ADVANCES IN C-V2X AND AUTOMOTIVE CONNECTIVITY

TESTING CONNECTED VEHICLES IN THE LAB


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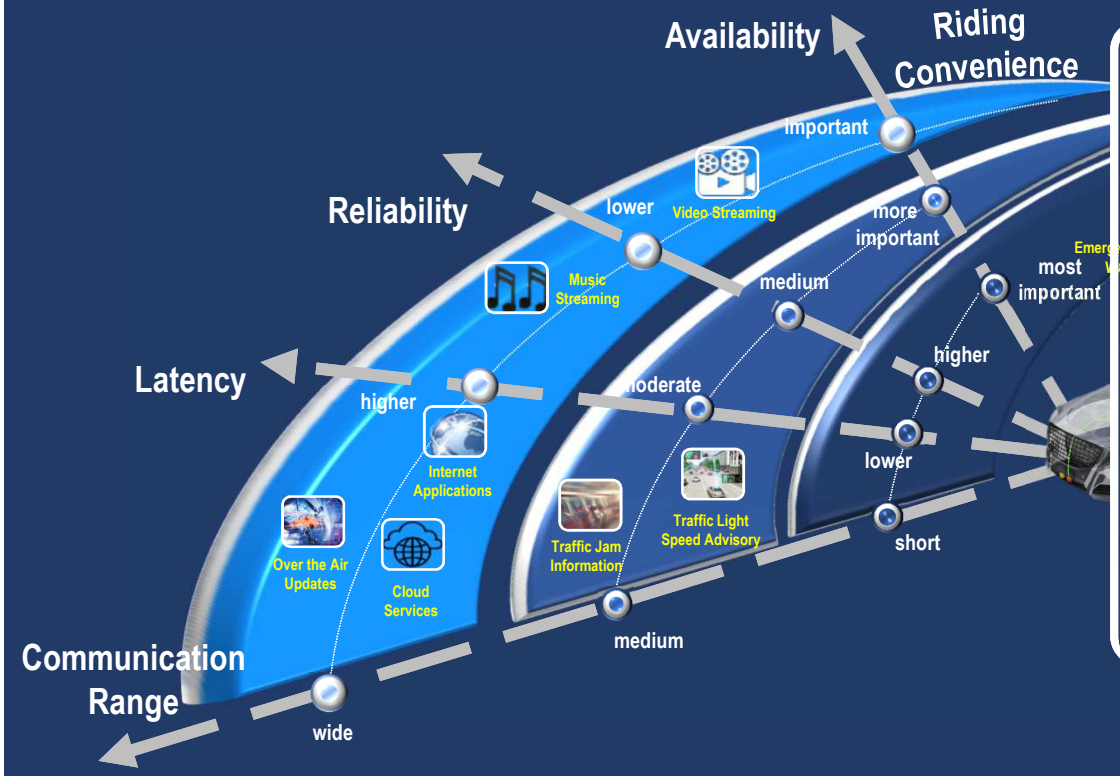
ROHDE&SCHWARZ
Make ideas real

CONTENT

- Automotive Use Cases and Key Performance Indicator
- 3GPP C-V2X Evolution
- Insights into C-V2X Features
- Frequency Regulation and Market Status
- Test Solutions
- Conclusion

CONNECTED MOBILITY
USE CASES AND THEIR KEY PERFORMANCE INDICATORS

AUTOMOTIVE COMMUNICATIONS REQUIREMENT
THE GUIDELINES FOR CELLULAR TECHNOLOGY STANDARDIZATION



Key Performance Indicator	Parameter Range (examples) from	to
Communication Range	Meter	Kilometer
Availability	In-coverage	Out-of-coverage
Latency	Milliseconds	Seconds
Reliability	90%	99.9999%
Throughput	Kb/s	Mb/s, Gb/s

TWO TYPES OF STANDARDIZED COMMUNICATION TECHNOLOGIES COMPETE TO SERVE THE MARKET

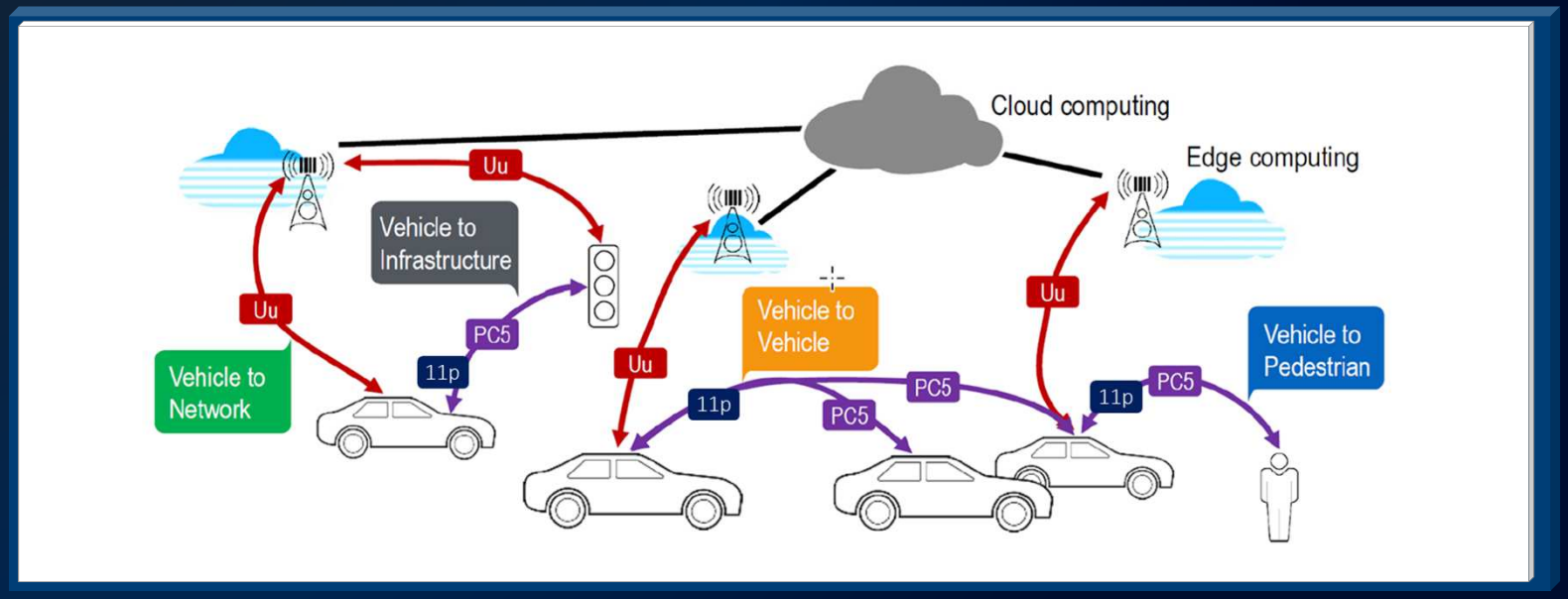
IEEE 802.11p

- 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
- 5.9 GHz ITS frequency band

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 5.9 GHz ITS frequency band

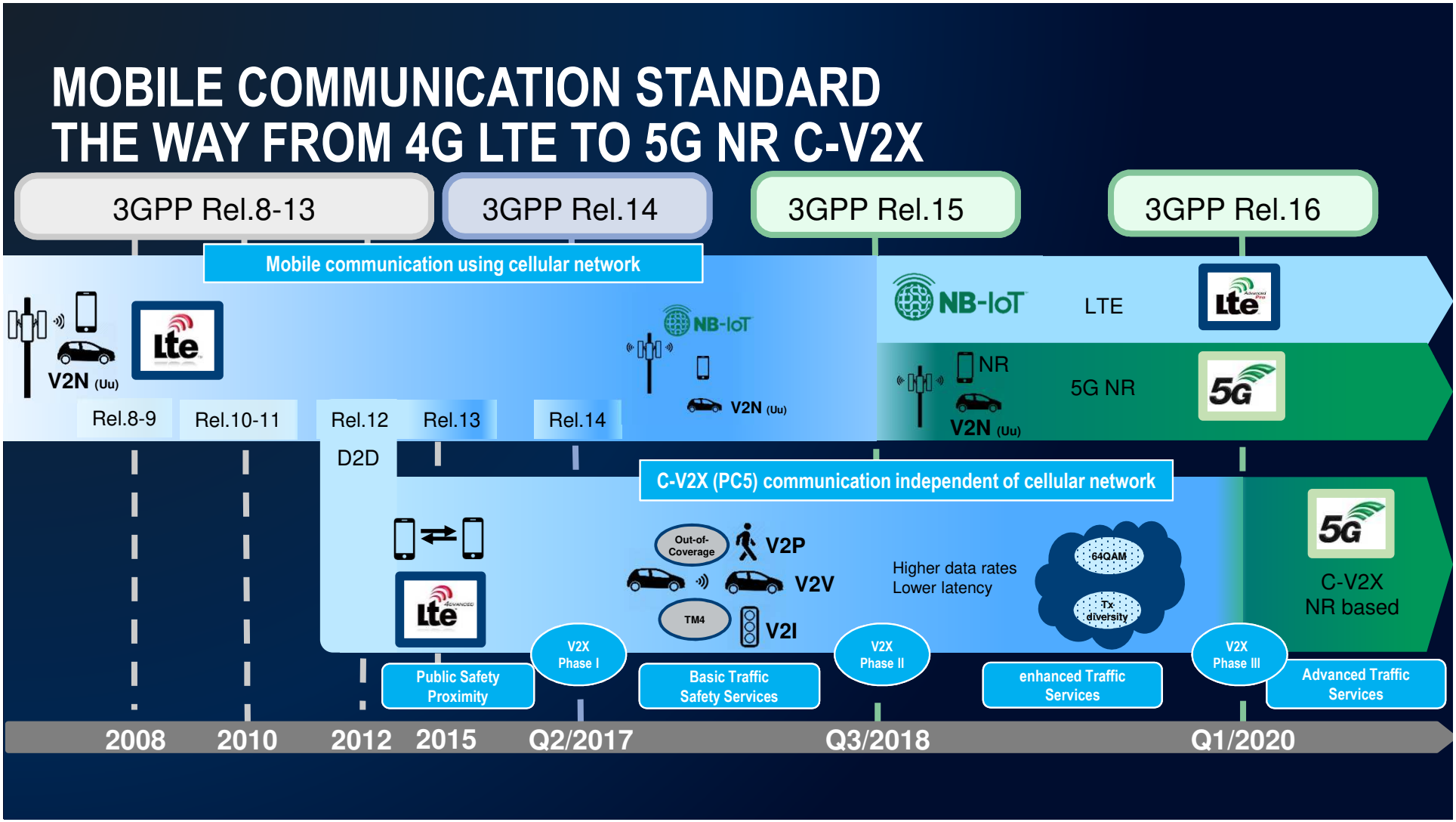
C-V2X NETWORK ARCHITECTURE
UBIQUITOUS CONNECTIVITY



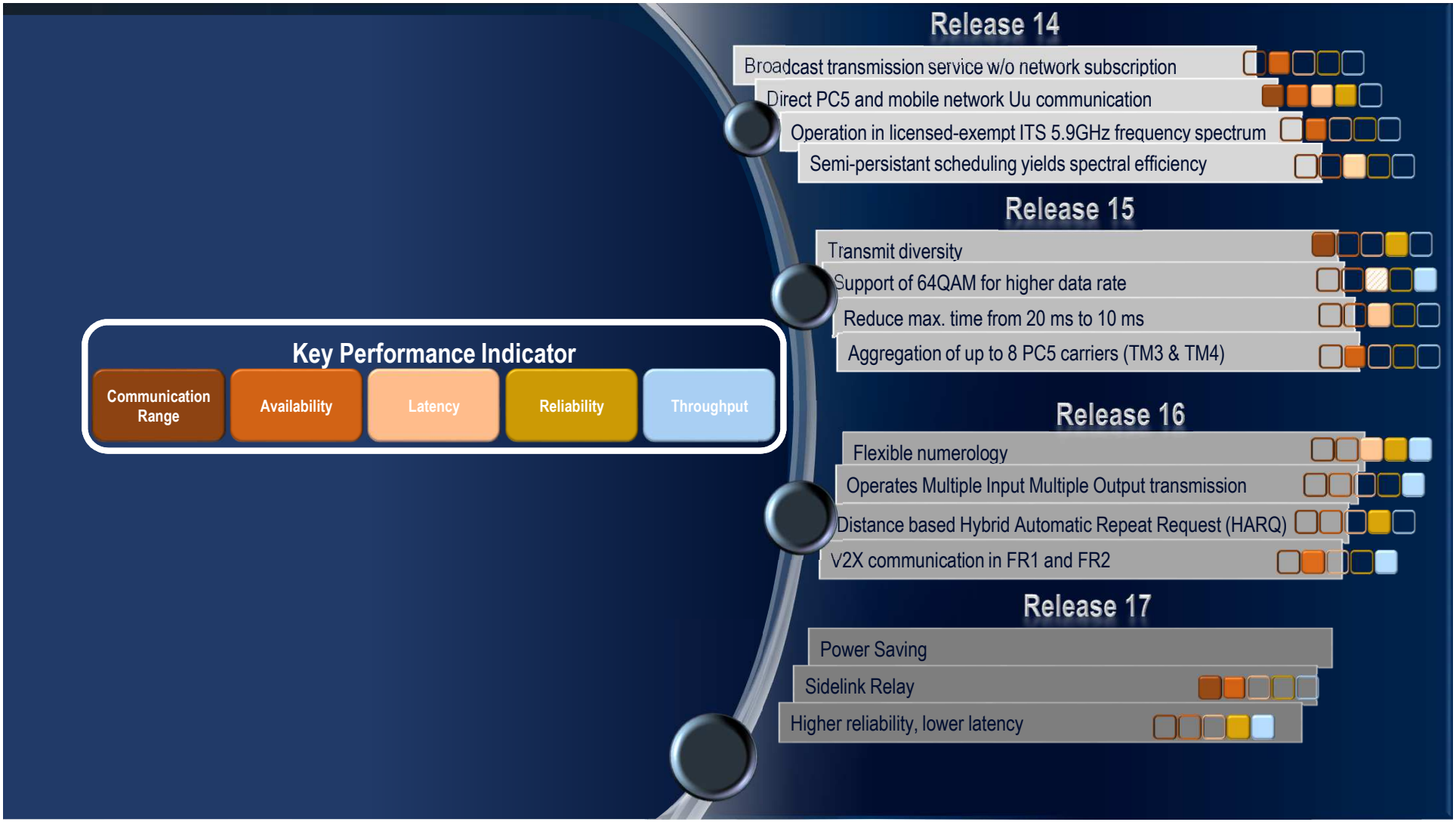
TECHNOLOGY SOLUTION FOR C-ITS
MESSAGE TYPES AND SYSTEM REQUIREMENTS

Message Type EU	Message Type USA	Message Type China
Cooperative Awareness Message (CAM) Vehicle status information (ETSI EN 302 637-2) **Decentralized Environment Notification (DENM)** Information about specific event (ETSI EN 302 637-3)	**Basic Safety Message (BSM)** Vehicle status information Optional event flags (SAE J2735, SAE J2945)	**Basic Safety Message (BSM)** Vehicle status information (T/CSAE 53-2017)

End-to-End Latency: 20ms – 500ms, Message Repetition: 1Hz – 10Hz, Range: 300m – 1km
Speed: 250km/h (absolute), 500km/h (relative)


MOBILE COMMUNICATION STANDARD
THE WAY FROM 4G LTE TO 5G NR C-V2X
3GPP Rel.8-13
3GPP Rel.14
3GPP Rel.15
3GPP Rel.16
Mobile communication using cellular network
V2N (Uu)
Lte
NB-IoT
V2N (Uu)
NB-IoT
LTE
Lte
NR
V2N (Uu)
5G NR
5G
Rel.8-9
Rel.10-11
Rel.12
Rel.13
Rel.14
D2D
C-V2X (PC5) communication independent of cellular network
Lte
Out-of-Coverage
V2P
V2V
TM4
V2I
Higher data rates
Lower latency
64QAM
Tx diversity
5G
C-V2X
NR based
V2X Phase I
V2X Phase II
V2X Phase III
Public Safety Proximity
Basic Traffic Safety Services
enhanced Traffic Services
Advanced Traffic Services
2008
2010
2012
2015
Q2/2017
Q3/2018
Q1/2020


Release 14
Broadcast transmission service w/o network subscription
Direct PC5 and mobile network Uu communication
Operation in licensed-exempt ITS 5.9GHz frequency spectrum
Semi-persistant scheduling yields spectral efficiency
Release 15
Transmit diversity
Support of 64QAM for higher data rate
Reduce max. time from 20 ms to 10 ms
Aggregation of up to 8 PC5 carriers (TM3 & TM4)
Release 16
Flexible numerology
Operates Multiple Input Multiple Output transmission
Distance based Hybrid Automatic Repeat Request (HARQ)
V2X communication in FR1 and FR2
Release 17
Power Saving
Sidelink Relay
Higher reliability, lower latency
Basic Services
Traffic Warning
Hazardous Information
2017
Enhanced Services
Extended Sensors
Collaborative Perception
2018
Advanced Services
Advanced Sensors Data Sharing
Intention Sharing
2020
Vulnerable Road User
Remote Operation
Enhanced Sidelink
Accurate Positioning
External Computing Power
2021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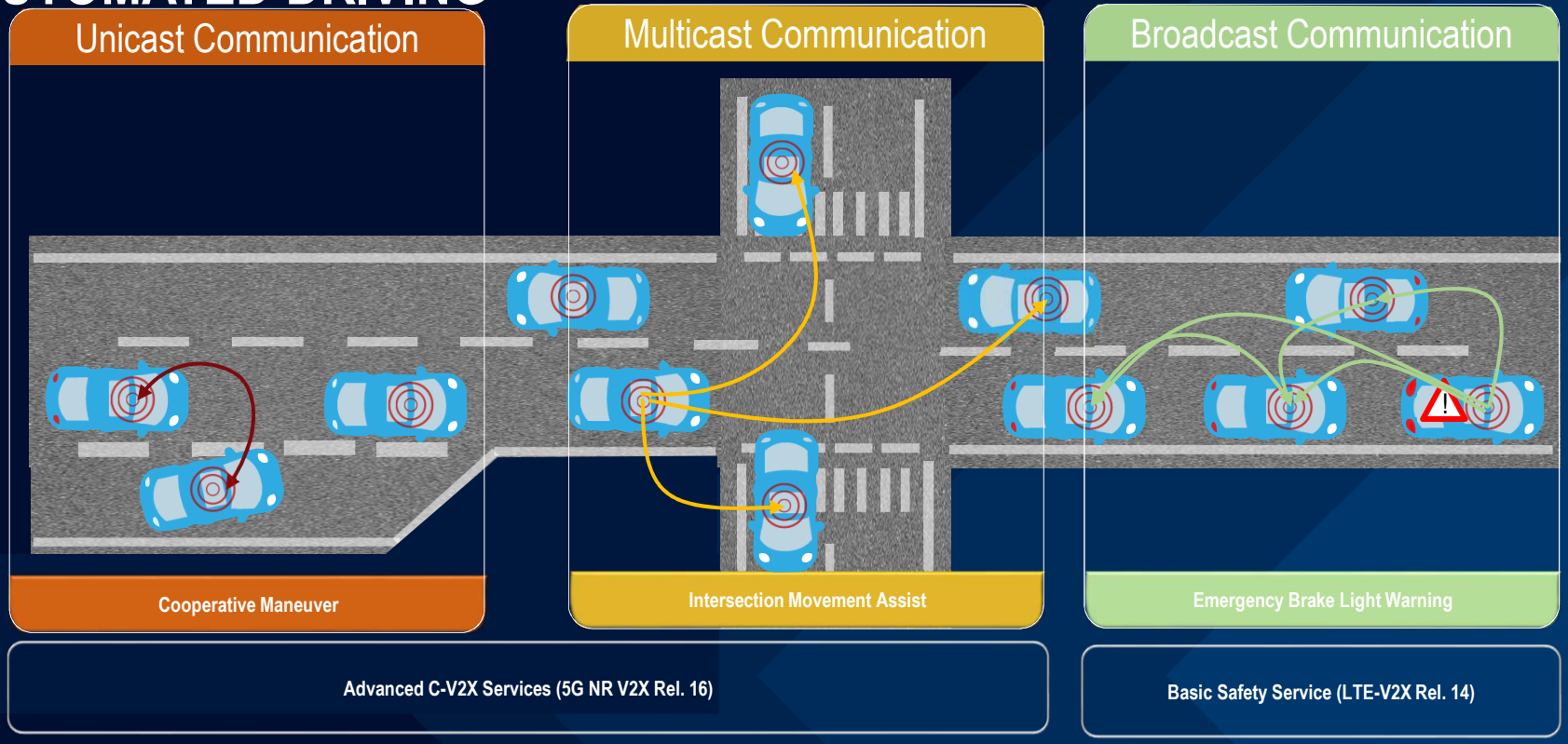
Higher reliability, lower latency
Key Performance Indicator
Communication Range
Availability
Latency
Reliability
Throughput

COMMUNICATIONS TYPES IN 4G LTE AND 5G NR TO SUPPORT AUTOMATED DRIVING



THE BOUNDARYLESS SUCCESS
WORLD MOVES CLOSER TOGETHER

2020

- More than 800 LTE networks in 240 countries
- Data traffic more than 90 Exabyte per month
- 409 Mobile Network Operators invest in 5G
- Roaming data per year 712 Peta Byte

2025

- 5.8 bn mobile subscriptions
- Population 95% in network coverage
- Data traffic raised to 200 Exa Byte per month
- Roaming data per year 1,700 Peta Byte

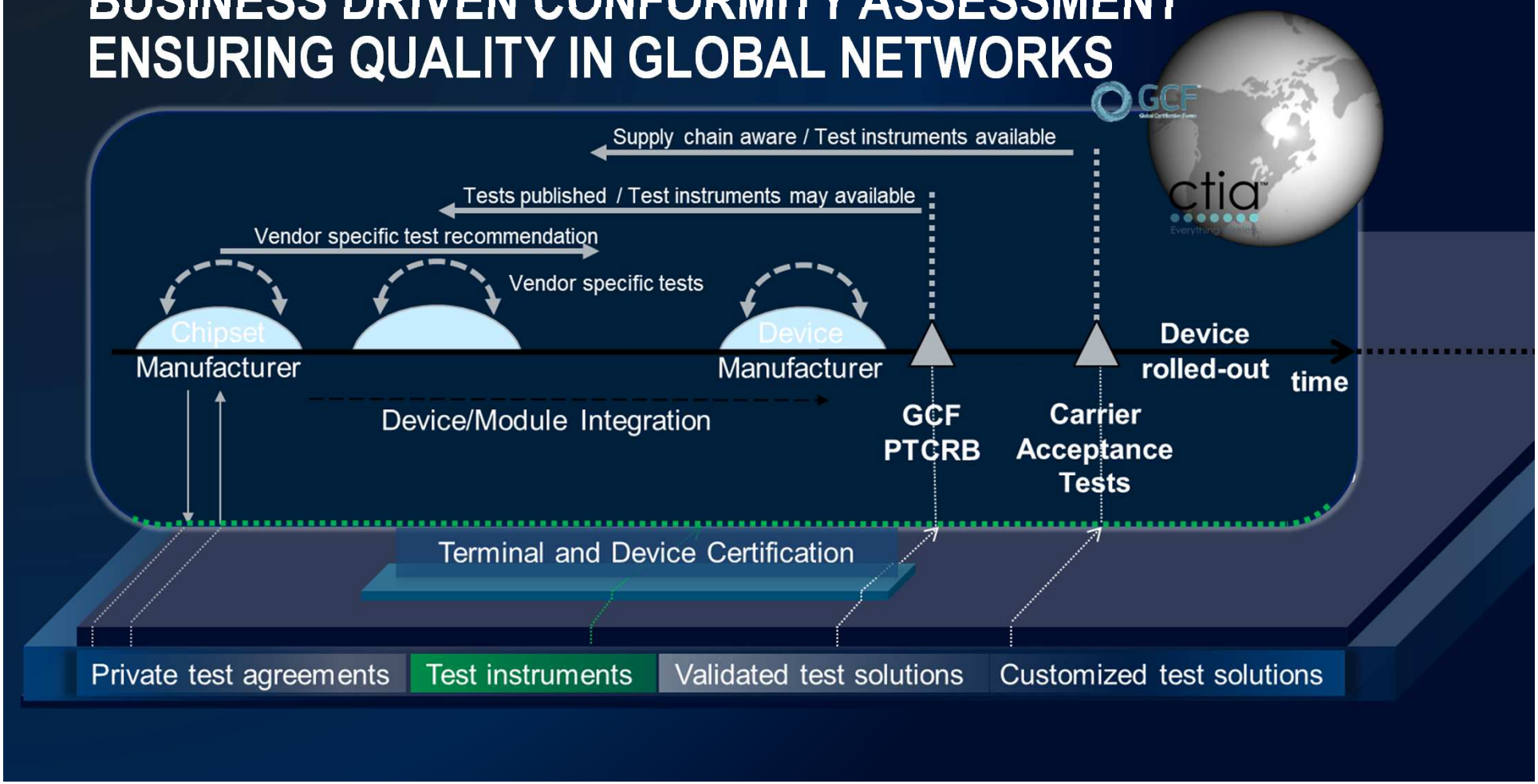
COMMON ASSESSMENT APPROACH ENABLING INTEROPERABILITY FOR GLOBAL ECOSYSTEM

- More than 800 LTE networks in 240 countries
- Data traffic more than 90 Exabyte per month

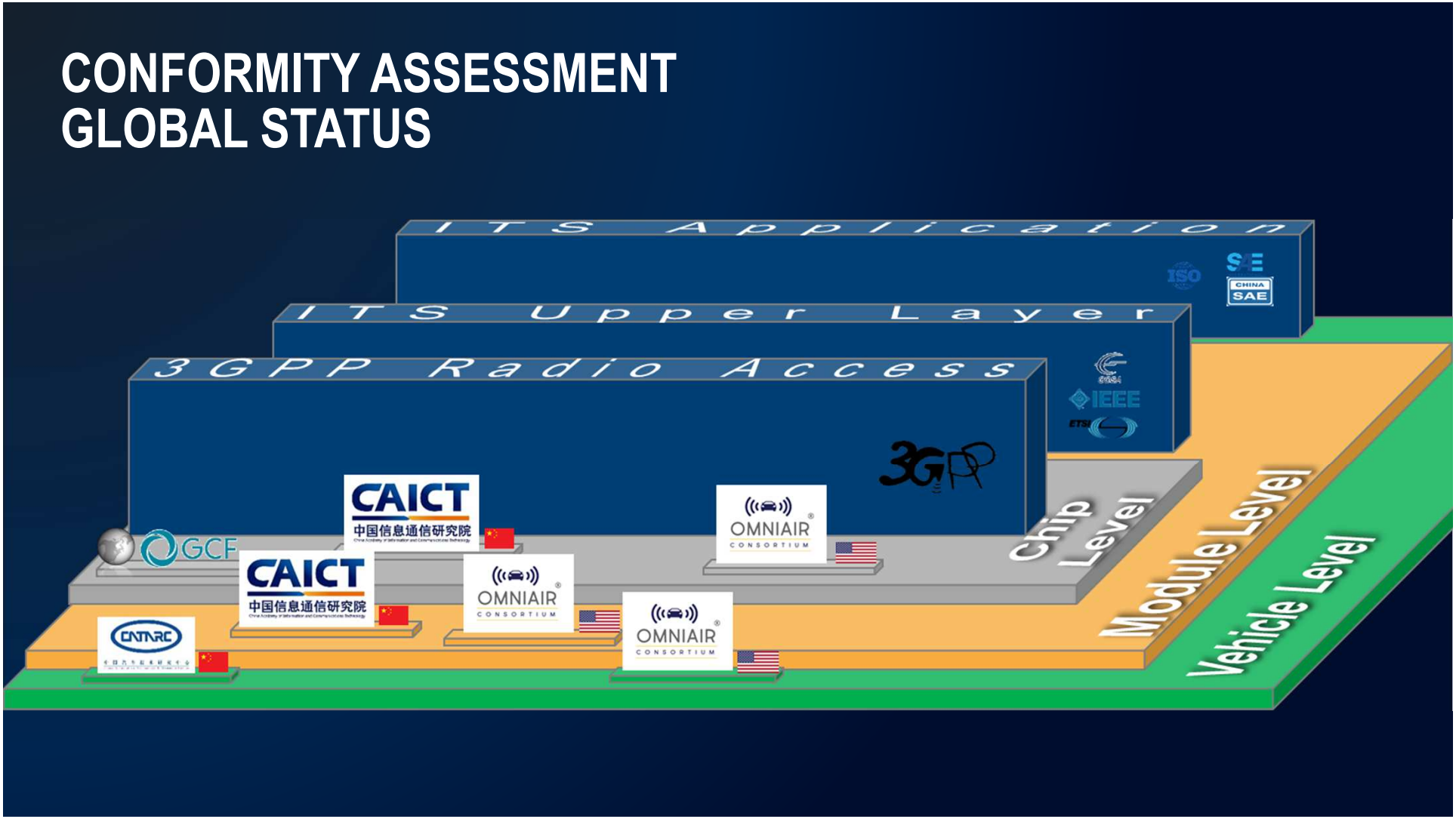
- **Global test regime established by mobile network operators ensures conformance and interoperability**
- **Does the automotive industry adopt same processes for Cellular V2X (C-V2X)?**

- Population 95% in network coverage
- Data traffic raised to 200 Exa Byte per month
- Roaming data per year 1,700 Peta Byte

BUSINESS DRIVEN CONFORMITY ASSESSMENT ENSURING QUALITY IN GLOBAL NETWORKS



CONFORMITY ASSESSMENT GLOBAL STATUS



R&S®CMW500 testplatform is applicable for test and investigation of many C-V2X use cases

Scalable

Precise & Repeatable

Performance optimized

3GPP RF

Allows customer to validate hardware using Rx and Tx measurements capability. Investigating to extend to automated CMWRun RF test cases based on 3GPP specification

MWC Demo

1a

3GPP PROTOCOL

3GPP Protocol Test Cases leveraging CMW500 protocol testing features and test automation tools

1b

TCU APPLICATION

Testing using CMW500 and Vector CANOE.Car2X system. Simulated environment allows real TCU software to be used with key interfaces (Ethernet, CAN) and protocols (AutoSAR etc.)

1c

E2E APPLICATION

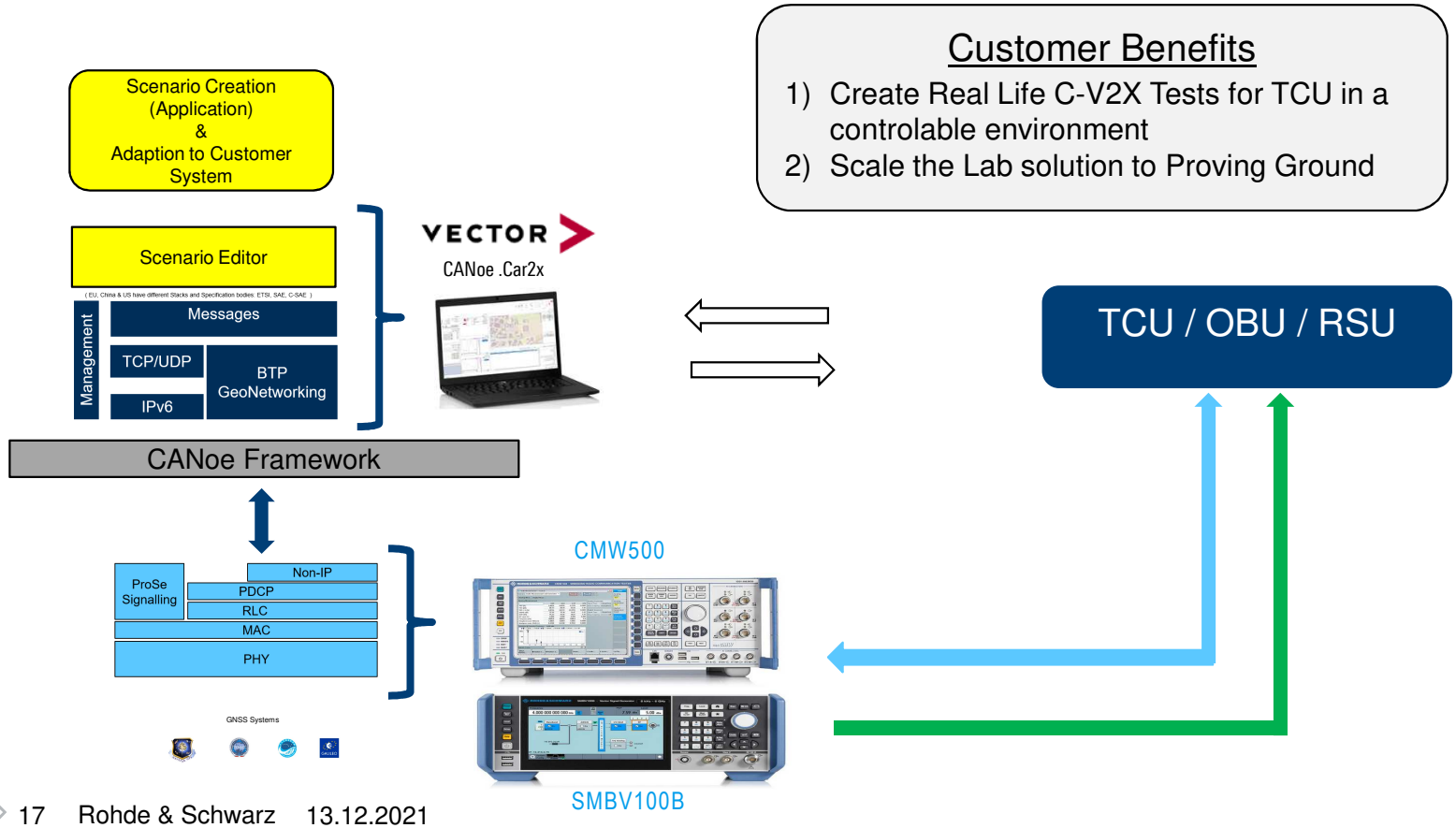
Product Idea

Investigating to extend to proving ground testing: offering a quick transition from lab to proving ground but leveraging your investments

1d

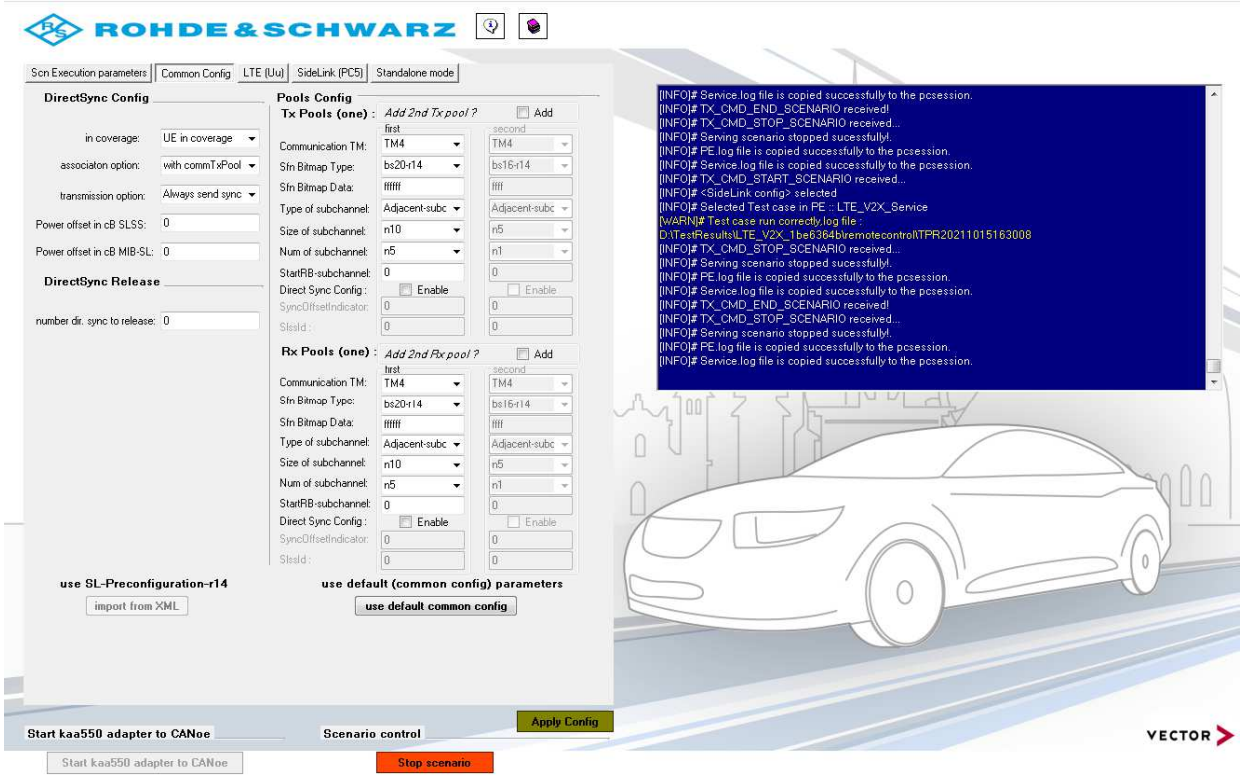
- E2E Application
- TCU Application
- ITS Stack
- 3GPP Stack
- 3GPP PHY

TCU APPLICATION TESTING



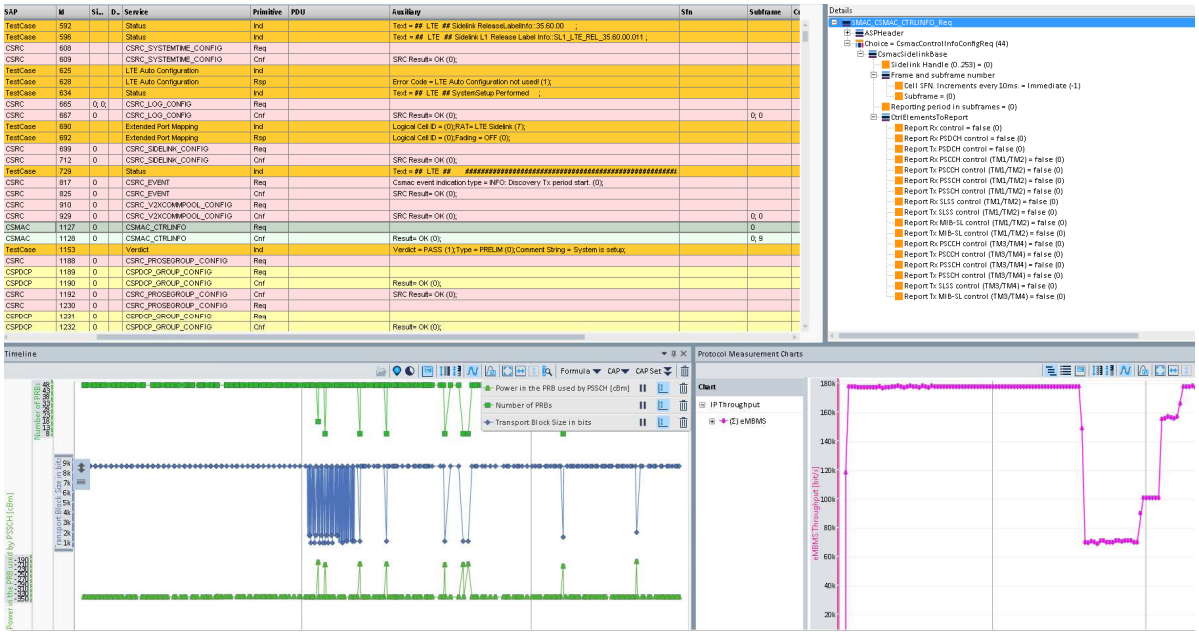
C-V2X SERVING SCENARIO - CMW-KAA550

- Dedicated interface to Vector's CANoe .car2x
- PC5 Interface Configuration
  - Tx/Rx Pool Configuration
  - SL Parametrization
- Offers LTE Cell SIB21 broadcast
- Direct Synchronization Configuration
- Control of the GNSS Simulator



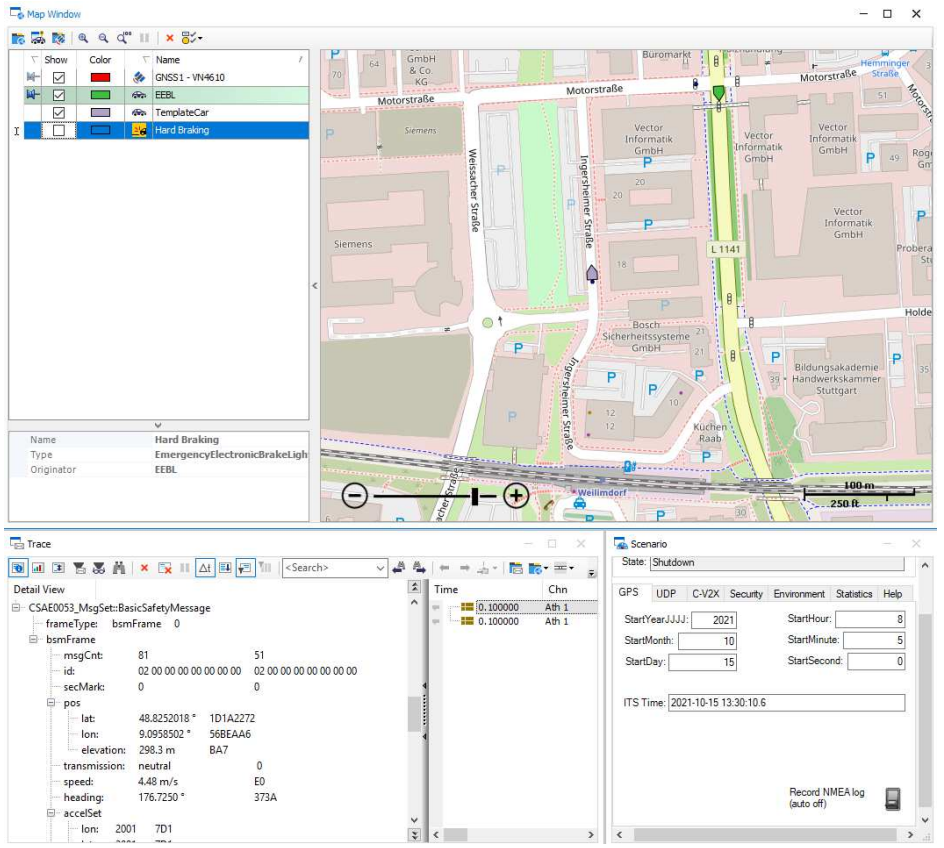
SIDELINK COMMUNICATION ANALYSIS

- Access to the full PC5 stack and corresponding messages
- Pool Configuration check
- Simulated Vehicles load analysis
- Sidelink Power reports
- MCS
- CRC Check
- Transport Block Size
- PRB Allocation



CANOE – ITS APPLICATION TESTING

- Interface to the Serving Scenario running on the CMW
- Scenario editor with simulated route recorded into NMEA format
- ITS Message Set for EU/US/CN
- Fully configurable Message Set on a per node basis
- Access to al message types information elements i.e. negative scenario testing
- Can emulate OBU and RSU
- Pre-defined Sample Scenarios based on the Day 1 scenario list for CN



CANOE – E2E ITS TESTING

ITS SAMPLE SCENARIOS

- AVW – Abnormal Vehicle Warning
- BSW/LCW – Blind Spot and Lane Change Warning
- CLW – Control Loss Warning
- DNPW – Do Not Pass Warning
- EBW – Emergency Break Warning
- EVW – Emergency Vehicle Warning
- FCW – Forward Collision Warning
- GLOSA – Green Light Optimal speed Advisory
- HLW – Hazardous Location Warning
- ICW – Intersection Collision Warning

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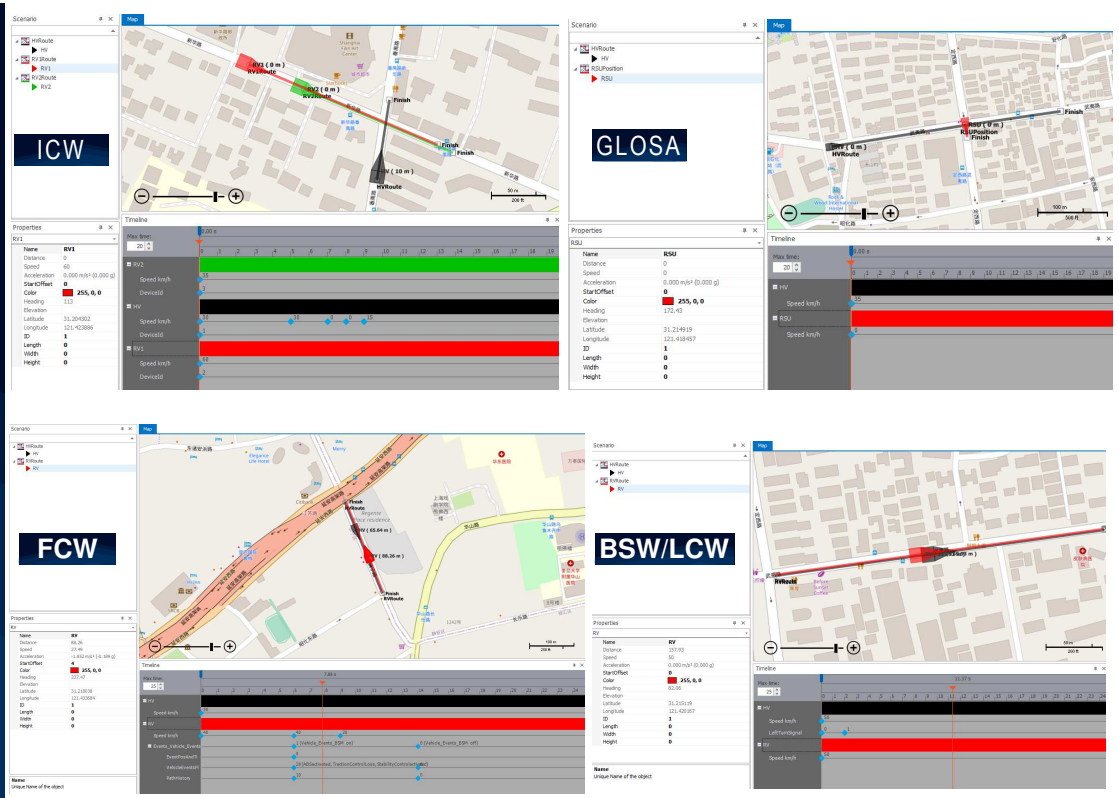

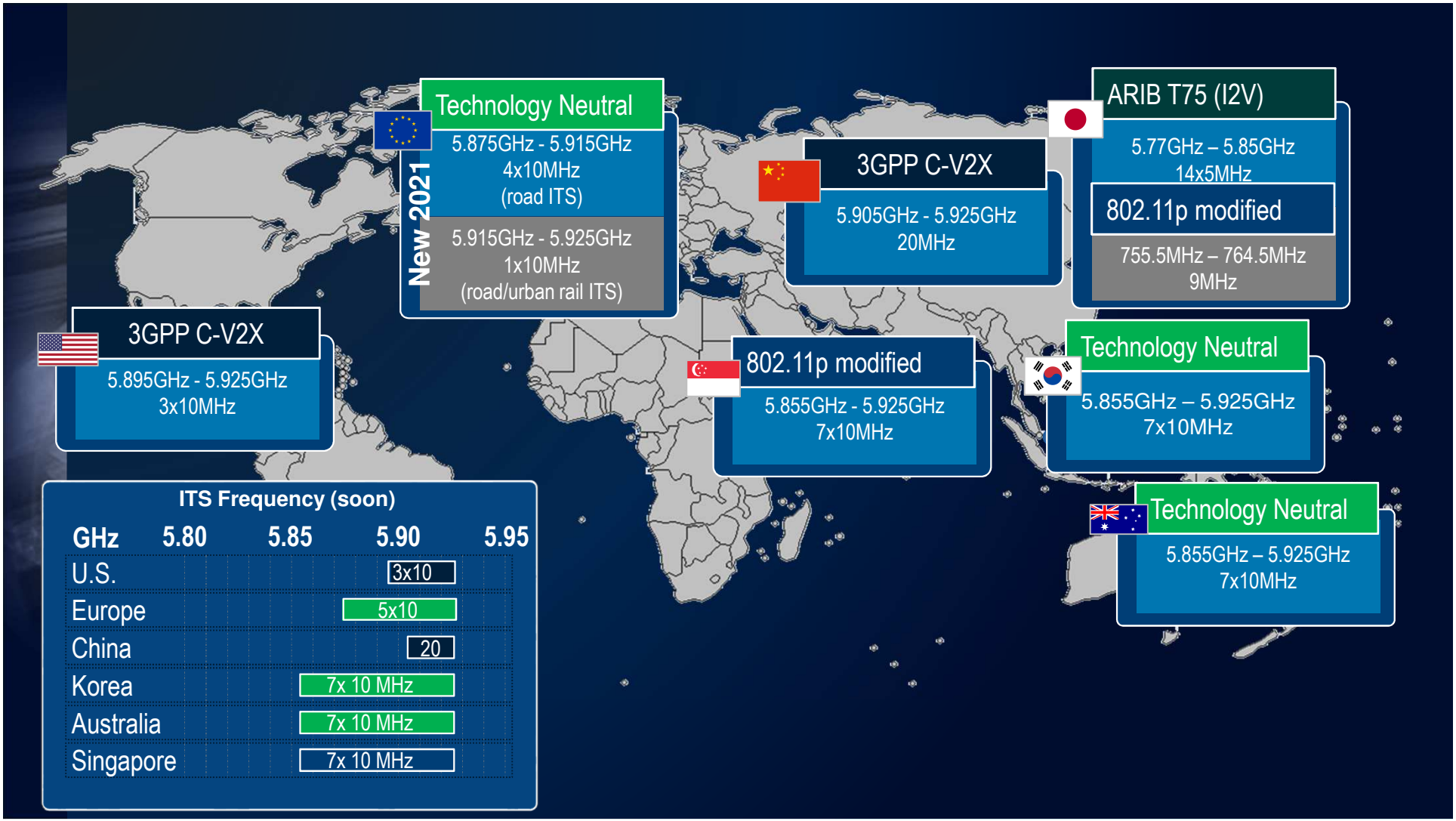
Technology Neutral
New 2021
5.875GHz - 5.915GHz
4x10MHz
(road ITS)
5.915GHz - 5.925GHz
1x10MHz
(road/urban rail ITS)
3GPP C-V2X
5.905GHz - 5.925GHz
20MHz
ARIB T75 (I2V)
5.77GHz – 5.85GHz
14x5MHz
802.11p modified
755.5MHz – 764.5MHz
9MHz
3GPP C-V2X
5.895GHz - 5.925GHz
3x10MHz
802.11p modified
5.855GHz - 5.925GHz
7x10MHz
Technology Neutral
5.855GHz – 5.925GHz
7x10MHz
Technology Neutral
5.855GHz – 5.925GHz
7x10MHz
ITS Frequency (soon)
GHz 5.80 5.85 5.90 5.95
U.S. 3x10
Europe 5x10
China 20
Korea 7x 10 MHz
Australia 7x 10 MHz
Singapore 7x 10 MHz

CONCLUSION

Cellular Vehicle-to-Everything communications (C-V2X) is reality

Testing and conformity assessment are key to achieve interoperability in the multi-vendor market

Enhanced development processes necessary to tap the full C-V2X potential

China is the first market, U.S. follows soon, Europe afterwards

Interoperability provides essential basis for cooperation on our roads

Joint automotive and mobile industry standardization to realize transport safety applications

Visit our webpage:

www.rohde-schwarz.com/V2X

THANK YOU.