Connected Vehicle (V2X) of Tomorrow

sponsored by Federal Ministry of Transport and Digital Infrastructure

VDI|VDE|IT

A Pilot Project for C-V2X

5GAA Workshop

May 23, 2019, Berlin, Germany

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Audi ERICSSON Qualcomm swarco TECHNISCHE UNIVERSITÄT KAISERSLAUTERN

Agenda

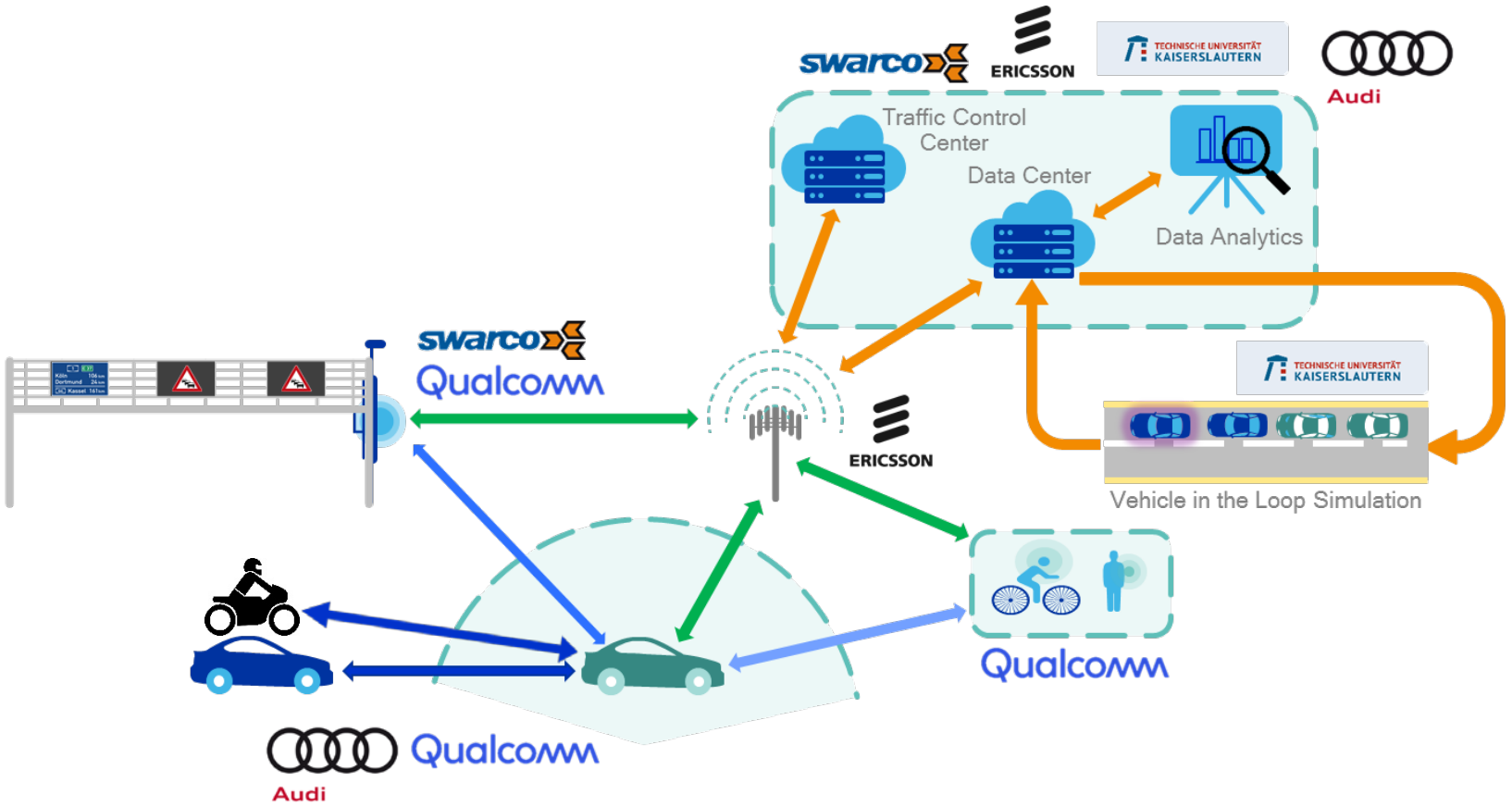
- Project Overview
- C-V2X System Architecture
- Use Case Examples
- Selected Results
- Summary and Outlook

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

Qualcomm Audi ERICSSON swarco Technische Universität Kaiserslautern Bundesministerium für Verkehr und digitale Infrastruktur

High Level C-V2X Network Architecture



PC5

V2V: Vehicle-to-Vehicle

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

V2P: Vehicle-to-Pedestrian

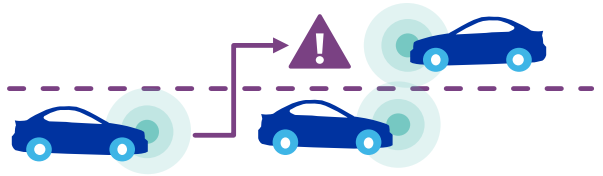
Uu

V2N: Vehicle-to-Network

Other (Backhaul) Links

Example Use Cases

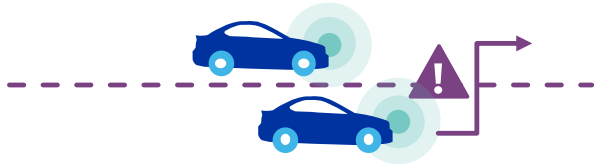
Emergency Electronic Brake Light & Forward Collision Warning



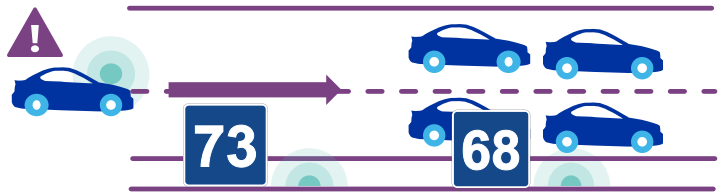
Do Not Pass Warning

Blind Intersection Movement Assistance

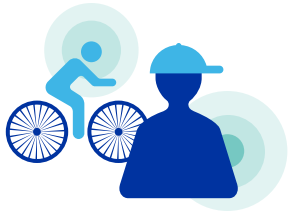
Road Works Warning / In Vehicle Information



Blind Spot Warning / Lane Change Warning



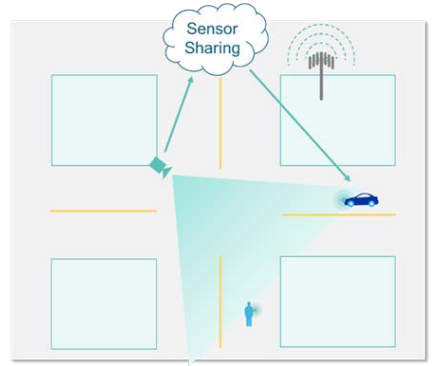
Queue Warning & Speed Recommendation for Shock Wave Damping



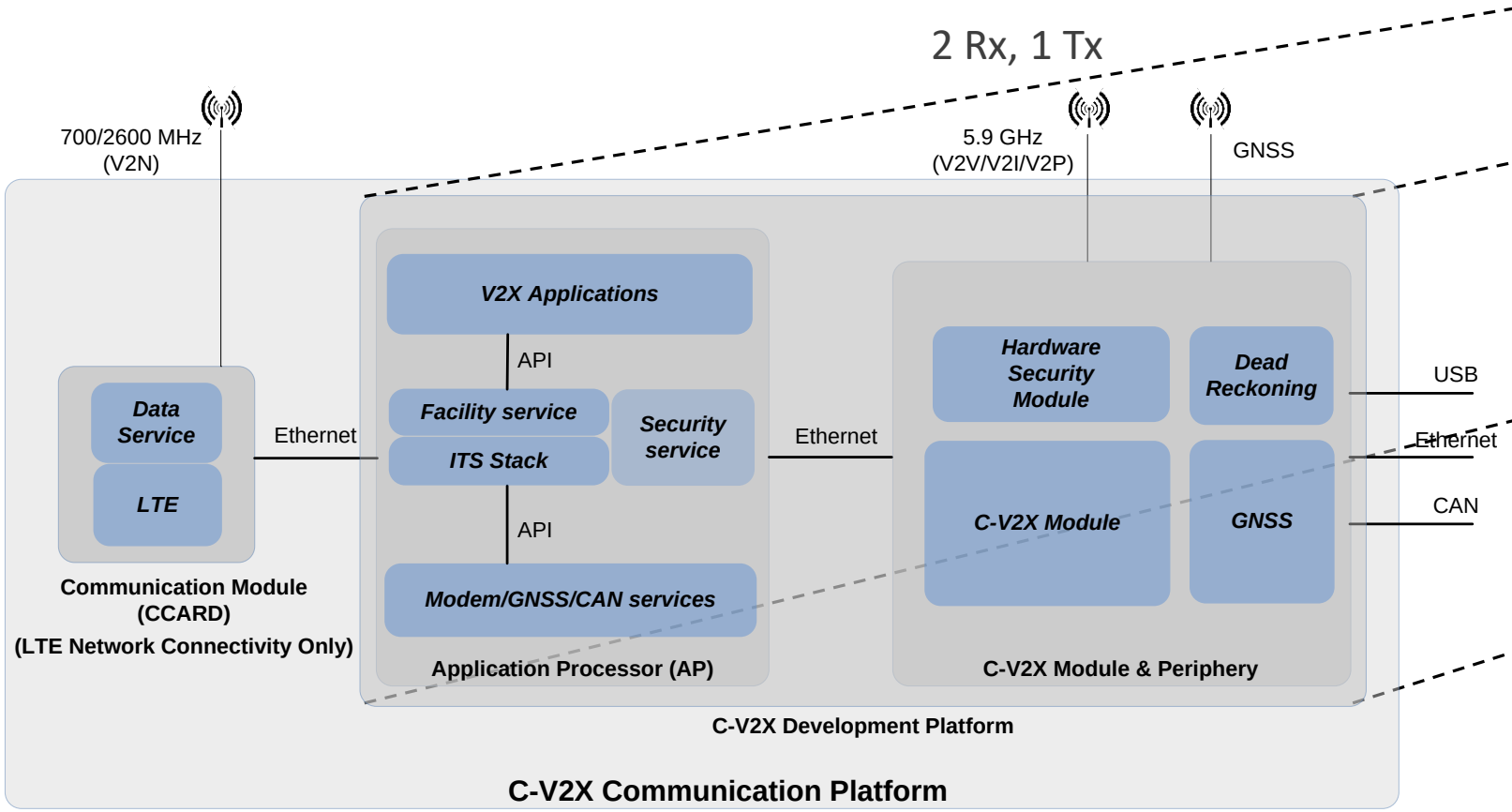
Vulnerable Road User (VRU) alerts

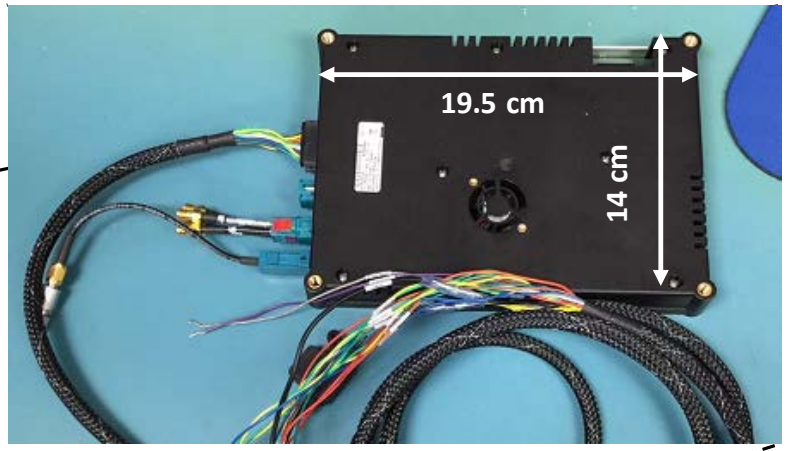
Follow Me (& other direct communication services)

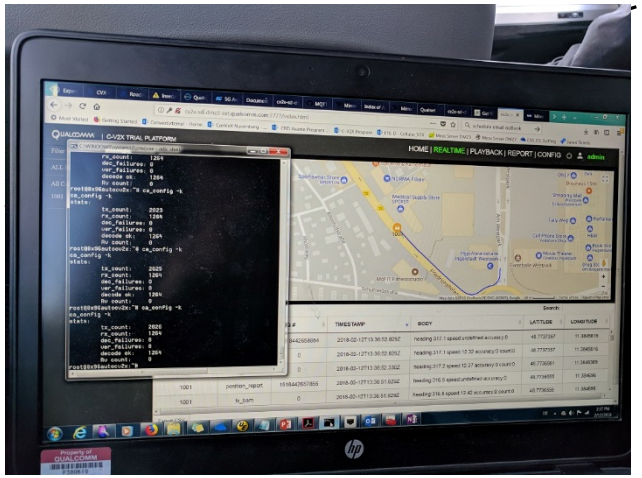
Sensor Sharing (V2N)



C-V2X Communication Platform



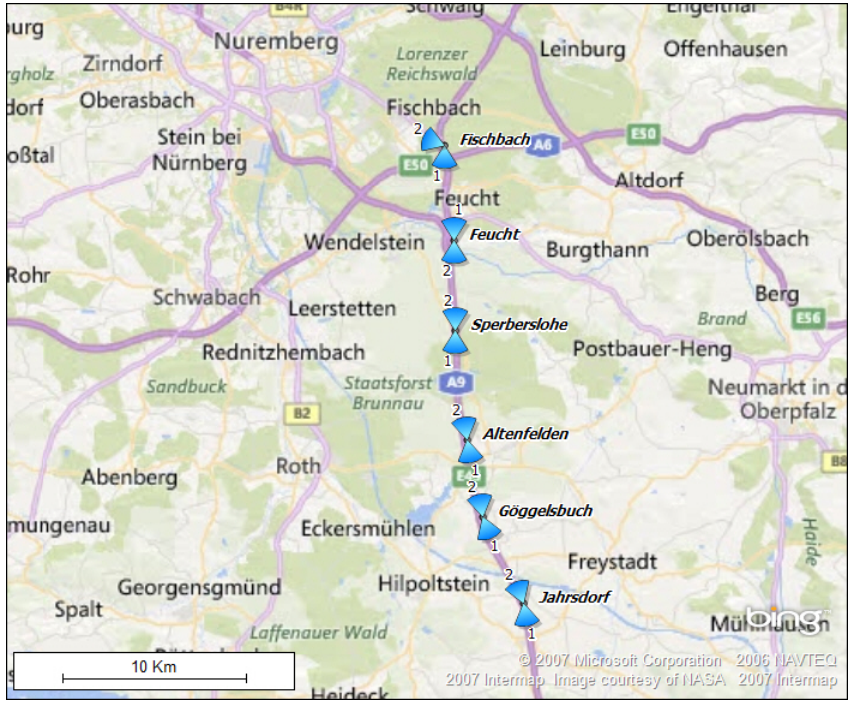


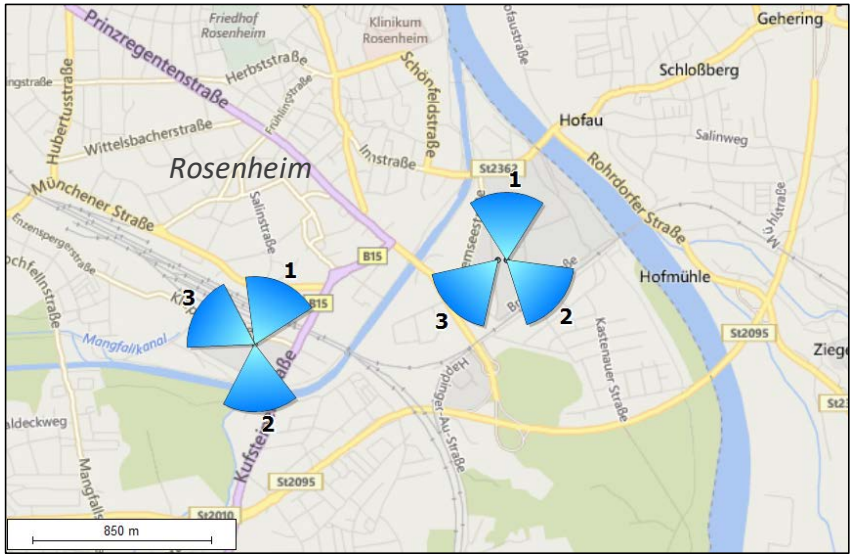


- C-V2X Communication platform can be integrated into both, vehicle and roadside ITS stations

Field Test Areas

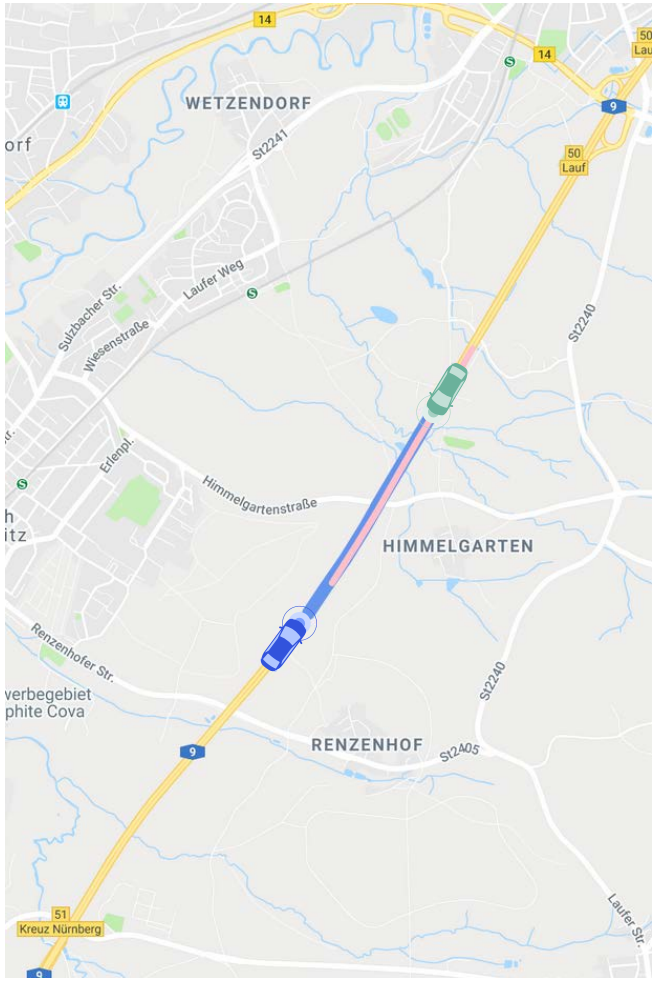
- Ericsson 5G testbed A9
  - 34 km section of the A9 south of Nuremberg
  - 6 base stations with 2 sectors each
- Ericsson 5G testbed Rosenheim
  - Urban and suburban environment
  - 2 base stations with 3 sectors each
- Testbed infrastructure owned and operated by Ericsson
- Supports V2N use cases and data upload via CCard



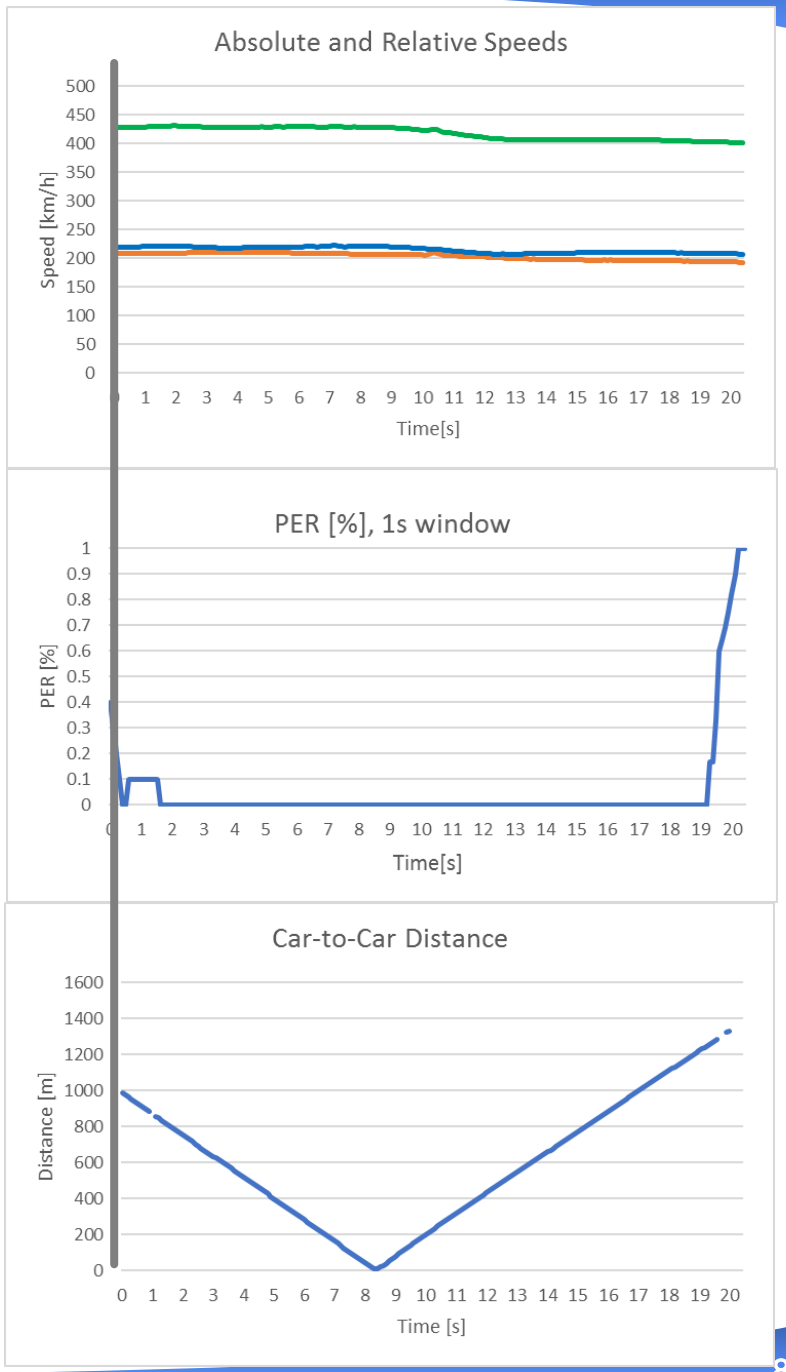


LTE-V2X High Vehicular Speed Testing

- 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)



ConVeX – Demo Event July 6, 2018

ConVeX – Demo Event July 6, 2018

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---

NEWS PROVIDED BY
Qualcomm Incorporated →
Apr 05, 2019, 07:30 ET

Full text here:

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)

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*

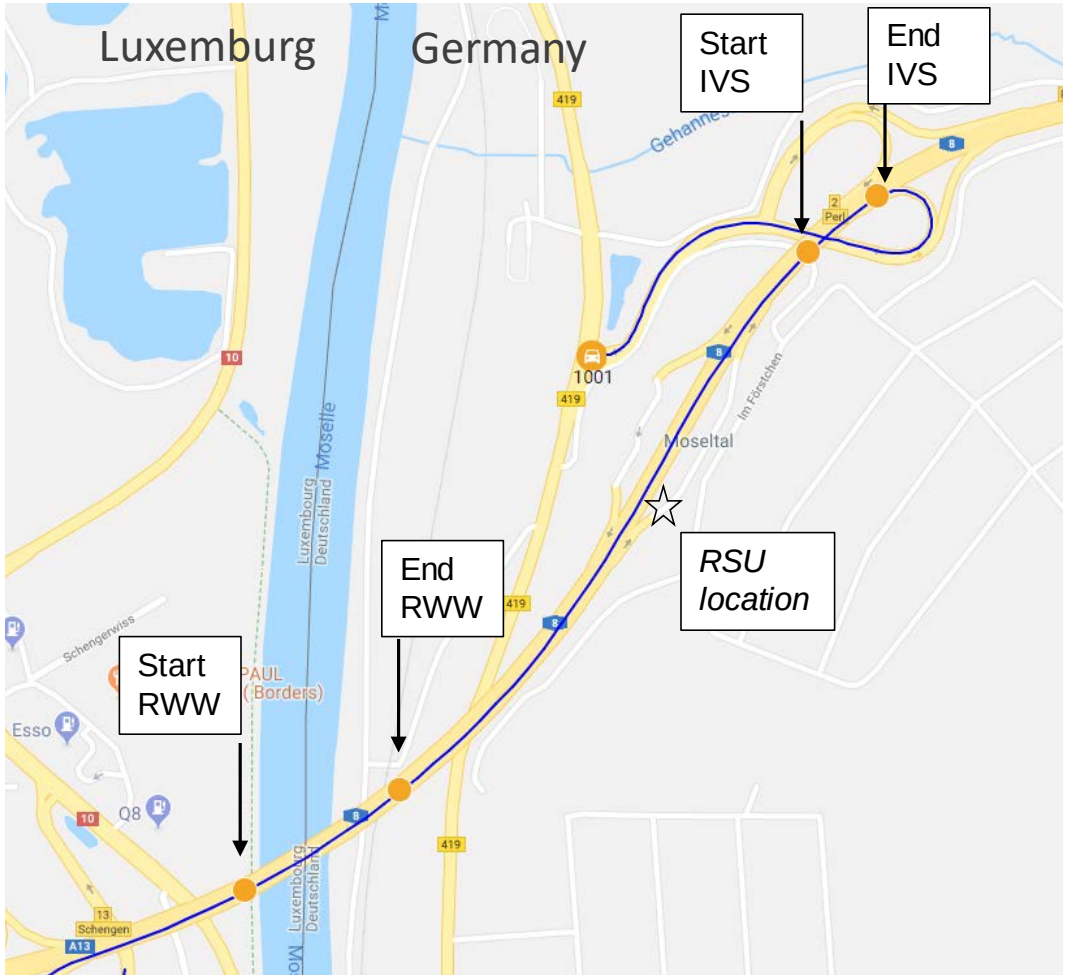
- Shown use cases
  - Roadworks Warning (RWW)
  - In-vehicle Signage (IVS)
  - Stationary Vehicle Warning (SVW)

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 catolog)
  - Future: „steer“ (autonomous) vehicles with fine commands => shock wave damping

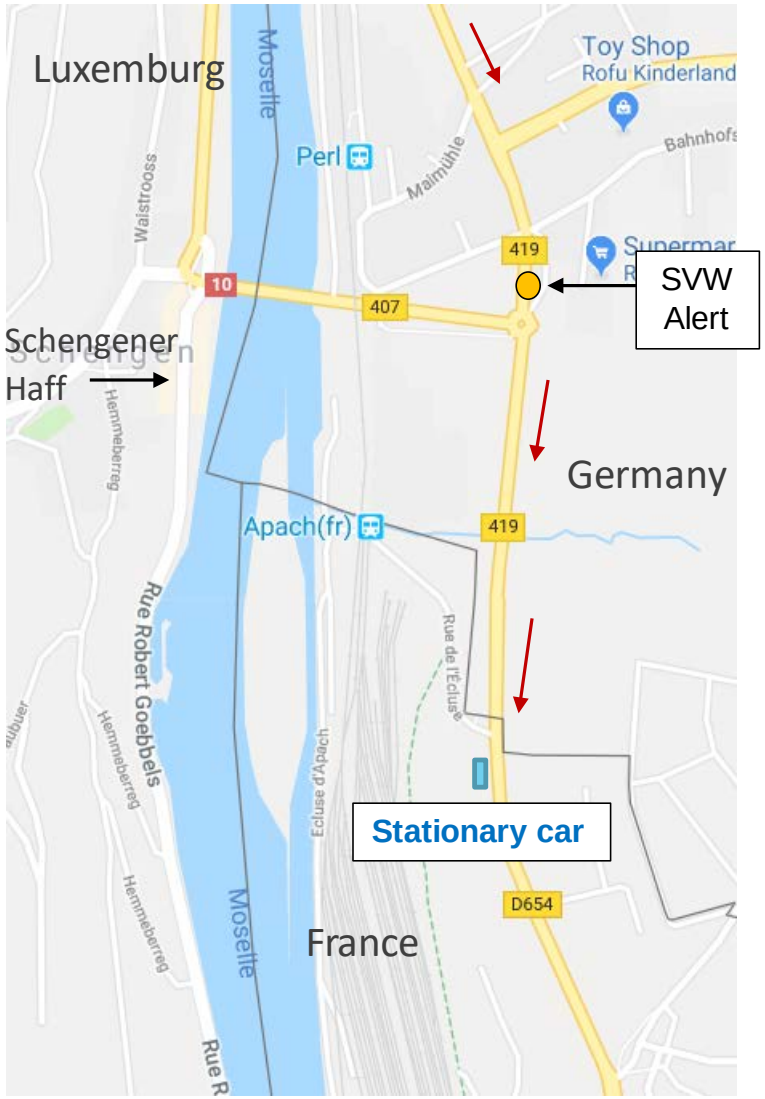
- Distance RSU to RWW start: about 700m
- Note that the zones are defined by the messages coming from the RSU (ITS application does location matching to trigger alerts)



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

Qualcomm | C-V2X TRIAL PLATFORM

HOME | REALTIME | VIDEO | REPORT | CONFIG admin

Filter Test Group 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)

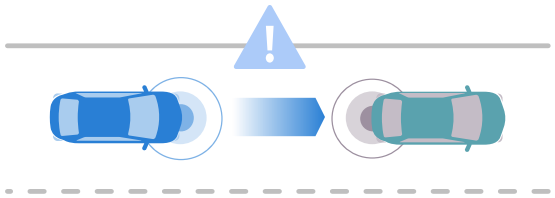
DEVICE NAME	MSG TYPE	SEQ #	TIMESTAMP	BODY	LATITUDE	LONGITUDE
1004	warning	16	2019-04-03T09:37:39.903Z	IVI enable:true duration:0 detail:speed limit: 99.9882942kmph, weight limit: 7.5tonnes	49.4843528	6.3746405
1004	warning	15	2019-04-03T09:37:04.823Z	Work Zone enable:false duration:0 detail:road construction	49.4791872	6.3677

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 safety
IEEE 802.11p

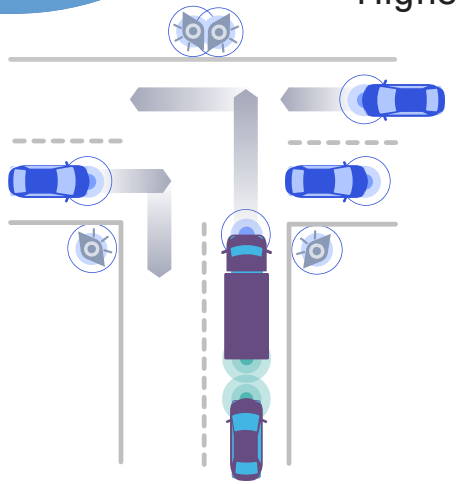


Basic and enhanced safety
C-V2X Rel-14/Rel-15 with enhanced range and reliability

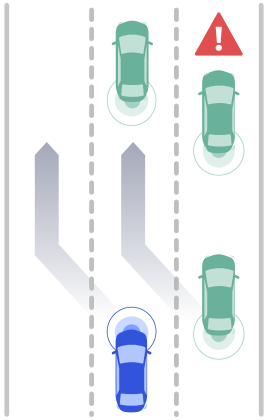
Autonomous driving use cases
5G NR C-V2X Rel-16

Backward compatible with Rel-14/Rel-15 enabled vehicles

Higher throughput
Higher reliability
Wideband carrier support
Lower latency

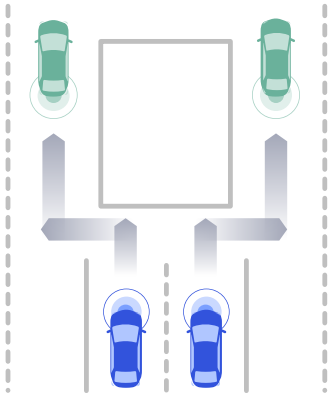


Sensor Sharing



Sudden braking and lane change on a freeway

Intention Sharing



Coordinated Driving

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

C-ITS Platform

Thank You

Questions?