A Pilot Project for C-V2X

5GAA Workshop
May 23, 2019, Berlin, Germany
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Agenda

- Project Overview
- C-V2X System Architecture
- Use Case Examples
- Selected Results
- Summary and Outlook
ConVeX – Connected Vehicle (V2X) of Tomorrow

- Funded by: German Ministry of Transportation and Digital Infrastructure (BMVI) in the program “Automated and Connected Driving on Digital Test Fields in Germany”

- Objective: Set-up testbed for first field tests of 3GPP LTE Release 14 Cellular-V2X (C-V2X) and validate performance and feasibility

- Consortium: Qualcomm (lead), Audi, Ericsson, Swarco Traffic Systems, Technical University of Kaiserslautern

- Duration: 1-December-2016 to 30-June-2019
High Level C-V2X Network Architecture

PC5

- V2V: Vehicle-to-Vehicle
- V2I: Vehicle-to-Infrastructure (i.e., to RSU)
- V2P: Vehicle-to-Pedestrian

Uu

- V2N: Vehicle-to-Network
- Other (Backhaul) Links
Example Use Cases

- Emergency Electronic Brake Light & Forward Collision Warning
- Do Not Pass Warning
- Road Works Warning / In Vehicle Information
- Blind Spot Warning / Lane Change Warning
- Queue Warning & Speed Recommendation for Shock Wave Damping
- Sensor Sharing (V2N)
- Vulnerable Road User (VRU) alerts
- Follow Me (& other direct communication services)

Blind Intersection Movement Assistance
C-V2X Communication Platform can be integrated into both, vehicle and roadside ITS stations.
Field Test Areas

- **Ericsson 5G testbed A9**
  - 34 km section of the A9 south of Nuremberg
  - 6 base stations with 2 sectors each

- **Ericsson 5G testbed Rosenheim**
  - Urban and suburban environment
  - 2 base stations with 3 sectors each

- Testbed infrastructure owned and operated by Ericsson

- Supports V2N use cases and data upload via CCard
LTE-V2X High Vehicular Speed Testing
• Conducted as part of the ConVeX Project

• Two cars driving in opposite direction on Autobahn A9 with highest possible speeds
• Close to error free communication between the cars when in LOS
• Range for this run was limited to ~ 1.2km due to morphology
• No impact of the high relative speed of more than 400 km/h (max. 430 km/h for this run)
Intersection Movement Assist (IMA)
The view from the motorcycle
Project Day @ “Cross-Border Digital Test Bed”

ConVeX Participates in World's First Multi-Country Cross-Border C-V2X Demonstration Across Europe

--- Audi, Ericsson, Qualcomm, SWARCO and Technical University of Kaiserslautern Work with Local Ministries of Transportation to Showcase C-V2X Safety Use Cases at New Trilateral Testbed in France, Germany and Luxembourg ---

Date: April 3, 2019
Countries: Germany, France, Luxemburg
Location: Schengen, Luxemburg
Attending:
- François Bausch (Luxemburgian minister of Mobility and Public Works)
- Anke Rehlinger (Minister for Economy, Labour, Energy & Transport of the Federal State Saarland)
- Élisabeth Borne (French Minister of Transport)
- Andreas Scheuer (German Federal Minister of Transport and Digital Infrastructure)
- Etienne Schneider (Luxemburgian Vice Primeminister and Minister of Economy)

Full text here: [Link]
Main focus here: Direct Communication (PC5)

- Direct communication important for cross-border scenarios
  - No Need for coverage of the cellular Network
  - No SIM Card
  - No roaming challenges
  - No “black out time“ when moving between different countries (and Networks)
  - Instead: *Seamless Cross-border Communication*

- Shown use cases
  - Roadworks Warning (RWW)
  - In-vehicle Signage (IVS)
  - Stationary Vehicle Warning (SVW)
V2I – Use Case Location Overview

- RSU location
- RWW triggers well before the border

- IVS: Speed Limit 100 km/h
  - Could be any sign content (reference to a catalog)
  - Future: „steer“ (autonomous) vehicles with fine commands => shock wave damping

- Distance RSU to RWW start: about 700m
- Note that the zones are defined by the messages coming from the RSU (ITS application does location matching to trigger alerts)

See video RWW_IVI
V2V SVW: Use Case Location Overview

• Use Case: SVW Germany - France
  - Stationary car at side of the street in France (blue square), hazard lights switched on
  - SVW triggered before round-about
  - Distance: about 500m

See video SVW
Additional Use Case: V2N based Time-To-Green

- Swarco traffic light showcased Time-To-Green and GLOSA
  - Here: V2N using Audi backend server
    - Commercial Audi implementation
    - This can also be done V2I

- Driver gets indication of
  - how long will the traffic light still be red
  - Which speed to go that it will turn green while approaching

- Trailer to visualize Roadworks Warning (RWW)
  - Additional RSU placed there
### Live C-V2X Demo @ Schengen Event

**Map View**
- Filter Test Group: None
- ID: None

**ALL DEVICES**
- All CARs
- 8000
- 8001
- 1004
- 1002

**All RSUs**
- Showing 1 to 5 of 5 entries (filtered from 1,000 total entries)

<table>
<thead>
<tr>
<th>DEVICE NAME</th>
<th>MSG TYPE</th>
<th>SEQ #</th>
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<th>BODY</th>
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<th>LONGITUDE</th>
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Evolving C-V2X Direct Communications towards 5G NR

- While maintaining backward compatibility

Evolution to 5G NR, while being backward compatible
C-V2X Rel-14 is necessary and operates with Rel-16

Basic and enhanced safety
C-V2X Rel-14/Rel-15 with enhanced range and reliability

Basic safety
IEEE 802.11p

Autonomous driving use cases
5G NR C-V2X Rel-16

- Backward compatible with Rel-14/Rel-15 enabled vehicles
- Higher throughput
- Higher reliability
- Wideband carrier support
- Lower latency
- Sudden braking and lane change on a freeway
- Sensor Sharing
- Intention Sharing
- Coordinated Driving

Sudden braking and lane change on a freeway
Summary and Outlook

- **C-V2X Technology**
  - Supports both, today’s basic safety and innovative advanced use cases
  - Designed to enable continuous evolution to 5G while maintaining backward compatibility

- **Initial Results**
  - Full integration of C-V2X technology into cars, motorcycles and roadside units
  - Reliable communication even ranges >1.5km and >430 km/h relative speed
  - Successfully tested interoperability between vehicles and road infrastructure

- **Next Steps in ConVeX**
  - Continued extensive testing, evaluation and optimization of basic safety use cases
  - Looking for suitable test routes that allow to bring C-V2X to the limits
  - Explore additional use cases for enhanced safety applications
Thank You

Questions?