



**KEYSIGHT
WORLD 2020**

Overcoming the Challenges of 5G C-V2X Testing and Deployment

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What is C-V2X and Why C-V2X?

Vehicle to Everything (V2X) Communications

ENHANCED SAFETY, ENABLING HIGHER LEVELS OF AUTOMATION

Vehicle-to-infrastructure (V2I)

e.g. traffic signal timing/priority



Vehicle-to-network (V2N)

e.g. real-time traffic / routing, cloud services



Vehicle-to-vehicle (V2V)

e.g. collision avoidance safety systems



Vehicle-to-pedestrian (V2P)

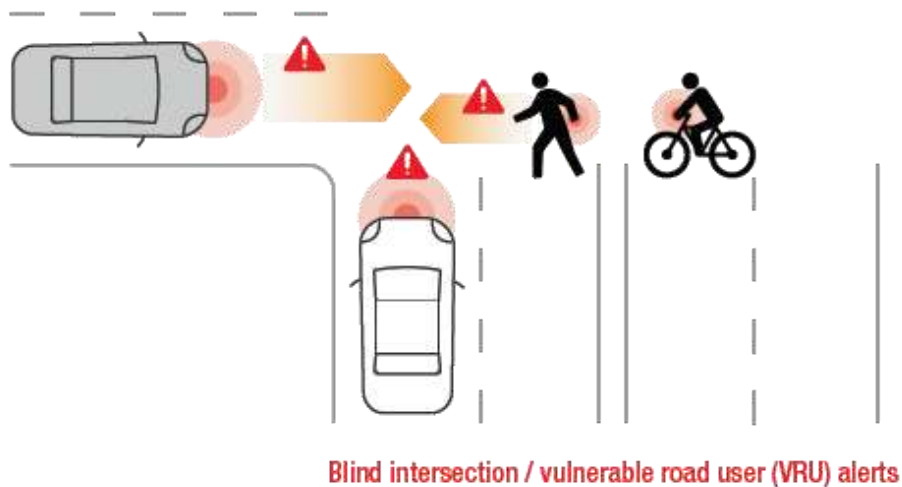
e.g. safety alerts to pedestrians, bicyclists



Critical Capabilities Enabled By V2X

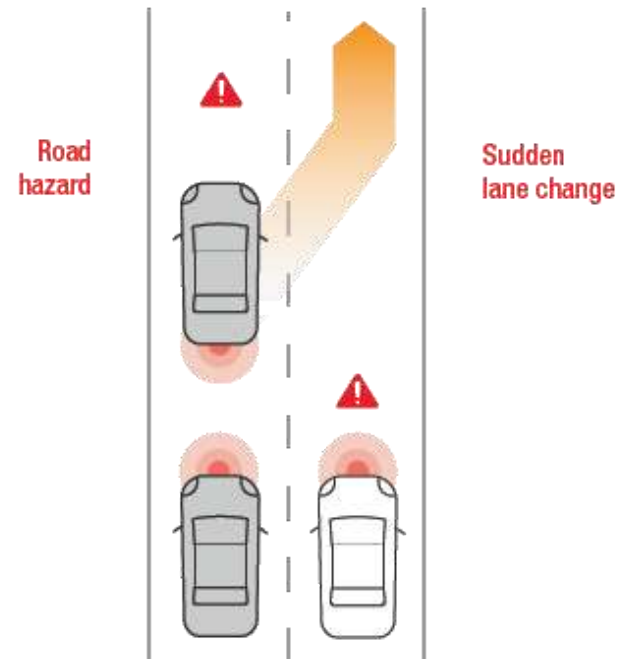
Non Line-of-sight Sensing

Provides 360 NLOS awareness, works at night and in bad weather conditions



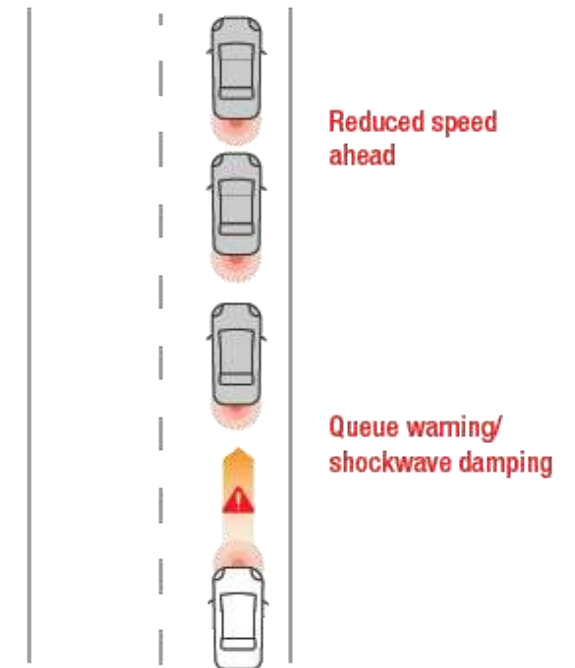
Conveying Intent

Shares intent, sensor data, and path planning info for higher level of predictability



Situational Awareness

Offers increased electronic Horizon to support soft safety Alerts and graduated warning



Enhancing Vehicle Safety & Autonomy

WIRELESS RANGE, PERFORMANCE, LATENCY & SPEED

- **Achieving fewer accidents, greater safety, more time: Vision for connected automated vehicles (CAVs)**
 - *Requirement:* Dependable wireless communication
 - *Attributes:* Superior range, high performance, low latency, high-speed connectivity
- **Enhancing connectivity: “Vehicle to everything” or V2X**
 - *Goal:* Enhanced safety & higher levels of autonomy
 - *Situation:* DSRC & Cellular-V2X technologies vying for dominance
- **Leveraging 5G: C-V2X**
 - *Foundation:* 5G New Radio (5G NR)
 - *Advantages:* Ultra-reliable, low latency, high bandwidth

V2X Technology Comparison – DSRC vs C-V2X

TECHNICAL & PERFORMANCE CHARACTERISTICS

Parameter	DSRC(WAVE)	ITS-G5	C-V2X	
			LTE-V2X	NR-V2X
Standards	IEEE 802.11p IEEE 1609.2/3/4 SAE J2945/1	IEEE 802.11p ETSI specifications (ITS-G5/C-ITS protocol stack)	3GPP releases 14, 15 SAE J3161	3GPP release 16 SAE J3161
Operating Frequency	5.850 – 5.925 GHz (7 channels, 1 guard band)	5.855 – 5.925 GHz (7 channels)	5.855 – 5.925 GHz(PC5) Licensed cellular spectrum for Uu-based V2N connectivity	5.855 – 5.925 GHz(PC5) Licensed cellular spectrum for Uu-based V2N connectivity
Channel Bandwidth	10/20 MHz	10 MHz	10/20 MHz for PC5 1.4 to 20 MHz for Uu	Wider bandwidths of up to 400 MHz, in addition to 10/20 MHz
Synchronization	Asynchronous	Asynchronous	Synchronous	Synchronous
Channel Coding	Convolutional coding	Convolutional coding	Turbo coding	LDPC /Polar coding
Channel Access Mechanism	CSMA/CA	CSMA/CA	Centralized or distributed scheduling – based on sensing with semi-persistent transmission	Centralized or distributed scheduling – based on sensing with semi-persistent transmission
Latency	5 – 20 milliseconds	5 – 20 milliseconds	10 – 20 milliseconds for PC5 20 – 50 milliseconds for Uu	< 1 millisecond for time-critical V2X applications
Consortium	OmniAir	Car 2 Car	5GAA	5GAA

V2X Technology Comparison – DSRC vs C-V2X

C-V2X IS GAINING MOMENTUM

- **Customers are asking consistent questions**
 - Which technology will be the ultimate winner?
 - What are the “politics” behind the technology deliberations in each region?
- We observe the following

V2X Technology Comparison – DSRC vs C-V2X

C-V2X IS GAINING MOMENTUM

- **Customers are asking consistent questions**
 - Which technology will be the ultimate winner?
 - What are the “politics” behind the technology deliberations in each region?
- **We observe the following**
 - **Winner:** C-V2X has momentum & is likely to prevail – especially with the roll out of 5G/R16
 - **Politics:** FCC NPRM support of C-V2X; Europe as opted for coexistence; China decided C-V2X

Testing Must Also Evolve

ORGANIZATIONAL IMPLICATIONS

- **Big picture:** Overlapping cycles of innovation

Stage of Cycle	R14 C-V2X	R15 C-V2X	R16 C-V2X	R17 C-V2X
Development	Done	Minor enhancements	In development	Future...
Conformance & Certification	Being developed	Under consideration	To be determined	To be determined
Deployment	2020/2021*	2020/2021*	2022/2023	2024/2025

* Will be region-dependent

Testing Becomes More Challenging

PAST, PRESENT & FUTURE

- **Issue 1: Designing to standards is a moving target**
 - 3GPP standards for C-V2X (e.g., NR-V2X) are still evolving
 - New capabilities, technologies, frequencies, bandwidths, data rates...
- **Issue 2: CAV use cases becoming more challenging**
 - Complex scenarios, congestion, sensor sharing, interoperability, etc.
 - NR-V2X enables highly advanced scenarios
- **Issue 3: Backwards compatibility is mandatory**
 - Testing new releases will be critical
 - Testing legacy releases will be essential



Moving from LTE-V2X to NR-V2X

What is Cellular-Vehicle to Everything (C-V2X)

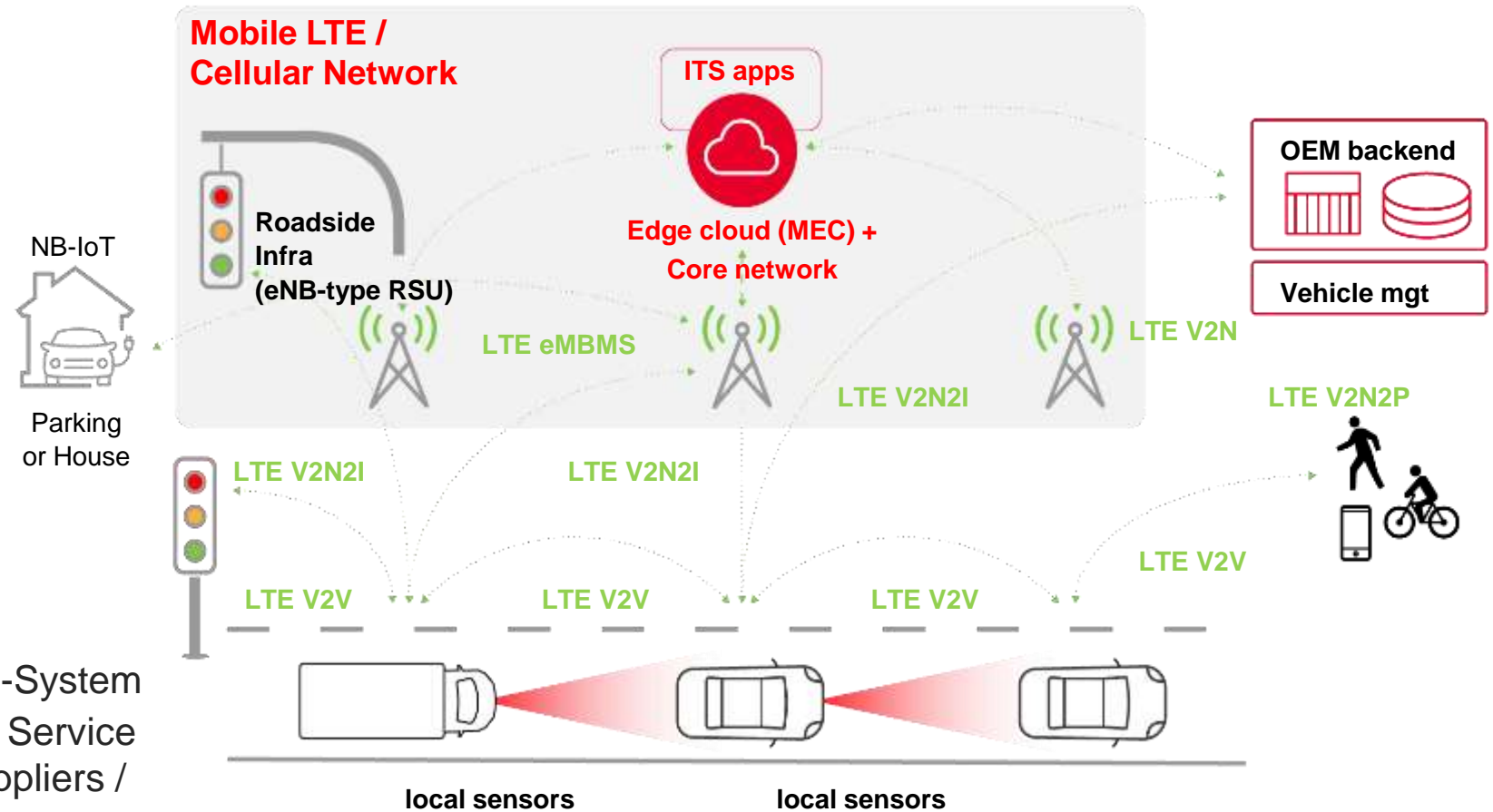
C-V2X OVERVIEW

V2X using Cellular technologies with or without network service

- Band 47 (5.9GHz) for Sidelink Communications (PC5)
- LTE-A 3GPP Rel.14 & 15
- 5G NR 3GPP Rel.16+

Benefits

- Cost Effective
- Evolution to 5G
- Better Security
- Improved Range
- Enhanced Reliability
- VRU Use Cases
- Large and Growing global C-V2X Eco-System
- Cellular Chipset Vendors / Wireless Service Providers / Automotive OEMs & Suppliers / Road Operators



Vehicle to Everything (V2X)

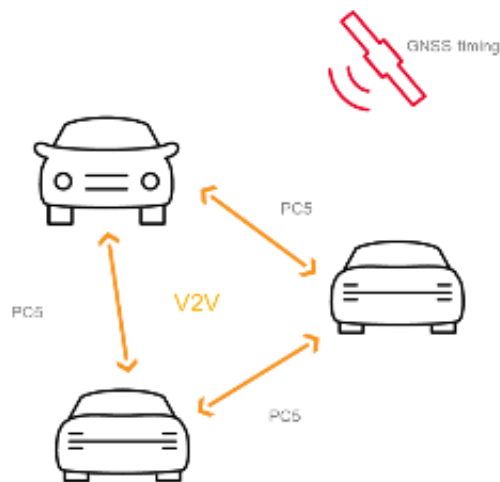
C-V2X, TWO COMPLEMENTARY COMMUNICATION MODES

- Direct

- Lower latency
- PC5 interface without eNodeB
- V2V, V2P, V2I at ITS bands (e.g. 5.9GHz)
- Network independent
- Short range (less than 1 kilometer)

Configuration 1

Dedicated carrier Distributed scheduling

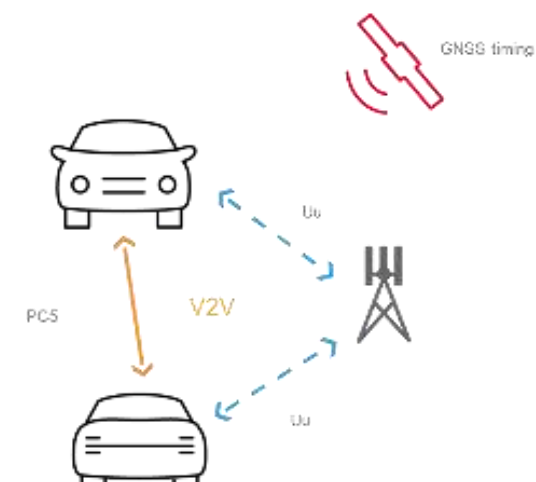


- Network

- Slower latency
- Uu interface with eNodeB
- V2N at the spectrums owned by network service providers
- Network required (e.g. Carrier Aggregation)
- Long range (more than 1 kilometers)

Configuration 2

Dedicated carrier eNB scheduling



Preparing for R16 & Beyond

A NEW CYCLE BEGINS

- **R16: Significantly enhances C-V2X PC5 link**
 - V2V/V2I: 5G NR improves latency & connectivity in sidelink
- ***What to watch out for in...***
 - **Development**
 - R16 specs frozen by July 2020
 - 3GPP working on R17 now, freeze planned for Sept 2021
 - Test requirements & capabilities must evolve with releases
 - *Ex: High-precision location, cooperative maneuvering, platooning, sensor sharing...*
 - **Conformance & certification**
 - Assume conformance testing will be mandatory
 - Use cases will become more complex & more detailed
 - Successful pre-conformance testing will depend on compliant solutions
 - **Interoperability & interference test**
 - Plugfests planned across all regions
 - Mitigation of coexistence interference with adjacent spectrum



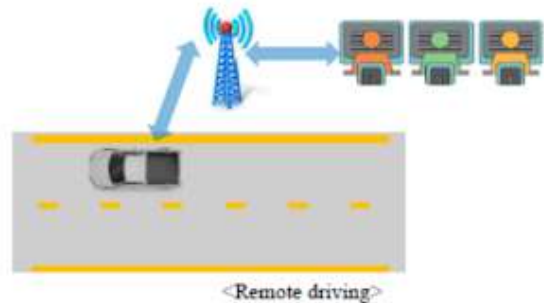
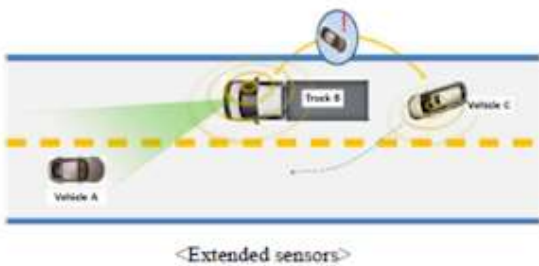
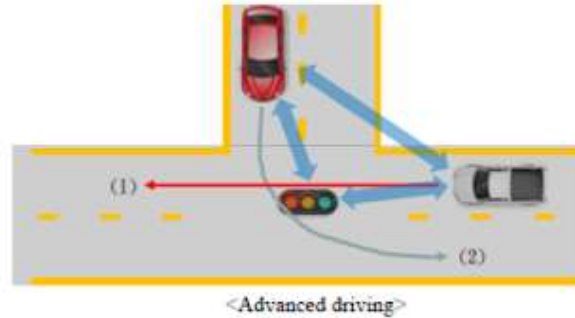
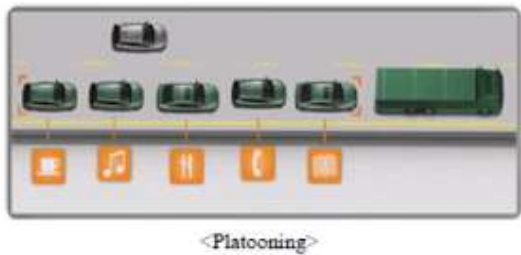
5G Will Change The World Including Automotive...



5G NR-V2X Release 16 (Advanced Safety)

- Leveraging vehicles as moving sensor platforms (Bandwidth)
- With 5G comes Enhanced Security

- SA1 study was completed with TR 22.886 and normative WI is approved in [1].
- Four categories of eV2X use cases



Source: ITRI

NR-V2X requirements for **autonomous driving** (SA1 TS22.186)

Use Cases	E2E latency (ms)	Reliability (%)	Data rate (Mbps)
Vehicle Platooning	10	99.99	65
Advanced Driving	3	99.999	53
Extended Sensors	3	99.999	1000
Remote Driving	5	99.999	UL:25, DL:1
	Lateral (m)	Longitudinal (m)	
Positioning Accuracy	0.1	0.5	

Note: 5GAA may adjust the above requirements according to inputs from car OEMs.

Source: 5GAA

C-V2X Challenges To Be Overcome



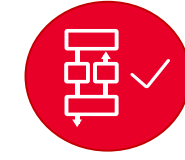
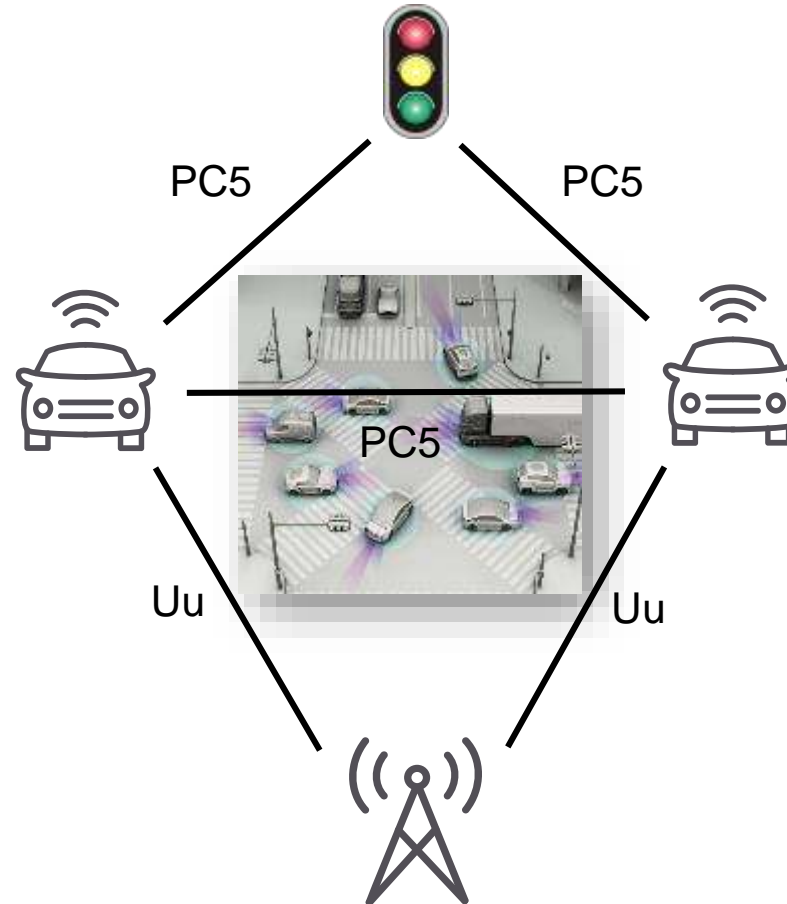
Ensure Performance Meets Safety Requirement

Ensure products meet performance specs (ETSI, 3GPP, SAE)



Interference Mitigation

Interference will be a critical factor to overcome as the spectrum between 2-6 GHz is extremely crowded and since V2X is a safety oriented system this is even more important to be tested.



Conformance to Global and Regional Standards

EU, North America, China and Japan all have different standards to adhere to. Conformance to these specs will be compulsory and therefore there is a need for test eqt and Test Labs to offer this service.



Interoperability

Multiple vendors developing V2X modules (C-V2X or DSRC) need to interoperate with each other and is a critical test that needs to be carried out.

Industry organisations (e.g. 5GAA) and standard bodies (e.g. 3GPP, ETSI) are addressing more challenges and developing solutions

Vehicle to Everything (V2X)

C-V2X REQUIRED MEASUREMENTS

- Test Cases

- Latency
- Reliability (PER)
- Interference and Co-existence
- Range (Sensitivity)
- Congestion Control
- Maximum Relative Vehicle Speeds
- Dynamic Channel Impairments

- Data Throughput
- GNSS Accuracy
- Interoperability
- Security
- Antenna Performance
- Certification
- More



- Solutions

- End-to-End RF, protocol, functional, and ITS stack tests
- GNSS Emulation for time and location synchronization
- Emulation and verification

C-V2X Signaling solution Overview

Keysight in 5GAA



ACTIVE PARTICIPATION IN THE STANDARDS



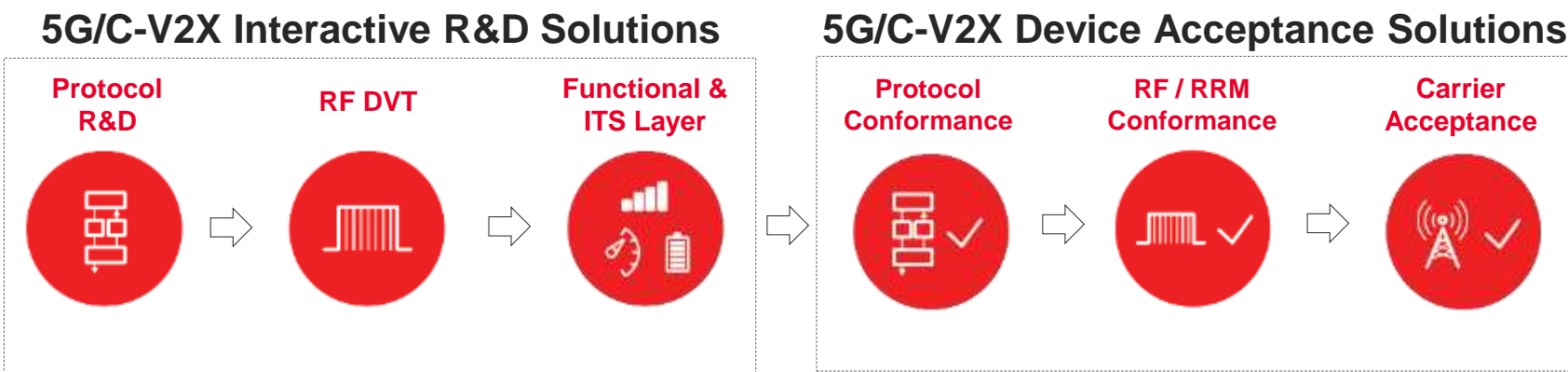
19/12/2019

**ETSI-5GAA C-V2X testing event in Europe
confirms high level of interoperability**

Keysight 5G & C-V2X Emulation Solutions

SUPPORTING OUR CUSTOMERS WORKFLOW

Keysight 1st
Solutions
across the entire
device R&D
workflow



UXM 5G Wireless Test Platform

SA8700A C-V2X Test Solutions

PAVES THE WAY FOR CONNECTED CARS

- **RF, Protocol, Message & Application Layer test**
 - Covers both interfaces:
 - User-to-UTRAN (Uu)
 - Direct Communication PHY sidelink (PC5)
 - **ITS Stack and Application Layer Test**
 - Offline scenario creation (Nordsys waveBEECreator)
 - Execute scenario (NordsysITS stack + Keysight)
 - **Congestion Scenario Test**
- Accelerates deployment of advanced safety features
- Includes GNSS emulator



C-V2X X-application
Sig Gen and X-series meas.



C-V2X Test Application
UXM 5G Wireless Test Platform



GNSS
MXG RF vector signal generator



5G NR Ready



Rel 14 C-V2X

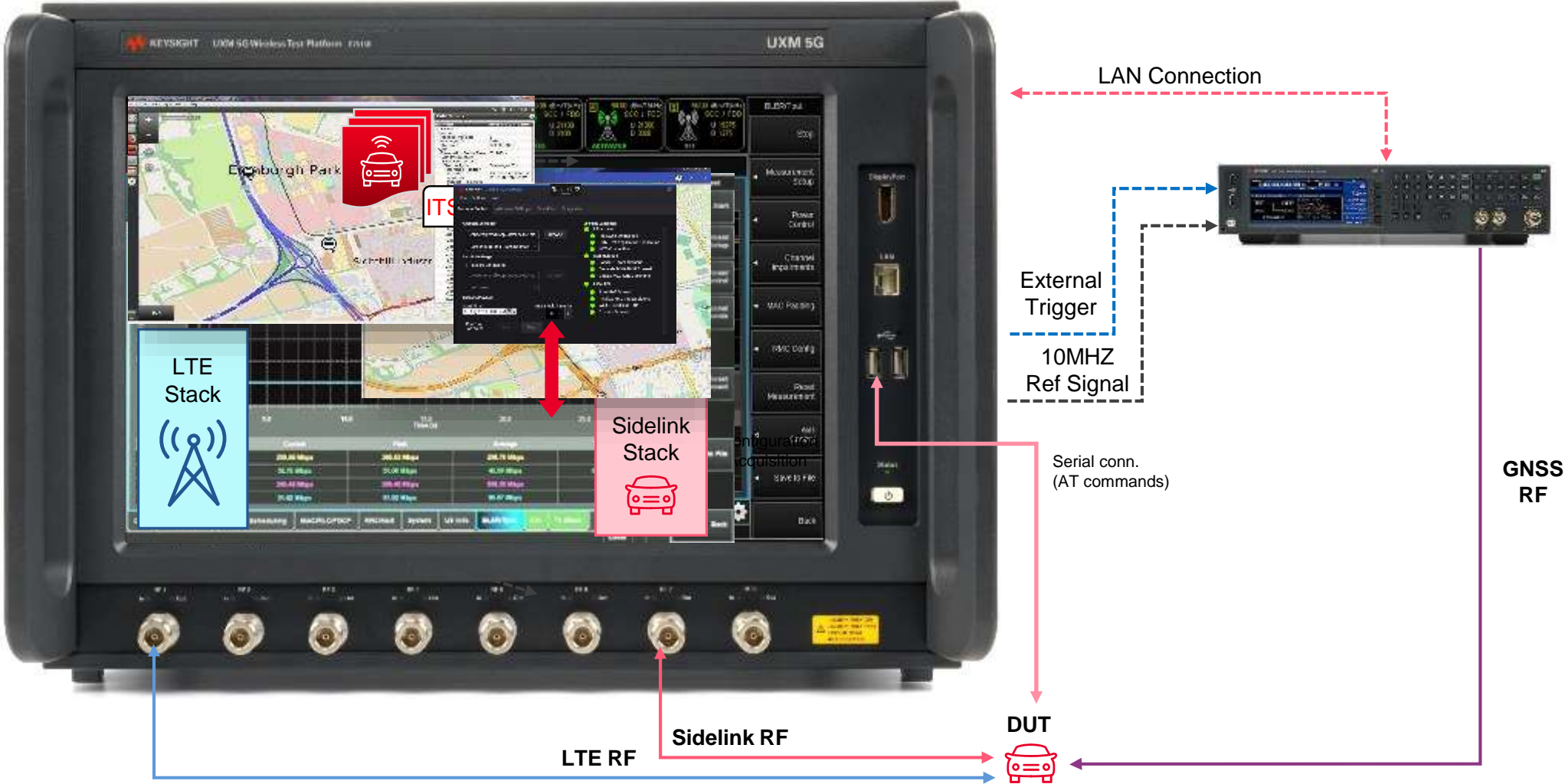


GNSS Emulation



Keysight C-V2X ITS Applications

SOLUTION OVERVIEW



1st to Achieve 3GPP C-V2X RF Conformance TC Validation

[HTTPS://ABOUT.KEYSIGHT.COM/EN/NEWSROOM/PR/2019/21NOV-NR19142.SHTML](https://about.keysight.com/en/newsroom/pr/2019/21nov-nr19142.shtml)



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Keysight First to Achieve 3GPP C-V2X Radio Frequency Conformance Test Case Validation

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Keysight solutions enable the automotive industry to accelerate commercialization of connected cars and autonomous vehicles

SANTA ROSA, Calif., November 21, 2019

Keysight Technologies, Inc. (NYSE: KEYS), a leading technology company that helps enterprises, service providers and governments accelerate innovation to connect and secure the world, announced that the company achieved 3rd Generation Partnership Project (3GPP) validation of the industry's first cellular vehicle-to-everything communications (C-V2X) radio frequency (RF) conformance test case. As a result, Keysight is enabling the automotive industry to accelerate commercialization of connected cars and autonomous vehicles.

Performance validation of C-V2X is crucial for C-V2X certification and commercialization. 3GPP validation of Keysight's conformance test case enables the C-V2X connected ecosystem to achieve performance compliance with the specifications of the 3GPP standards, both for Release 14 and 5G new radio (NR) Release 16. The test case

GCF C-V2X Status

Feb 2020: First protocol C-V2X Validation

April 2020: More validations done for C-V2X

- Keysight is the only one with both protocol and RF C-V2X test cases validated.
- Keysight is exclusive in RF C-V2X test cases validations.
- In the protocol space, we are equivalent to other test platform.

WI	Description
WI-281-47	Vehicle to Vehicle (V2V) for E-UTRAN Rel-14
WI-282-47	Vehicle to Everything (V2X) for E-UTRAN Rel-14

Keysight C-V2X ITS Applications

NORDSYS AND KEYSIGHT SOFTWARE COMPONENTS



Real World



Generate real V2X messages
of scenarios in-field
waveBEE®creator



Live V2X traffic analysis
in the lab
waveBEE®touch



Reduce costs by
simulating multiple car
and ITS station at once.

Offline scenario creation

(Nordsys waveBEEcreator)

- Easy-to-access and quick visual scenario creation via touch-gestures
- All types of V2X messages supported (traffic and infrastructure)
- Supports US, EU standards (China coming soon)
- Multiple entities (cars, traffic lights, etc.) and events in a single scenario
- Easy integration of DUT into scenario
- No need for auxiliary car system modulation (e.g. CAN-bus)

Execute scenario

(NordsysITS stack + Keysight)

- Live-simulation and generation of V2X-messages
- Real, secured V2X-communication for realistic scenarios
- Network and physical layer uses UXM5G
- Congestion generation of up to 500 vehicles

Analyze Scenarios

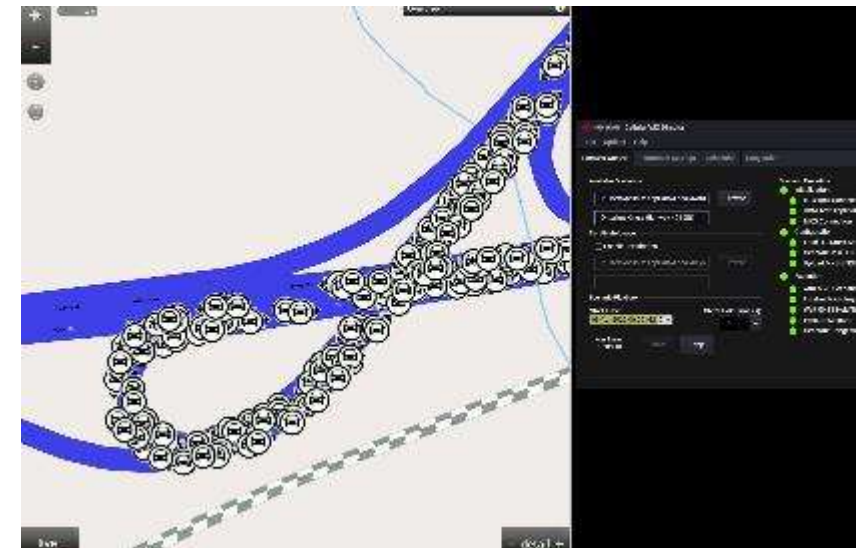
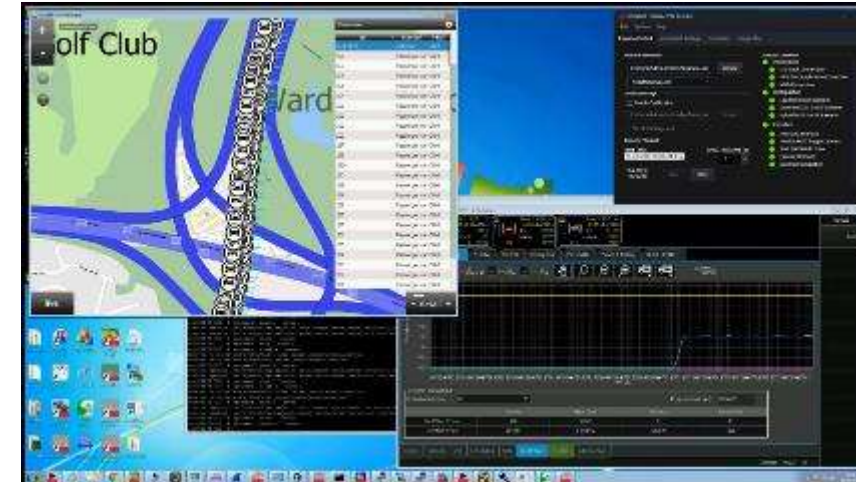
(Nordsys waveBEETouch)

- Real-Time visual scenario view
- Human-Readable message information (path history, lane information, signal phases, vehicle dimensions, etc)
- Record and replay function for in-depth analysis
- Detailed message dissection of raw and interpreted values
- Customizable filters for multi-level message analysis

Congestion Testing

STRESS TEST TO VERIFY PERFORMANCE GOALS

- **Stress test in lab to ensure devices work as designed**
 - *Verify application-layer behavior of devices*
- **Accurately & repeatably test use cases with varying levels of congestion** (e.g., EEBL, FCW)
 - *Repeatably test under different congestion conditions (e.g., # stations, varying distances between stations & more)*
 - *Vary “shapes” of congestion stations (e.g., linear, circular)*
 - *Modify directions of stations during tests*
- **Vary output power & periodicity based on number of stations enabled during tests**
 - *Simulate “near real-world” conditions in lab or test house*



Demo

SA8700A C-V2X Test Solution

Keysight C-V2X Test Solution Portfolio

SAME X-APPS ACROSS HARDWARE PLATFORM

End-to-End Signaling Test

UXM5G + MXG & N7609C Signal Studio for GNSS



Non-Signaling PHY layer Test

N9080EM4E LTE C-V2X Mod Analysis on X-Analyzers (w/ Multi-Touch GUI)



N7626C Signal Studio for V2X on X-Series Sources



E6640A EXM Wireless Test Set
LTE C-V2X X-App as the product number of:
V9080EM4E LTE V2X Measurement Application
Y9080EM4E LTE V2X Measurement and
Waveform Application





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