

# Testing the 5G Connected and Autonomous Vehicle

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**ROHDE & SCHWARZ**



# Outline



Future mobility and the way to autonomous driving

V2X Communication

C-V2X – The way to 5G

C-V2X testing and test solutions

eCall and it's challenges

The way forward - NGeCall

NGeCall testing and test solutions

Summary and Q&A



# Cooperative and Automated Driving

## Social, environmental and climate impact

### Safety



### Efficiency



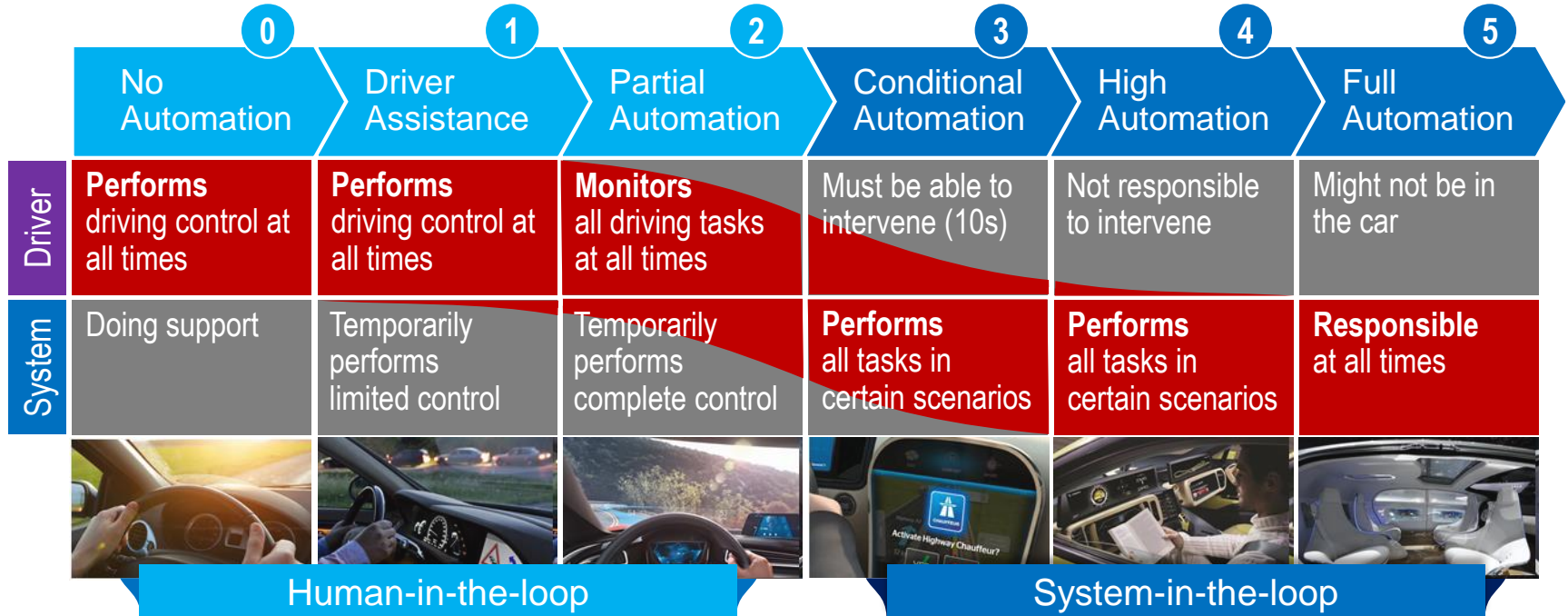
### Convenience



Wireless communication yields transformation from **egosystem** to **ecosystem**

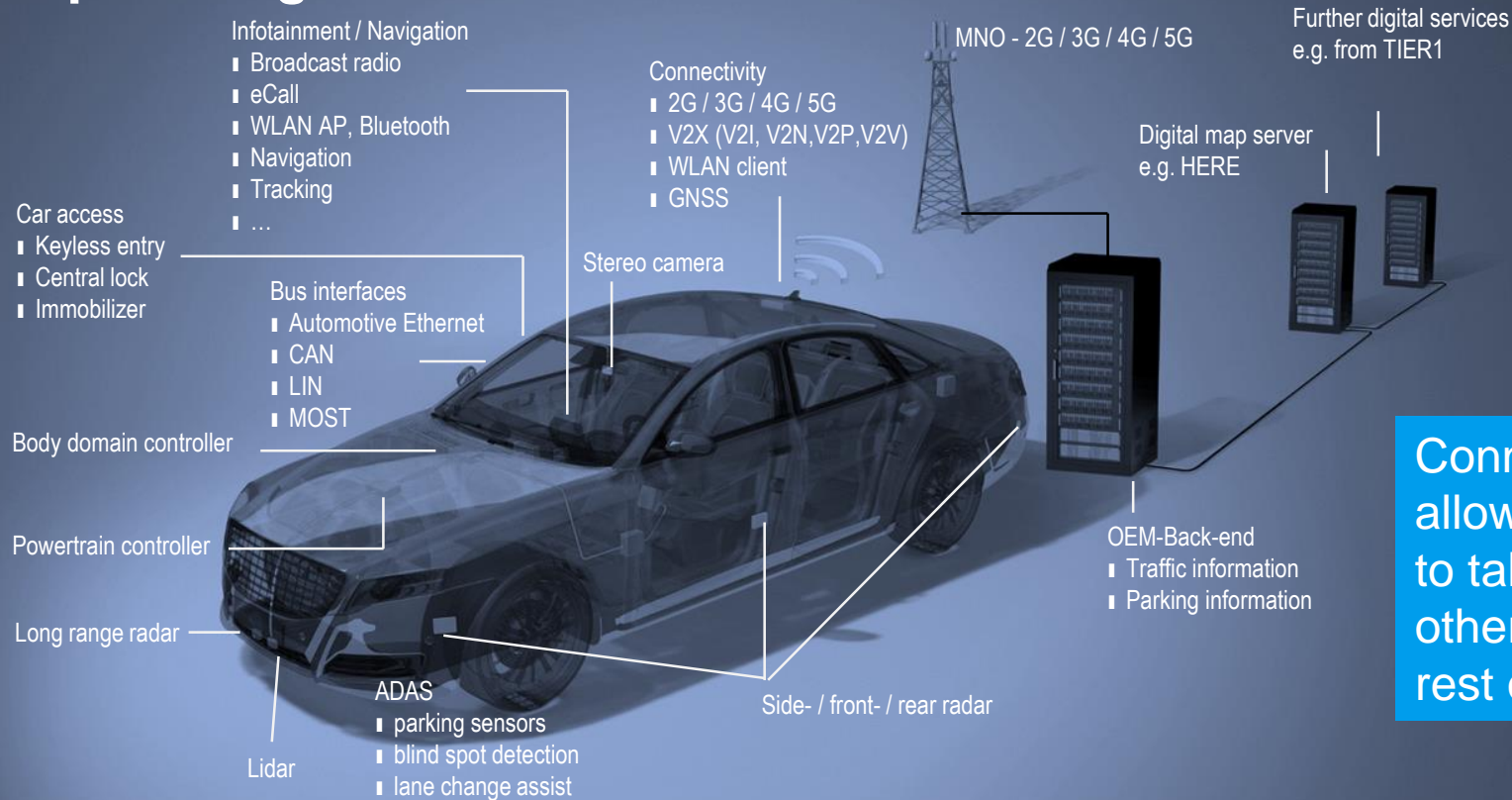
New automotive functions on basis of cooperation between automakers, digital content providers, mobile network operators, road authorities, regulation bodies

# Six levels of driving automation



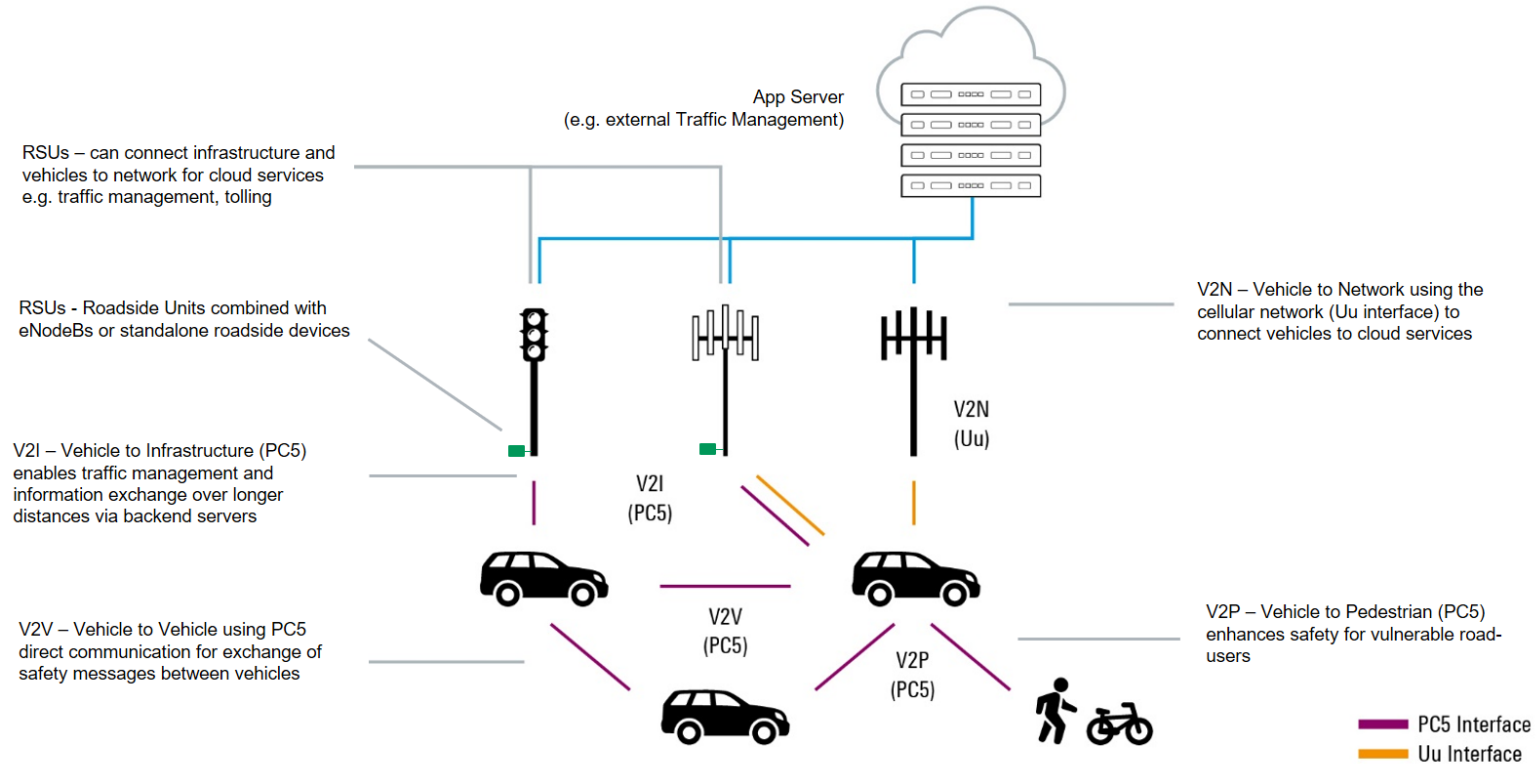
SAE J3016 Level of Automation (LoA) specified by Society of Automobile Engineers(SAE)

# Upcoming vehicle architecture



Connectivity  
allows vehicles  
to talk to each  
other and the  
rest of the world!

# V2X Communication



# V2X Technologies

GSM, UMTS, LTE, 5G

## 3GPP LTE-V2X

- 3GPP LTE-V2X Release 14
- V2V published in 2016, V2X in 2017
- Industry term: Cellular V2X (C-V2X)
- Peer-to-peer ad-hoc communication:
  - service continuity, to operate independent of any centralized system
- Backend connectivity through mobile network
- V2V targets 5.9GHz ITS frequency band

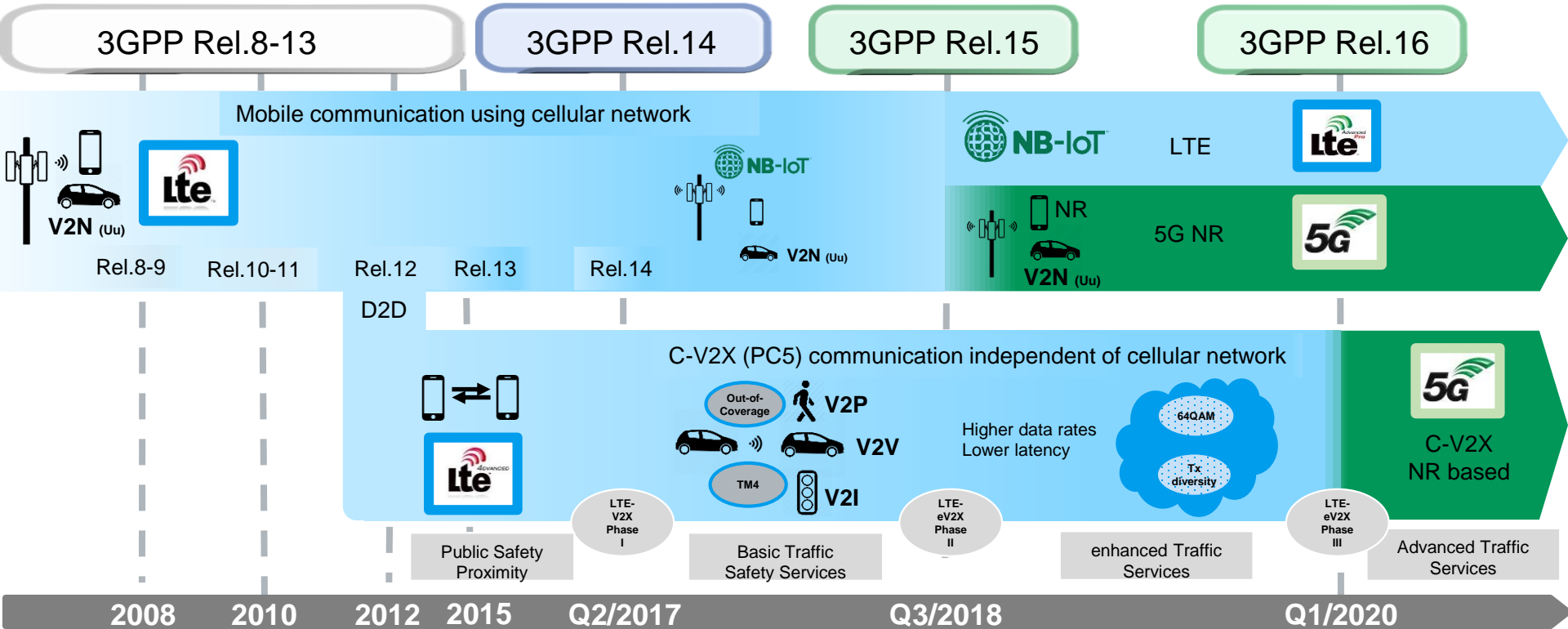
C-V2X

## IEEE 802.11p

- Amendment to IEEE 802.11 (derived from 11a)
- Ratified in 2010
- EU: Car-to-Everything (C2X), ITS-G5
- U.S: Dedicated Short Range Communication (DSRC), WAVE
- Peer-to-peer ad-hoc communication
- Backend connectivity through Road Side Units
- 5.9GHz ITS frequency band

C-V2X, DSRC

# C-V2X - The road to 5G



# Cooperative Intelligent Transportation System (C-ITS)

## Short-term Deployment

### Phase I (Rel. 14)

V2X – LTE based for Basic Safety

- High speed, out-of-coverage (TM4) communication

### Data Transfer to Exchange

- Vehicle Status Information
- Environment Information

### Emergency Electronic Brake Lights



### Intersection Movement Assist



### Left Turn Assist



### Queue Warning



# Cooperative Intelligent Transportation System (C-ITS)

## Mid-term Deployment

See-Through



Real-Time Awareness



Vulnerable Road User Discovery



### Phase II (Rel. 15)

enhanced (e)V2X – LTE based

- Lower latency, Increased bandwidth
- Transmit diversity

### Data Transfer to Exchange

- Sensor Data
- Intention Information
- Trajectory Data

Speed Harmonization



Sensor Sharing



# Cooperative Intelligent Transportation System (C-ITS)

## Long-term Deployment

### Phase III (Rel. 16)

#### 5G New Radio (NR) V2X-PC5

- further increase data rate,
- support new spectrum
- new numerology
- Use Case: URLLC (eg. Remote- or Autonomous driving)

### Data Transfer to Exchange

- Extended Raw Sensor Data
- Enhanced Intention Information
- Improved Trajectory Data

### Cooperative Maneuver



### Remote Controlled Parking



### Data Sharing for Autonomous Driving



### Data Offloading



# R&S C-V2X Test Solutions

We support you to realize the vision of C-V2X enabled cooperative and automated driving

## Production



### CMW100 K06

#### Production test

- Frequency range up to 6GHz,
- 160MHz Bandwidth
- High accuracy
- Parallel test up to 8 RF ports
- CMW-KM570 C-V2X PC5 Meas.

## Conformance



### CMW500 PT + SMBV100A

#### LTE-PC5 protocol communication test

- Data Transmission
- Data Reception
- Performance Testing (Fading)

#### GCF Protocol Conformance

- GCF Work Item 281 (V2V)
- GCF Work Item 282 (V2X)

## Application

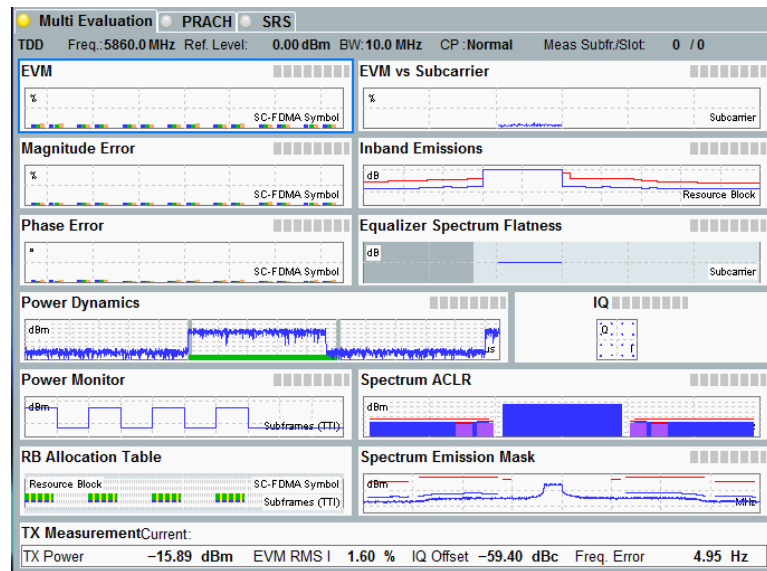


### CMW500 PT + SMBV100A/B + CANoe .Car2x

#### LTE-PC5 Applications test

- Development and Test of C-V2X Scenarios
- Graphical Scenario Editor
- Reproducible test scenarios
- Test of all layers
- Support of all common automotive bus connectivity

# LTE R14 C-V2X TX Measurements (CMW-KM570)



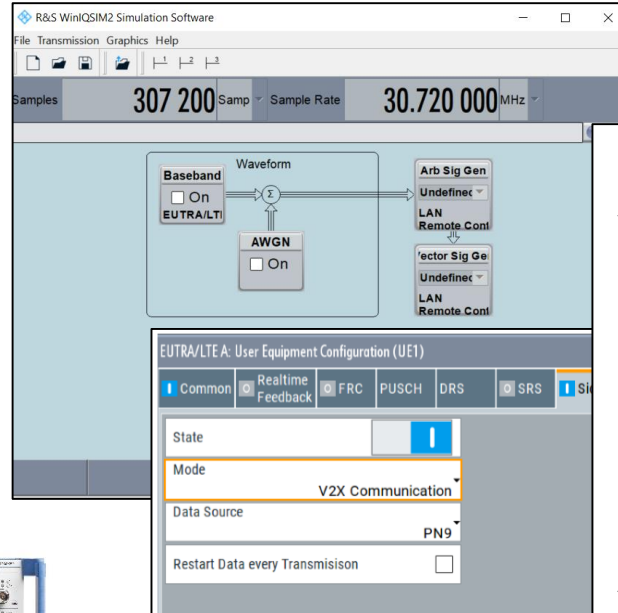
## Supported measurements

- Error Vector Magnitude (EVM)
- EVM vs. Subcarrier
- Magnitude Error
- Inband Emissions
- Phase Error
- Equalizer Spectrum Flatness
- Power Dynamics
- IQ Constellation
- Power Monitor
- Spectrum ACLR
- RB Allocation Table
- Spectrum Emission Mask
- TX Power
- Frequency Error



# C-V2X RX tests KW570/KW500 or KV1xxA

- generate your own C-V2X waveform files
  - ➔ available **CMW-KW570/KW500**
    - C-V2X Side link
    - Flexible Param. Config
    - Example Waveform available
- play „pre-defined“ waveform (ARB) files
  - ➔ available **CMW-KV1xxA**
    - dedicated C-V2X Chipset's

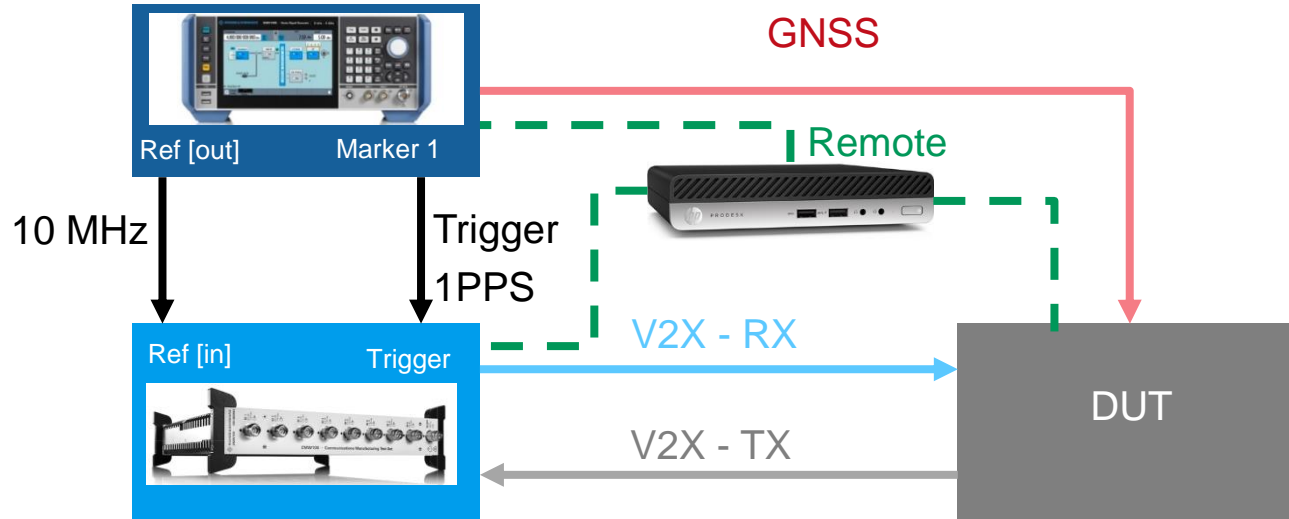


Radio signal:	V2X sidelink
Bandwidth:	10 MHz
N_subchannel:	1
TX mode:	3
PSSCH:	
In frame:	0
In SF:	0
RBs:	0, 1
PSSCH:	
In frame:	0
In SF:	0
RBs:	2 to 49
Content:	PN9
SCI 1 content:	00000000100110000001000000000000
Priority:	3
Resource reservation:	4
Frequency resource location of initial transmission and retransmission:	6
Time gap between initial transmission and retransmission:	4
Modulation and coding scheme:	5
Retransmission index:	1



# Test Setup

## LTE R14 C-V2X RX/TX Measurements



Also supported by CMW500

# CMW-KW570 WinIQSim Waveforms

## Use Case

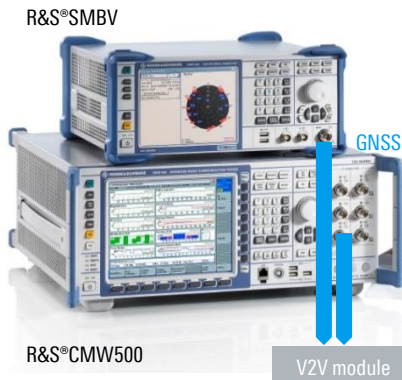
C-V2X RF RX tests			
Reference sensitivity level for V2X Communication	Minimum throughput requirement for specific input power level.	36.521	7.3G
Maximum input level for V2X Communication	Verify to receive data with average throughput for a specified reference measurement channel	36.521	7.4G
Adjacent Channel Selectivity (ACS) for V2X Communication	Ability to receive data with average throughput in the <b>presence of an adjacent channel signal</b>	36.521	7.5G
In-band blocking for V2X Communication	Throughput shall meet requirement for the specified measurement channels with <b>unwanted interfering signal</b> in range from 15MHz below to 15MHz above the band.	36.521	7.6.1G
Out-of-band blocking for V2X Communication	Throughput shall meet requirement for the specified measurement channels with <b>unwanted CW interfering</b> signal falling more than 15 MHz below or above the band.	36.521	7.6.2G
Spurious response for V2X Communication	Ability to receive wanted signal without exceeding degradation due to <b>the presence of an unwanted CW</b> interfering signal at any other frequency.	36.521	7.7G
Wide band Intermodulation for V2X Communication	Ability to receive data average throughput in <b>presence of two or more interfering signals</b>	36.521	7.8.1G
Spurious emissions for V2X Communication	Power of emissions generated or amplified in a receiver that appear at the antenna connector	36.521	7.9G



# Protocol- and Protocol Conformance Test Solution for C-V2X

## Test and certification of C-V2X communication devices

### LTE-V2X (PC5) Test setup



Essential to ensure Interoperability  
and required performance

Munich | 19-Jun-2018 | Test & Measurement

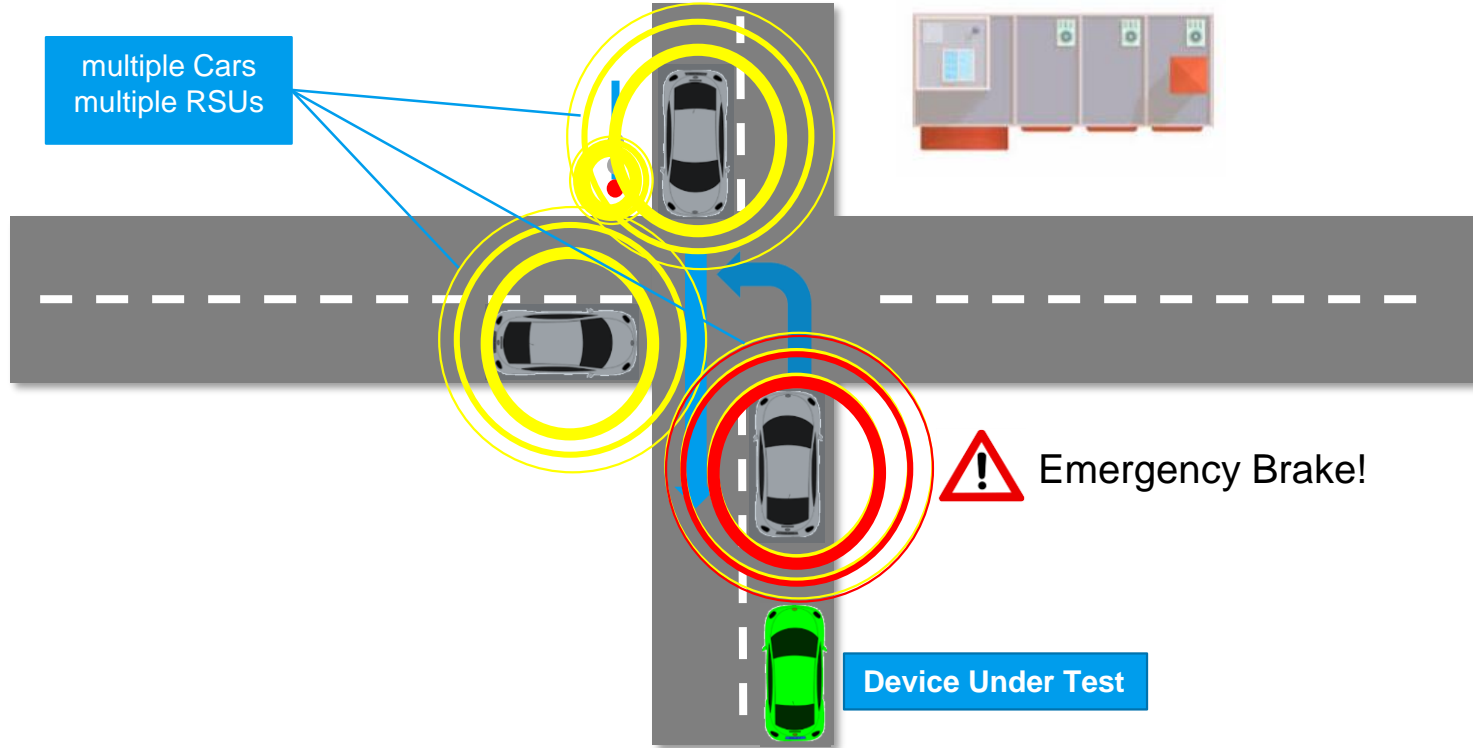
Rohde & Schwarz delivers 3GPP C-V2X  
device testing for GCF protocol  
conformance

Columbia | 09-May-2018 | Test & Measurement

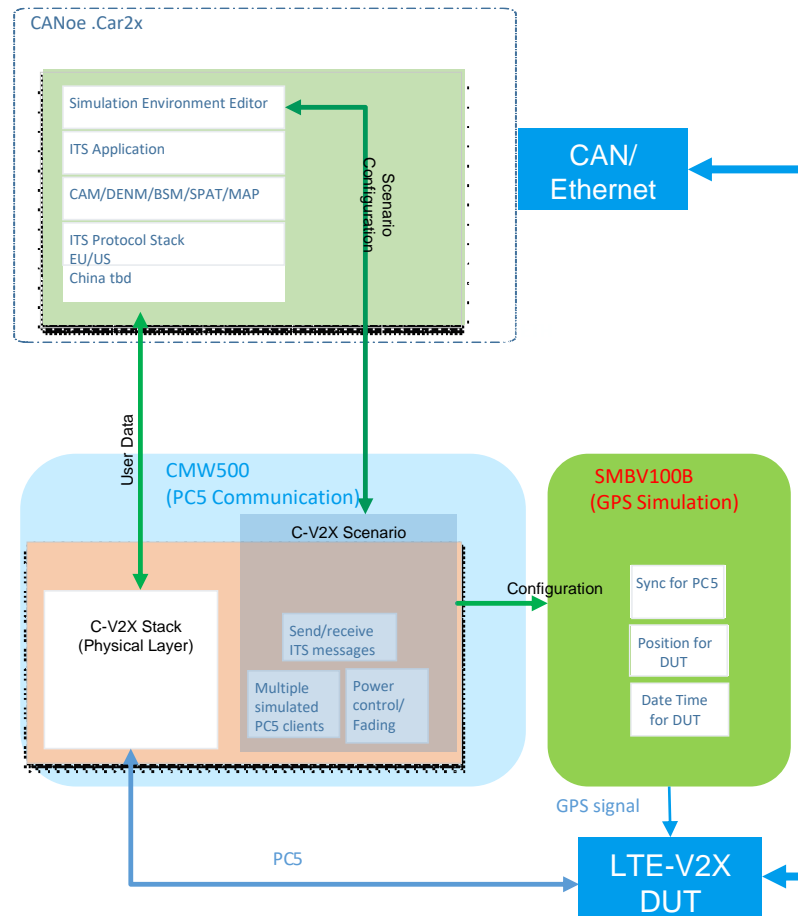
Rohde & Schwarz first to provide 3GPP Cellular-V2X device  
testing through application layer

- LTE-PC5 communication test
  - Transmission Mode 4 (3GPP Rel.14, PSCCH, PSSCH)
  - Out-of-coverage operation with GNSS synchronization
- GCF Protocol Conformance
  - LTE-V2V GCF Work Item 281 (V2V)
  - LTE-V2X GCF Work Item 282 (V2X)

# Requirement: Development of complex C-V2X scenarios



# System Overview

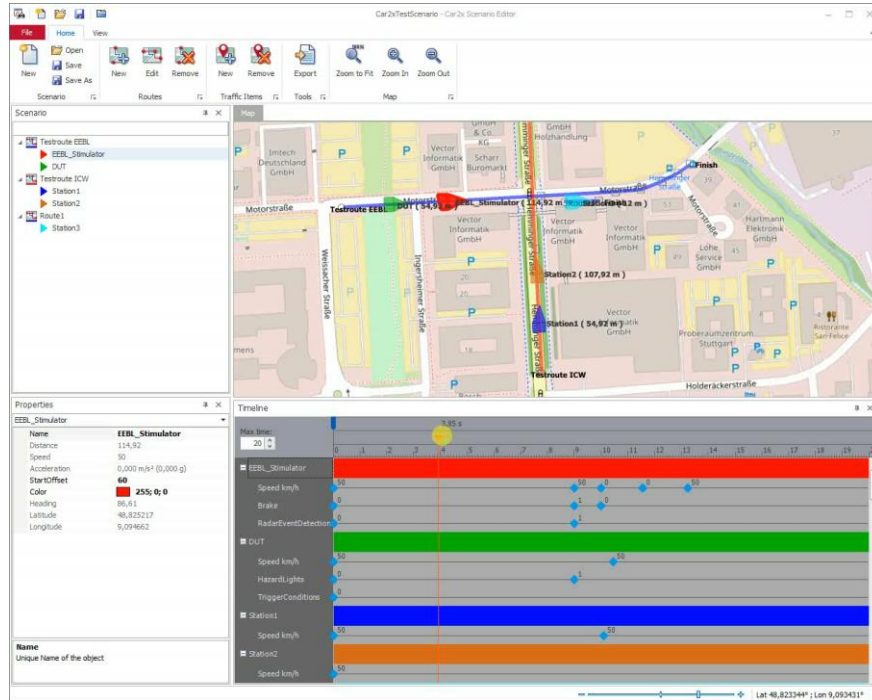


CAN/  
Ethernet

VECTOR

ROHDE & SCHWARZ

# C-V2X Graphical Scenario Editor



- Scenario editor provides GUI to easy and fast configure a traffic scenario
- Parameter like velocity and further specific events can be assigned
  - e.g. vehicle speed, RF parameters, Fading scenarios
- Defined traffic scenario is translated by CANoe .car2x which creates the messaging and forwards it into the radio environment
- CMW500 simulates data transmission over PC5 interface and forwards received information to CANoe
  - Enables verification of TX and RX communication

# CANoe .car2x - User Interface (Example)

Start/Stop Scenario

Load scenarios  
File explorer

Simulated scenario

Configured  
ITS-Stations

Configured  
ITS-Events

Message Content  
details

Send and received  
messages of  
simulated cars  
and the DUT

Extraction of transmitted  
DUT data (details)

Configuration CMW and  
SMBV parameters and start  
stop of C-V2X serving

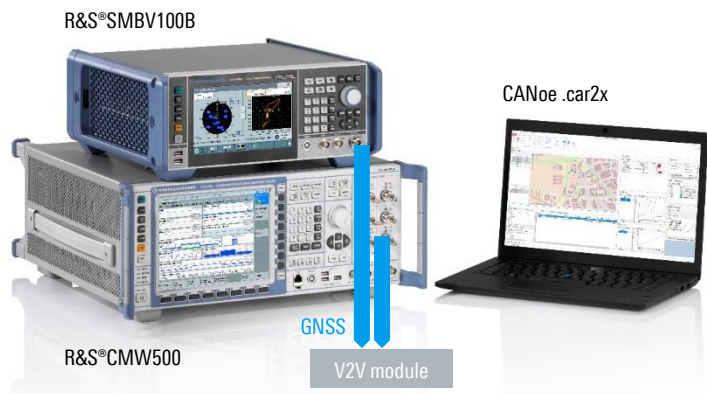
Analysis: DUT Speed  
indications

Analysis: Message Counter



# Cellular-V2X end-to-end application layer test solution

## C-V2X E2E Application layer test solution



- **The combined solution covers all layers**
  - The 3GPP Radio Access Layers for C-V2X Mode 4
  - The region specific ITS protocol layers such as EU ITS-G5 and U.S. WAVE
  - The ITS application message sets
- **Configure and test 3GPP Rel.14 C-V2X traffic scenarios in a lab environment**
  - Comfortable and easy to use graphical scenario editor
  - Tests are 100 % reproducible
- **The test solution allows bus connectivity**
  - CAN, LIN, MOST, FlexRay, and Automotive Ethernet
  - To analyze results or stimulate the ECU remotely

25-28 February 2019

## C-V2X E2E Application Test Solution



Rohde Schwarz

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Cellular V2X testing in R&D and production presented at GSMA MWC 2019

Rohde Schwarz • 545 views • 2 months ago

Testing critical V2X traffic scenarios in the lab is important for the automotive industry. Rohde & Schwarz demonstrated an easy to use solution for testing the application layer on 3GPP Rel.14 cell...

<https://youtu.be/h-wD0AFcGdk>



3GPP cellular V2X testing in production presented at GSMA MWC 2019

Rohde Schwarz • 297 views • 2 months ago

Rohde & Schwarz demonstrates cellular V2X non-signaling testing at GSMA Mobile World Congress 2019 in Barcelona. 3GPP cellular vehicle-to-everything (C-V2X) is one of the technologies considered

<https://youtu.be/GJvzjvRzs-w>



**Free webinar: V2X – the building blocks of an intelligent transport system**

[https://www.rohde-schwarz.com/solutions/test-and-measurement/automotive/connectivity/vehicle-to-everything-communications/v2x-webinar-register\\_250993.html](https://www.rohde-schwarz.com/solutions/test-and-measurement/automotive/connectivity/vehicle-to-everything-communications/v2x-webinar-register_250993.html)

# Outlook - Future solution with CMX500 for 3GPP Rel. 16

## Support C-V2X on it's way to 5G!



### R&S 5GNR & C-V2X test platform

- <6GHz Frequency range
- mmWFreq possible with remote radio heads

### C-V2X E2E Application test with CANoe .car2x

- Test of Uu and PC5 interfaces
- PSSS/SSSS (Synch), PSBCH (Broadcast), PSCCH (Control SCI), PSSCH (Data)
- SIB21, RRC (Dedicated Msgs), DCI 5A
- Multiple UE emulation (several hundred)
- Functional & Protocol Test (L1/L2/L3) and modem bring-up
- RF Measurements: EVM, ACLR, OBW, SEM, Chan Power, Tx On/Off Mask (CMW-KM570)
- Add impairments such as multipath, pseudo-range error, and CW interference signals in real-time while the signal is playing

### GNSS via SMBV100B

...

# Summary



- The vehicle of the future needs connectivity for
  - Safety, Efficiency and Convenience
- V2X is an important feature to realize the autonomous vehicle
- C-V2X today is not 5G – it's LTE Rel.14
  - 5G will improve the system and provide additional features for C-V2X
- R&S provides a broad portfolio for testing C-V2X
  - Production with CMW100
  - MLAPI Protocol and Protocol Conformance Tests
    - First certified setup with certified GCF test cases
- R&S supports C-V2X E2E Application Test for reliable scenario testing with ITS Stack in a lab environment
  - Together with solution partner Vector
  - Reliable, repeatable interoperability tests for C-V2X
  - Create of own user scenarios and verify them in the lab
  - Configure parameter like velocity, RF parameters, Fading scenarios and further specific events
- R&S will support C-V2X on it's way to 5G with CMX500

# eCall and its challenges - Leading the way to Next Generation eCall



# What is eCall?



**eCall is an emergency notification system** which immediately alerts the emergency services after a collision of a vehicle

It is a feature to improve traffic safety and save lives across Europe!



Faster awareness of an accident...

...ambulance arrives faster...

... more lives could be saved!


# Regulation Situation



## Europe

### eCall



- 31<sup>st</sup> March 2018
- EU + 
- Network: GSM (WCDMA) opt.
- GNSS: GPS + GALILEO + SBAS/EGNOS
- Emergency number 112
- In-band modem
- MSD EN 15722
- Vehicle category
  - M1 and N1 (2018)



## Russian Federation

### ERA-GLONASS



- January 2015
- Russia and EACU (Eurasian Customs Union)
- Network: GSM and UMTS
- GNSS: GLONASS (+ GPS opt.)
- Emergency number 112
- In-band modem + SMS
- MSD EN 15722 (+ ext. fields opt.)
- Vehicle category
  - M1 and N1 (2015)
  - M2 and M3 (2016)
  - N1 with weight > 2,500kg
  - N2 and N3 intended for transport of hazardous cargo
  - All others (2017)

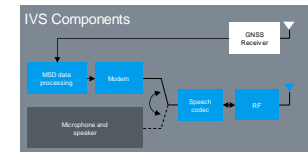
### EU Vehicle category description

- M1:** Passenger car
- N1:** Pick-up, Van
- M2:** Small Bus
- M3:** Bus
- N2:** Commercial Truck
- N3:** Large Commercial Truck

Russian ERA-GLONASS System is harmonized with the EU eCall System.  
Basic functions are similar with a few additional features.

# Testing the eCall IVS

## Conformance and performance testing



E2E testing (TS 103412 / CEN16454 / GOST)

### R&S E2E Conformance Test Solution



GNSS testing (Annex VI , UN-R 144, GOST)

### R&S GNSS Test Solution



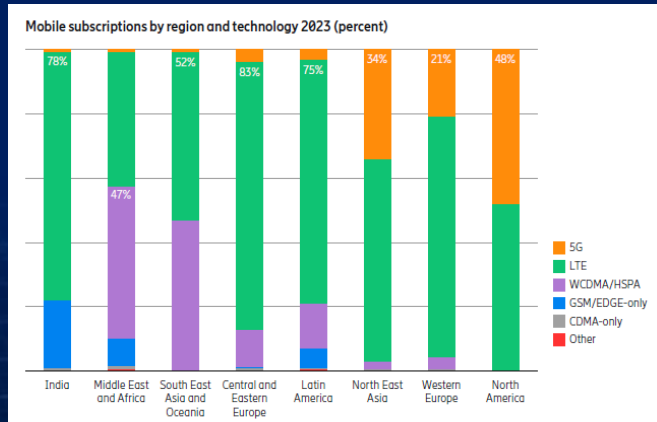
- The CMW-KA094 solution for eCall complies with the standard CEN EN 16454:2015 – **certified by an independent test house**
- R&S CMW500 and SMBV100A are in line to certification for conformity of the **Federal Agency for Technical Regulation and Metrology (Rosstandart)**



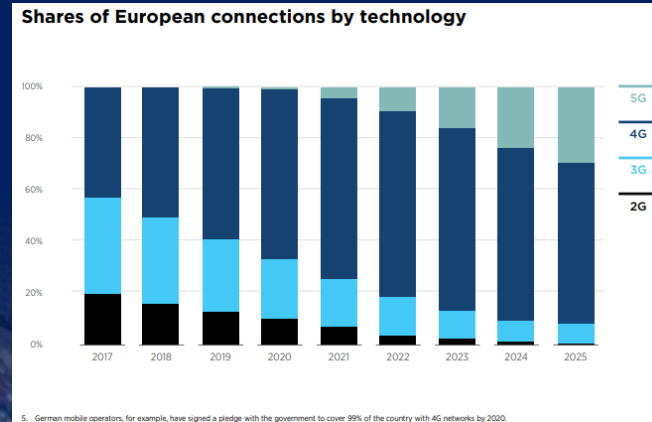
## How future-proof is eCall?



# The network infrastructure changes!



Source: <https://www.ericsson.com/en/mobility-report/reports/november-2018>



S. German mobile operators, for example, have signed a pledge with the government to cover 99% of the country with 4G networks by 2020.

Source: <https://www.gsma.com/mobileeconomy/europe/>

- Several operators announced that they want to shut down their GSM network or want to re-farm the GSM frequencies for LTE
- The networks evolve to 4G (5G) technology – fully IP-based infrastructure (no CS domain anymore)

**Cars typically last 10 years to 15 years on the road, so we need a long-term solution!**

# The way forward: Next Generation eCall



# Next Generation eCall (NGeCall) - Details

- Next-Gen eCall moves from 2G/3G to 4G/5G
  - from circuit switched to packet switched
  - from voice data to IP data
- Most important information is the position information and the voice communication
  - The solution to support voice services in LTE (VoLTE) is the IMS (IP Multimedia Subsystem)
  - IMS will be the **service enabler** for NGeCall as well
    - Minimum Set of Data (MSD) sent in SIP Invite (during call setup)
    - VoLTE voice communication
- IMS eCall standards are ready
  - Defined by IETF (Internet Engineering Task Force) standard.
  - 3GPP Rel. 14 defines Network indicator for eCallOverIMS-Support ([available on CMW500!](#))



# NGeCall Standards

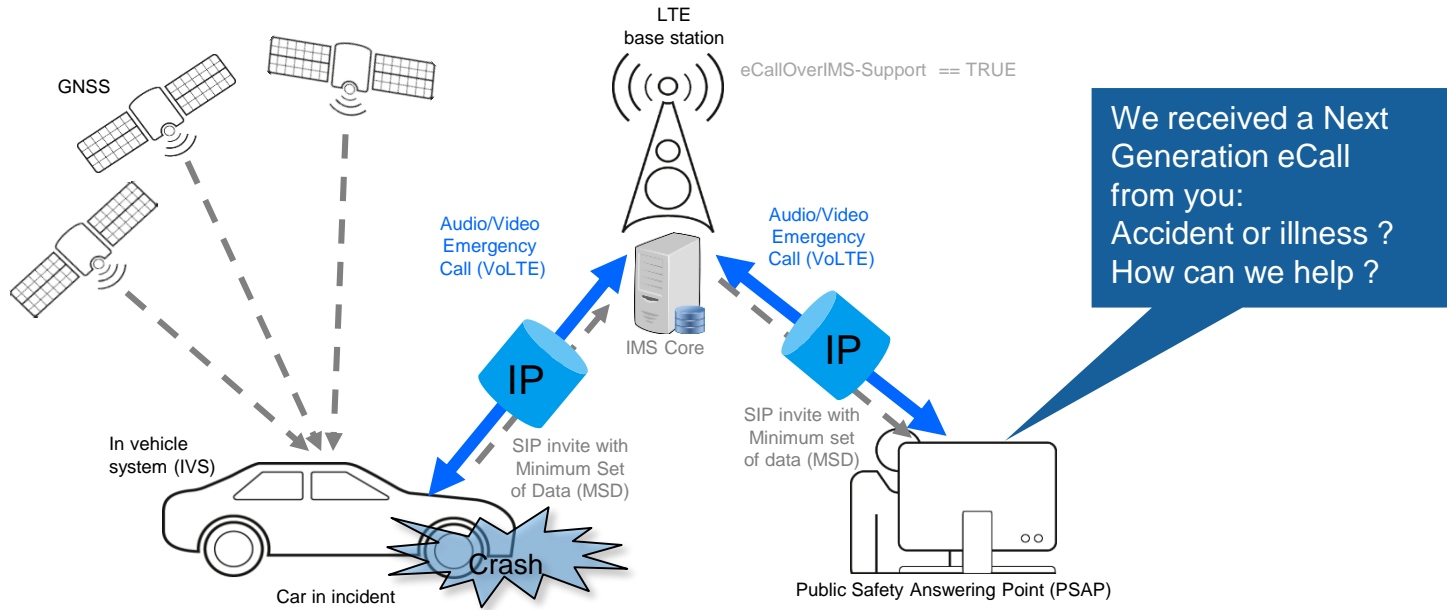
Scope	Specification
IP Multimedia Subsystem (IMS) emergency session	3GPP TS 23.167
IP multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP)	3GPP TS 24.229
Next-Generation Pan-European eCall	IETF rfc8147
Additional Data Related to an Emergency Call	IETF rfc7852
Next-Generation Vehicle-Initiated Emergency Calls	IETF rfc8148
Intelligent transport systems - eSafety - eCall High level application Protocols (HLAP) using IMS packet switched networks	CEN TS 17184
End-to-end conformance test specification for IMS based packet switched systems	CEN TS 17240



# NGeCall System Overview

NGeCall is a manually or automatically initiated emergency call and transmission of an MSD...

- ... from the IVS to PSAP via [LTE network using IMS for MSD transmission.](#)



# Main differences of NGecall

## ecall today

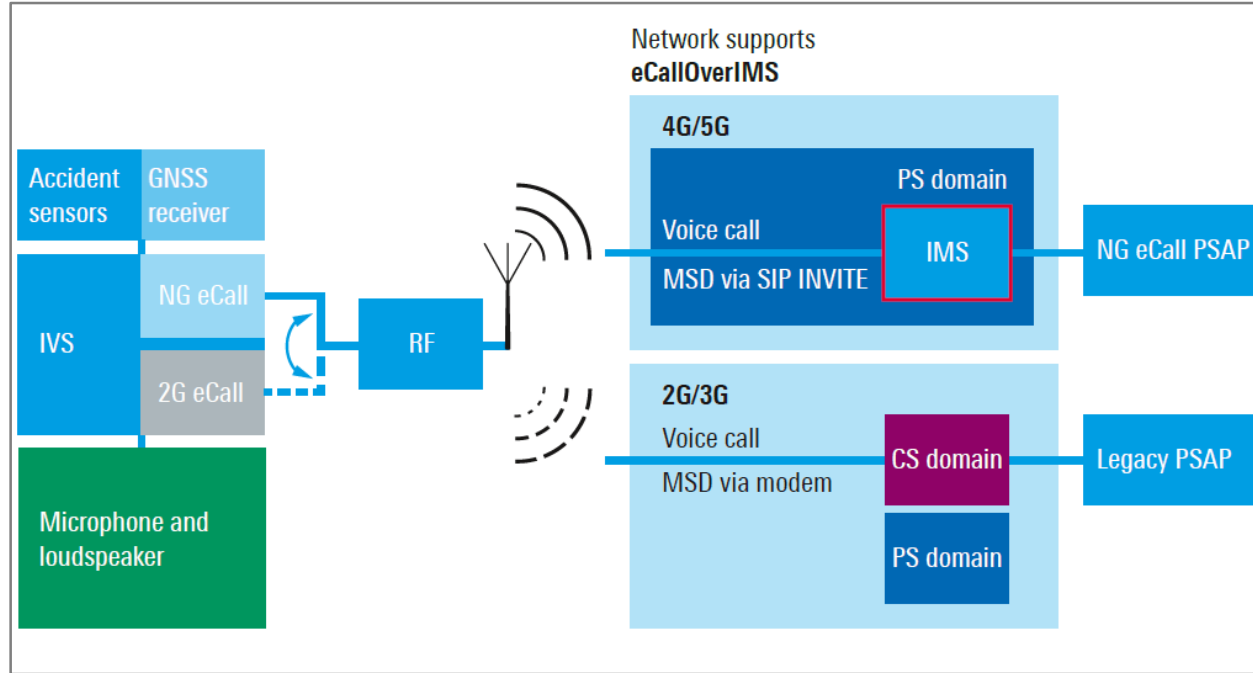
- Accident
- IVS 112 ecall via CS-GSM
- Setup voice channel
- Connect In-Band modem for data transmission
- Send MSD via in-band modem
- Connect microphone/loudspeaker of the vehicle for voice communication of the driver with 112 operator
- Operator can talk to driver and see MSD data
- MSD Re-request: Interrupt of voice communication for in-band modem transmission

## NG112 eCall

- Accident
- IVS 112 NGecall via LTE VoIP (VoLTE)
  - MSD send via IMS call setup Message
- Setup voice channel
- Connect driver with 112 operator
- Operator can talk to driver and see MSD data
- MSD Re-request: Without interruption of voice communication



# Co-existence of NGeCall with CS eCall



- Network has indicator in SIB1 message (LTE) for NG eCall
  - UE must be able to determine if NGeCall is supported before call establishment
- PS domain (LTE) is chosen when network indicates support via eCallOverIMS Flag
- CS call is selected when network indicates no support via eCallOverIMS Flag

# Test requirements and test fields

## LTE Connectivity

- LTE network attach
- NGeCall indicator interpretation (SIB 1)
  - Supported / Not supported

## Handover\*

- LTE cell reselection
  - Circuit Switch Fall Back (CSFB)
    - based on NGeCall indicator to GSM / WCDMA
- \*CMW500 multi cell setup required

## Audio Quality

- VoLTE Audio Quality Test (AMR-NB/AMR-WB/EVS)

## IMS

- IMS emergency registration
- Emergency call setup procedure
- Emergency call (SIP-INVITE - MSD)
  - Auto/Manual/Test modes
  - Raw MSD content available
  - Decoding possible
- VoLTE voice call
  - Call established
  - Hang-up Call
  - Redial test
- SIP INFO request to update MSD
- ...

## GNSS

- EU2017/79 Annex VI or ECE/TRANS/WP.29/2017/132
- Position accuracy 2D Error

## Other

- MSD transferred over VoLTE (in-band audio)
  - receive MSD (Raw/Decoded)
  - transmission time
- IVS Performance tests
- HLAP – Conformance tests
- ...



# NGeCall advantages and future possible extensions



## Advantages:

- Fast due to no waiting time for MSD transmission (MSD with SIP-Invite)
- Robust solution – uses packet data services with error correction/retransmission
- High data rates for packet vs. in-band modem (<560bps under best channel conditions)
  - Enables fast transmission of large amounts of data
- No interruption of voice conversations due to concurrent services with voice
- Easily harmonized standard across other wireless interfaces e.g. 5G networks

## Future possible extensions:

- Other data, e.g., vehicle diagnostics, medical/health, crash and surrounding environmental sensors, vehicle deceleration profile
- Other media types, e.g., video telephony, video stream, telepresence, high-quality audio, text for disability access, text for language translation



# NGeCall advantages and future possible extensions

## Future possible extension:



## Sensor-enabled emergency services

Much more use cases beyond automotive eCall, for example



## Benefits using sensor-enabled emergency services :

real-time exchange of  
relevant information

early detection of  
emergencies

enhanced emergency  
situational awareness

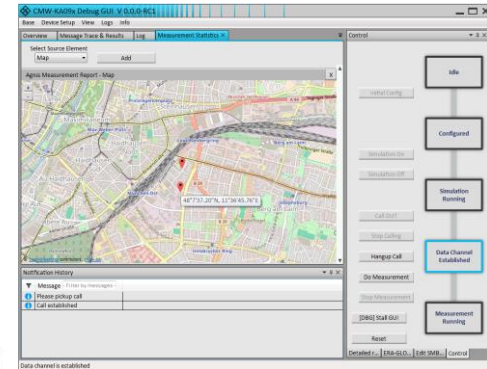
# Preparing the Future!

## New Option: CMW-KA096 for Next Generation eCall testing

Extension of the market leading eCall/ERA-Glonass test solution with the new NGeCall test application using the R&S®CMW500 as an LTE network emulator with an [integrated](#) IMS server.

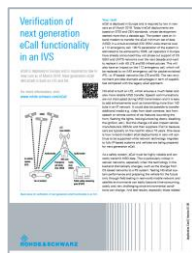
Option: R&S®CMW-KA096 test software:

- Test solution for NGeCall
- LTE cell and IMS server configuration
- MSD reception and decoding
- VoLTE audio and video call support
- GNSS positioning measurements
- ...



R&S Next Generation eCall Test Software

# Application Card, MWC Video and other material provided by R&S



## AppCard:

[https://www.rohde-schwarz.com/au/campaign/ng-ecall-appcard/ng-ecall-appcard-register\\_234254.html](https://www.rohde-schwarz.com/au/campaign/ng-ecall-appcard/ng-ecall-appcard-register_234254.html)

## News 220:

[https://cdn.rohde-schwarz.com/magazine/pdfs\\_1/article/220/NEWS\\_220\\_15\\_NGeCall\\_en.pdf](https://cdn.rohde-schwarz.com/magazine/pdfs_1/article/220/NEWS_220_15_NGeCall_en.pdf)

## Webinar:

[https://www.rohde-schwarz.com/solutions/test-and-measurement/automotive/automotive-media-center/webinar-ecall-and-its-challenges\\_250094.html](https://www.rohde-schwarz.com/solutions/test-and-measurement/automotive/automotive-media-center/webinar-ecall-and-its-challenges_250094.html)



<https://youtu.be/aJkZ4W1ErmU>

# Summary



- eCall and ERA-GLONASS are deployed and in operation
  - Rohde & Schwarz provides the ideal solution for standard-compliant testing of eCall/ERA-GLONASS
- CHALLENGES AHEAD – The infrastructure changes!
  - Cars typically last 10 – 15 years on the road **a long-term solution is required!**
  - Co-existence of NGeCall with CS eCall is required
- The way forward: Next Generation eCall
  - Future proof solution for 4G/5G
  - IMS will be the service enabler for NGeCall
  - Provides advantages and future possible extensions
    - Fast, High data rates, No interruption of voice conversations...
    - Sensor enabled emergency services could be established, eCall via VoWLAN
- Rohde & Schwarz provides already today the test solution for Next Generation eCall



Rohde & Schwarz -  
Solutions for all trends in the automotive industry!



Thank you!

