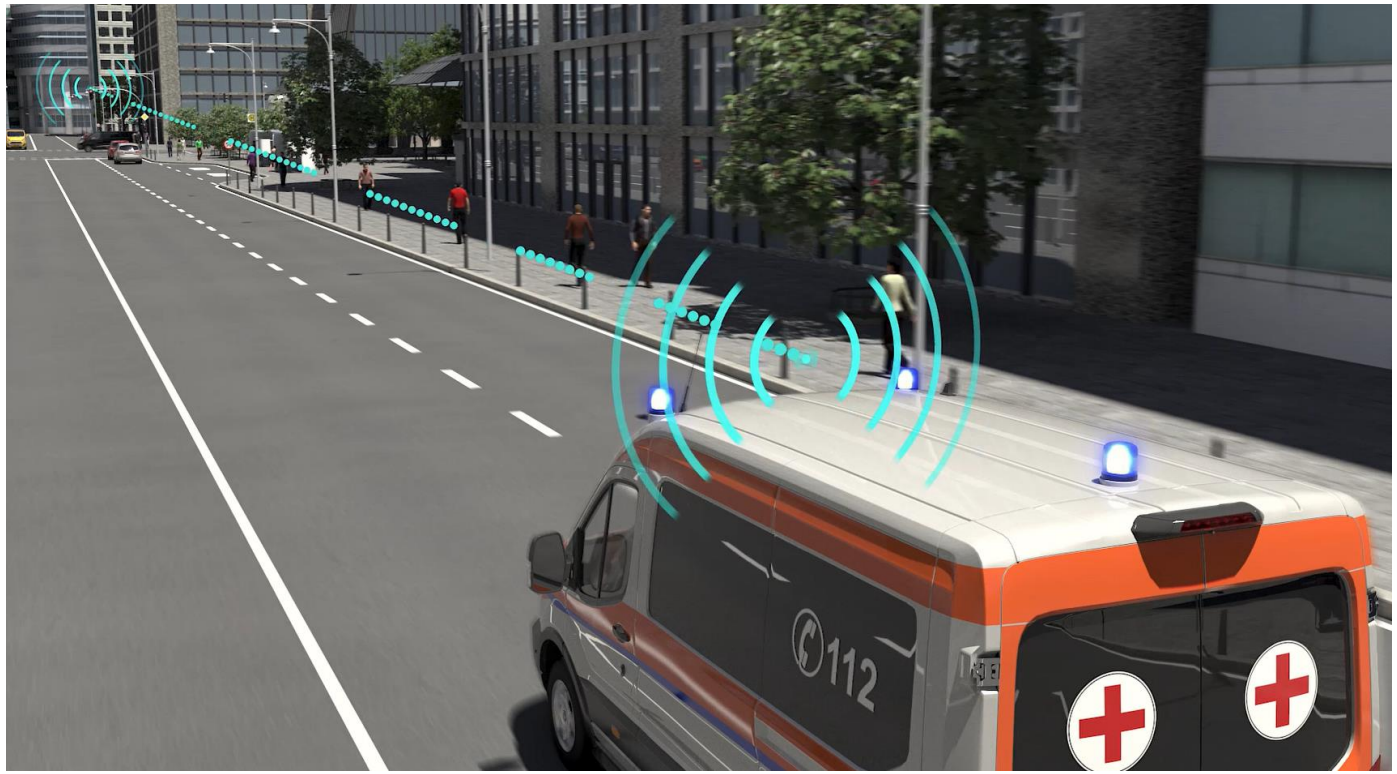
# Testing & Validation - Results

## Communication Benchmarking

| | Range | Latency | Connection stability | Closed Loop Test Findings | Result |
|---|---|---|---|---|---|
| **Baseline Requirements:** | **>=300 m** | **<500 ms** | **Minimal Packet loss** | --- | --- |
| **ITS-G5 Road-Side-Units** | ✓ | ✓ | ✓ | Works well within required range | ✓ |
| **Cellular Network via MQTT & Vodafone V2X Backend** | ✓ | ✓ | ✓ | Works basically well even with 1Hz SPAT frequency, higher SPAT frequency desired to face potential packet loss and edge cases | ✓ |
| **Cellular Network via MDM & Vodafone V2X Backend** | ✓ | Not evaluated for time reasons | | | ? |
| **C-V2X PC5 Sidelink Direct Communication** | Technology not available in test field | | | | ? |

# 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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