KEYSIGHT WORLD2018

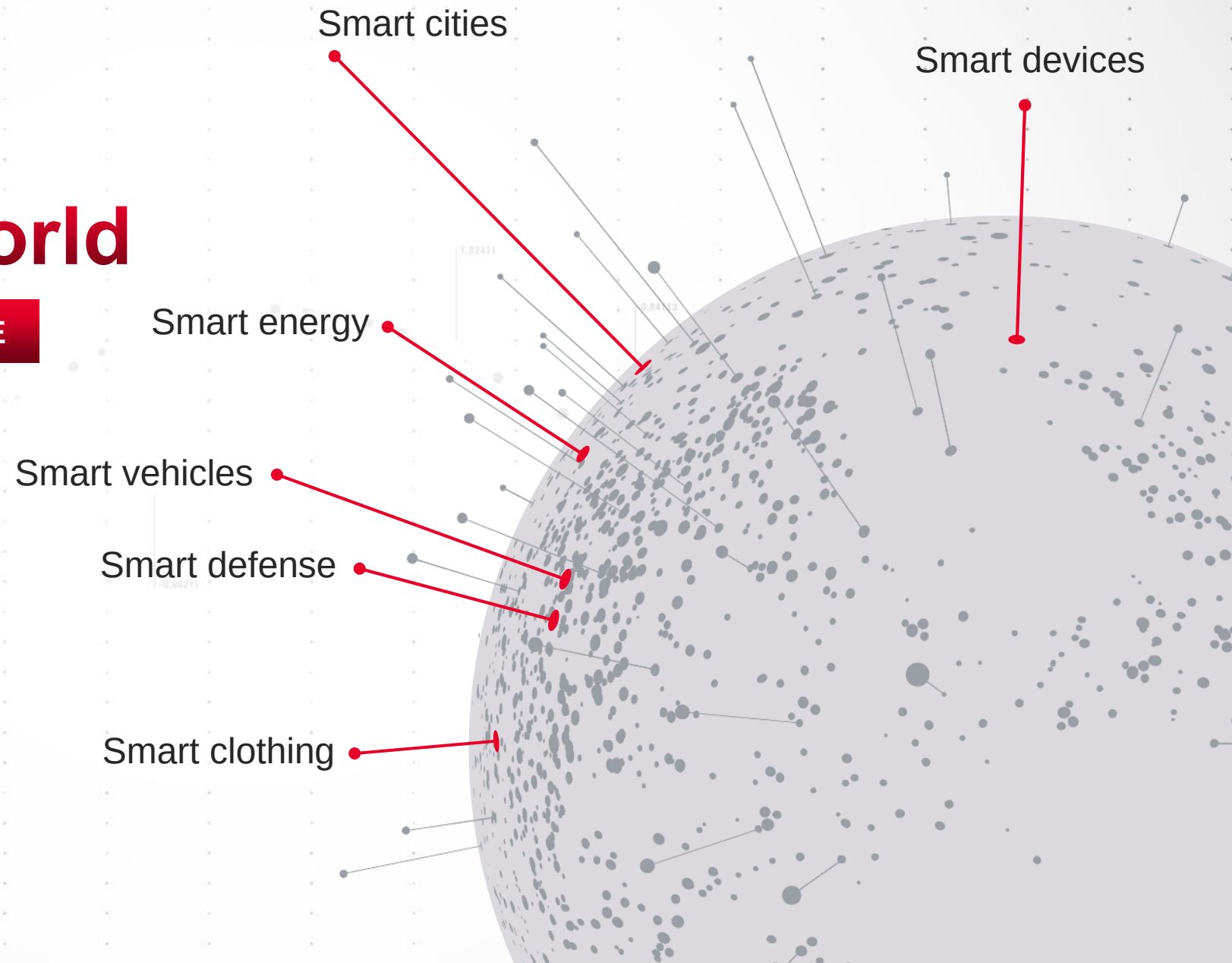
V2X Design and Test Solutions for the Connected Car

Solution Marketing Engineer / Keysight Technologies

Seung-Taek Chang

Technology Connects the World

INNOVATION IS EVERYWHERE



KEYSIGHT TECHNOLOGIES

Technology Requirements Keep Advancing

MORE SPEED, LESS POWER, PERFECT ACCURACY

NETWORKS/CLOUD

- More Data
- More Security
- More Protocols

COMMUNICATIONS

- Faster Speeds
- More Connections
- More Bandwidth

DEVICES

- Denser Boards
- More Features
- Longer Lasting

IoT

- Connected Car
- Connected Grids
- Connected YOU

Our Expectations Are Growing: The Car Industry

LAST 220+ YEARS (1770 – 1997)

Cugnot – Steam Powered

1770

Benz – Combustion

1885

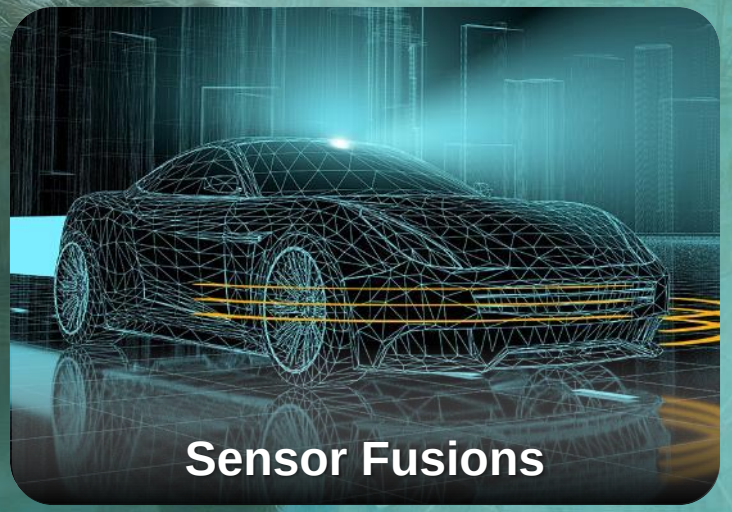
Toyota – Hybrid Electric

1997

Progress was electromechanical in the first **220+ Years**

Pace of Innovation is Accelerating

LAST 20+ YEARS



2004 → 2016 → 2020+

Innovation has completely **revolutionized** the industry

Technology Requirements Keep Advancing

MORE ELECTRONICS, MORE EFFICIENCY, MORE SENSORS

Electronics

- Better diagnostics
- Automotive Ethernet
- Infotainment

Batteries

- Longer range
- Higher densities
- More eco-friendly

Connectivity

- More information
- Better safety
- Easier navigation

Sensors

- Electro-mechanical
- Driver vision
- More autonomy

Evolution of Sensors in Vehicles

Mechanical Designs Starting in 1976

- Basic electronics
- Mostly mechanical
- No connectivity

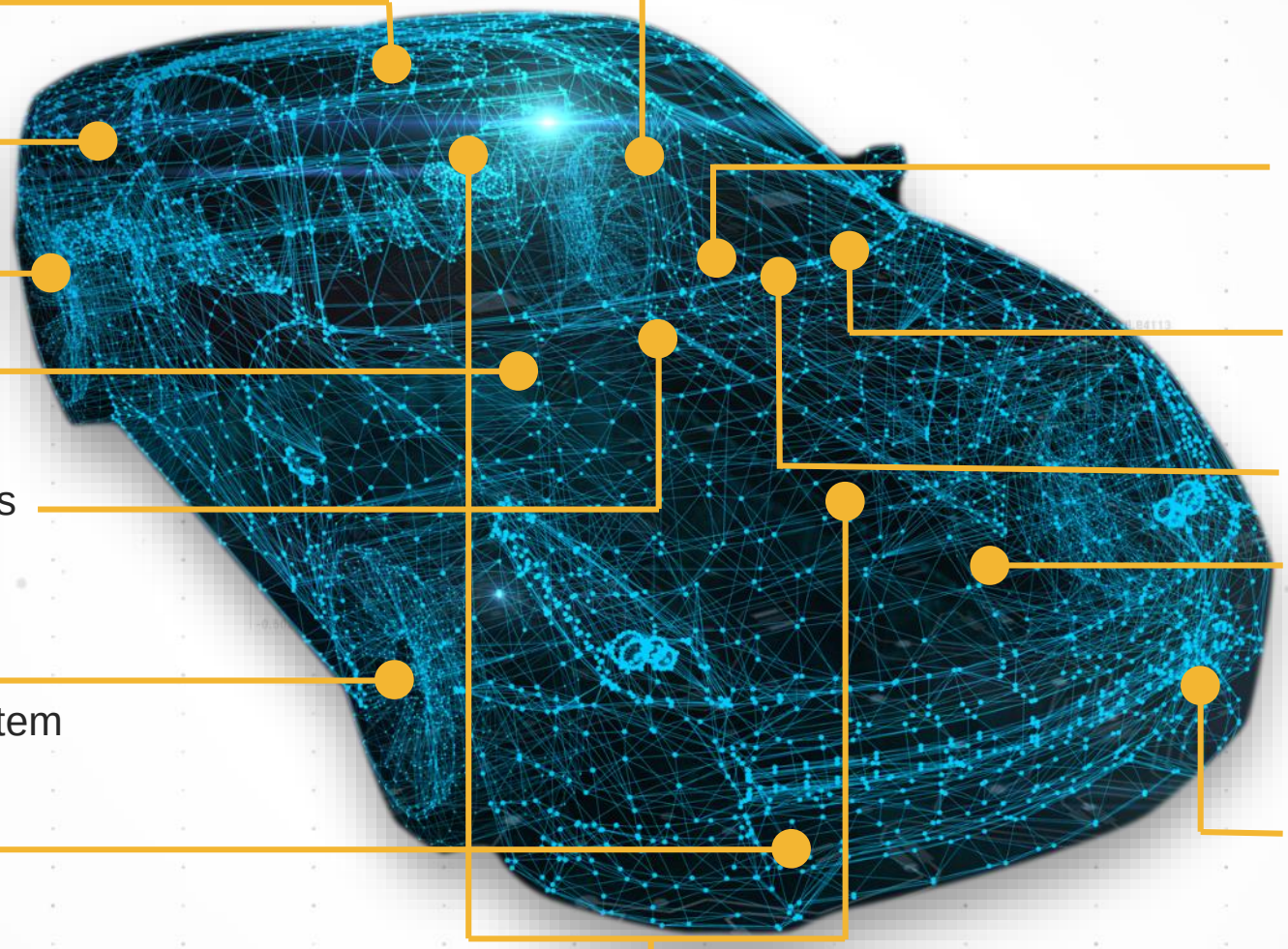
Assisted Driving Starting in 1997

- Electronic safety systems
- Integrated electronics
- Electric control units
- Infotainment

Autonomous Coming Next

- Sensor fusions
- Autonomous processing
- Auto-charging technologies
- Multi-connectivity

Innovations Through Multiple Technology Domains



V2X (V2V/V2I/V2P/V2N)

Radar Collision Avoidance

Electronic Stability Control Module

Climate Control System

Infotainment/Navigation Modules (DVD, eCalls, Hands Free Telephony, GPS)

Anti brake Locking system
Tire Pressure Monitoring system

Emission Control Module

Power Steering Control
Rear-view camera
Backup sensors
Power Seat Control

Personnel Occupancy Detection Systems (PODS) for Air Bag systems

Remote Keyless Entry

Instrument Clusters

Fuel Injection Module
Power Train &
Engine Management
(MiL, SiL, HiL)

Adaptive Lightning Control

Hybrid Electric Vehicle
(HEV) / Electric Vehicle (EV)

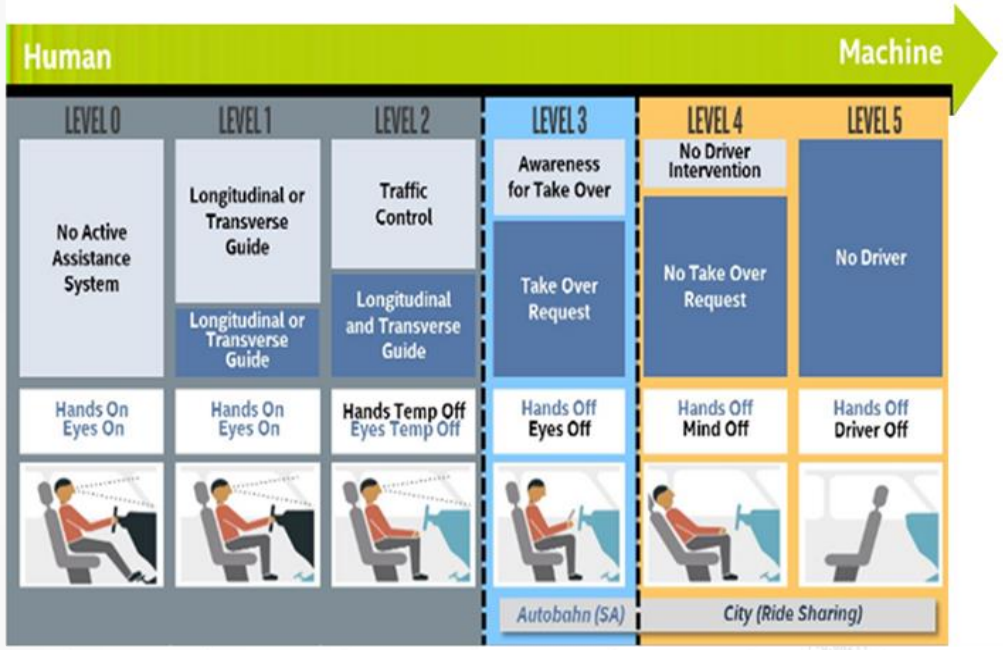
Autonomous Driving

BENEFITS

- Safer world with 90% fewer car accidents
- More productive life from less traffic congestion and driving time
- Better energy efficient transportation and environmental benefits
- More efficient car-sharing and car-utility
- Better urban land utilization
- More innovations, investments and newer business models
- And, more

Autonomous Driving

STATE OF THE INDUSTRY: AUTONOMOUS DRIVING WILL HAPPEN SOONER THAN EXPECTED



	L0	L1	L2	L3	L4 / L5
Radar	N/A	0-3	0-5	3-6	6-20
Cameras	N/A	0-1	3-5	3-6	3-6
Ultrasonic	N/A	4-8	8-12	radar	radar
Secure V2X	No	No	Some	Yes	Yes

- ADAS & Autonomous driving will need multiple sensors, high power computing and artificial intelligence : OEMs, suppliers, non-traditional automotive players (e.g. wireless, data, semiconductor, car-sharing), invest heavily
- Infrastructure will be established to support real-time information flow
- Several projects are executed all over the world, e.g. China, Korea, USA/California, Germany, Singapore, etc. in order to develop and test in controlled and save environment.
- Fully autonomous cars are only a few years away. Technological, regulatory, and consumer adoption hurdles still remain, but progress is being made

V2X – Enhanced Safety, Enabling Higher Levels of Automation

Forward Collision Warning

Motorist Advisories and Warnings

Red Light Violation Warning

Connection Protection

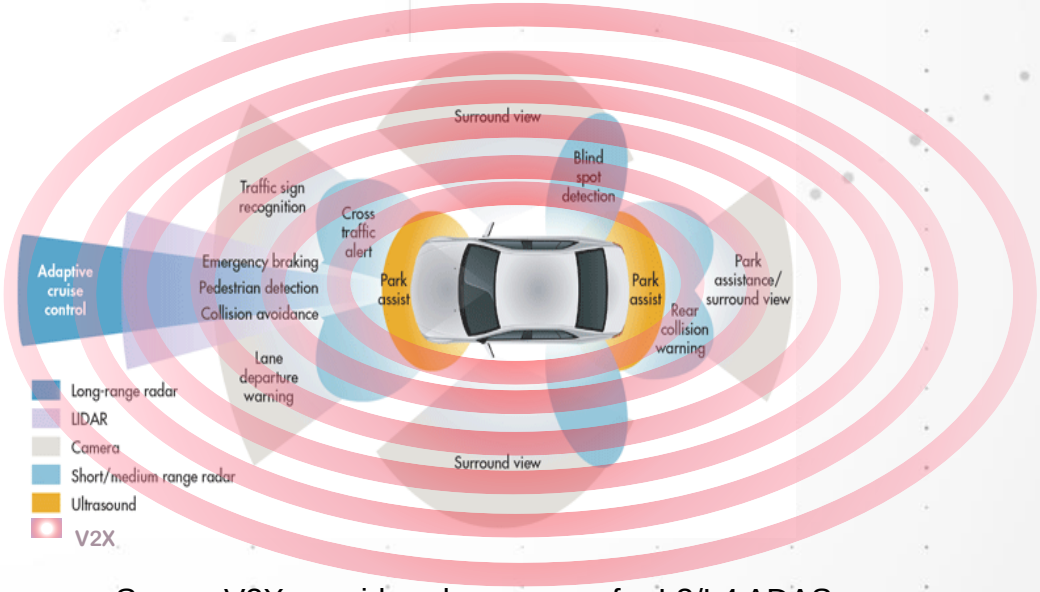
Eco-Traffic Signal Timing

V2V, V2I, V2P, V2N …

Technology to enhance driving experience, prevent accidents and collisions, assist traffic flow, enable higher levels of automated driving.

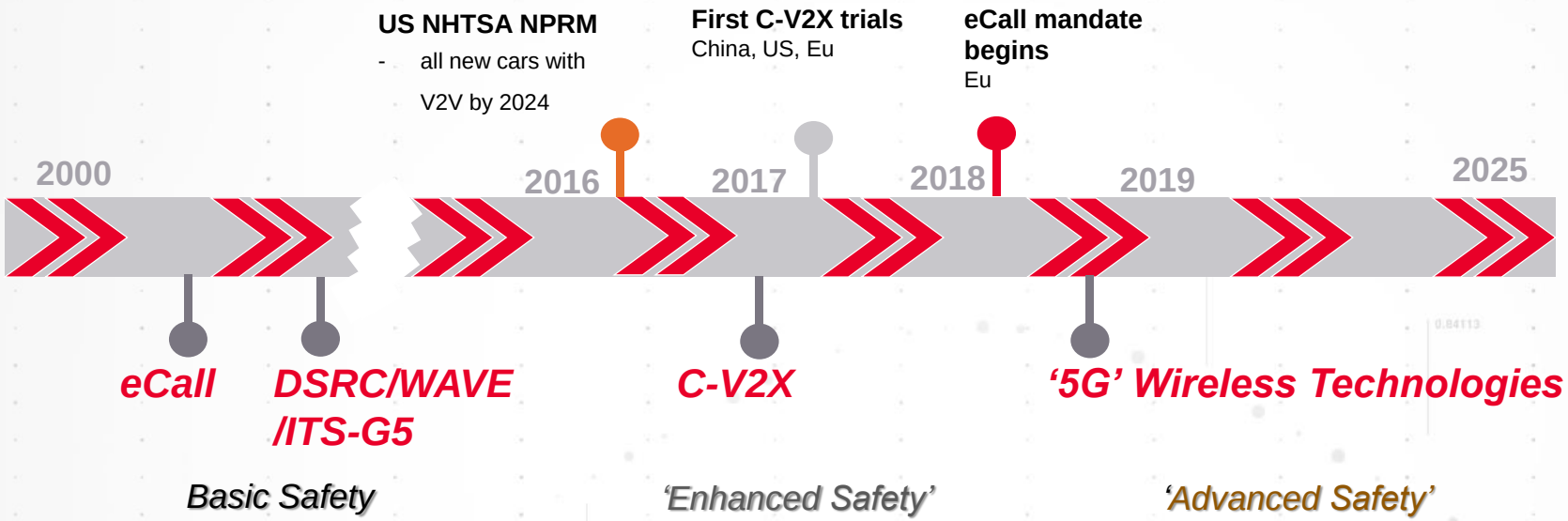
2 wireless technologies are currently being proposed -

- ❑ DSRC (based on IEEE 802.11p)
- ❑ C-V2X (based on 3GPP Rel-14 LTE-A Pro)



Secure V2X considered necessary for L3/L4 ADAS

V2X Technologies: Evolution

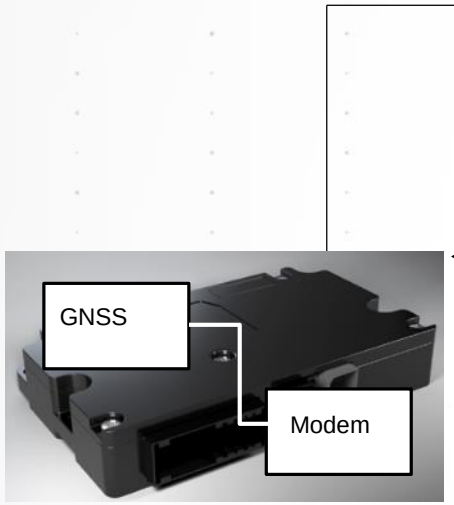


- DSRC - IEEE802.11p based
  - Based on 802.11a:
    - robust performance for short packets.
  - Products ready with actual deployments, extensive interop tests and field trials.(DOT/NHTSA)
  - Adopted or being considered by some regions.

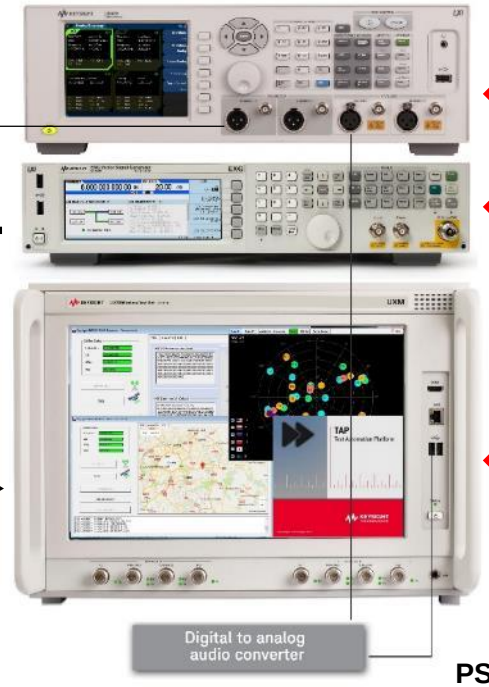
- C-V2X – 3GPP LTE-based
  - Reuses LTE UL frame structure (Rel 14): require tight freq. & time sync.
  - Longer symbol and GI durations
  - Leveraging more recent PHY technologies: e.g. more advanced coding.
    - Improved air interface : Uplink: SC-FDM. Downlink: OFDM
    - Multi-antenna technology : Diversity, MIMO, Beam-forming
    - High spectrum flexibility : Flexible BW, FDD and TDD, new and existing bands
  - Still on going extensive field trials/testing.(more and more coming)
  - Qualcomm, Huawei and 5GAA are promoting heavily.

Keysight E6950A eCall Conformance Test System

VERIFY IVS MODULE FUNCTIONALITY



IVS Module



U8903B Audio Analyzer – PESQ/POLQA Test

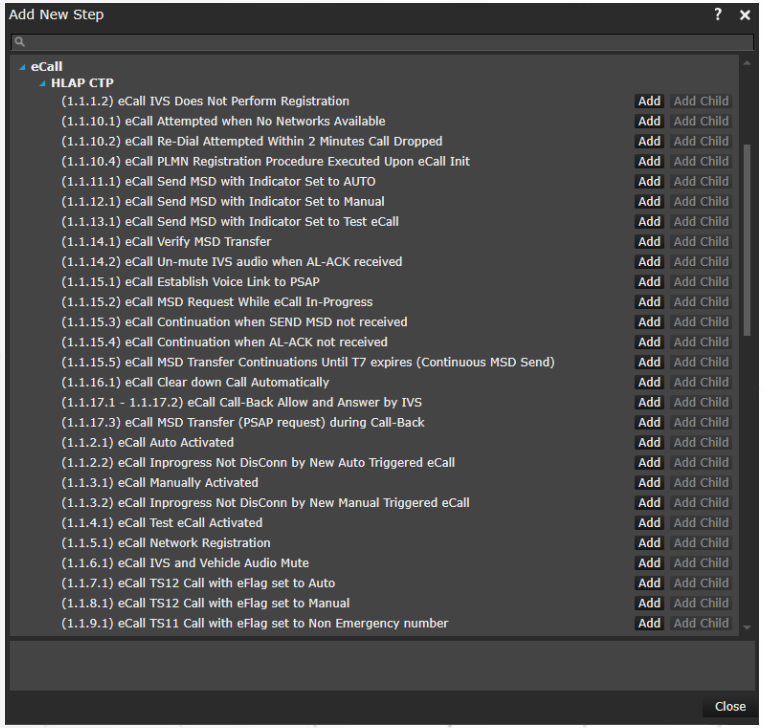
N5172B EXG GNSS Emulator

E7515A UXM Cellular Base Station Emulator

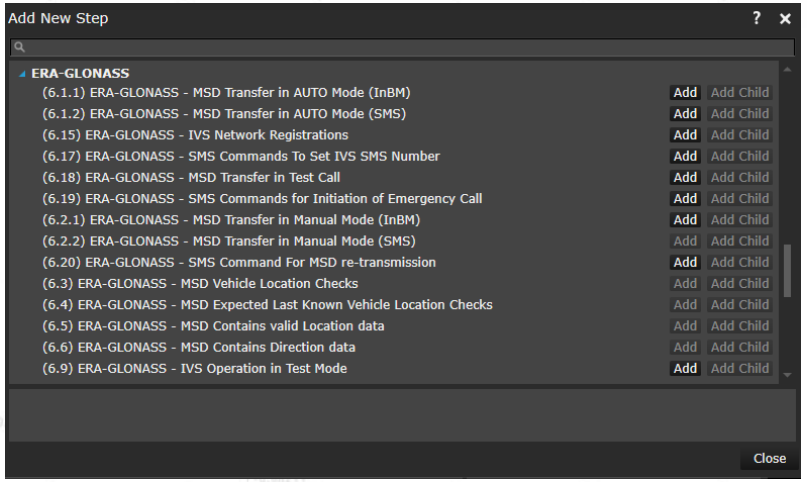
PSAP software running inside UXM (optionally on separate PC when using 8960)

eCall/ERA-GLONASS Automated Test

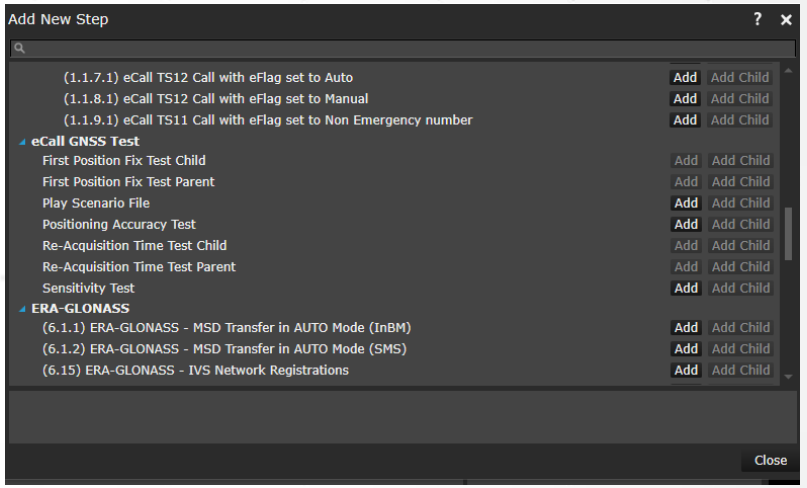
TAP AUTOMATION



eCall Test Cases
ETSI_TS 103 412



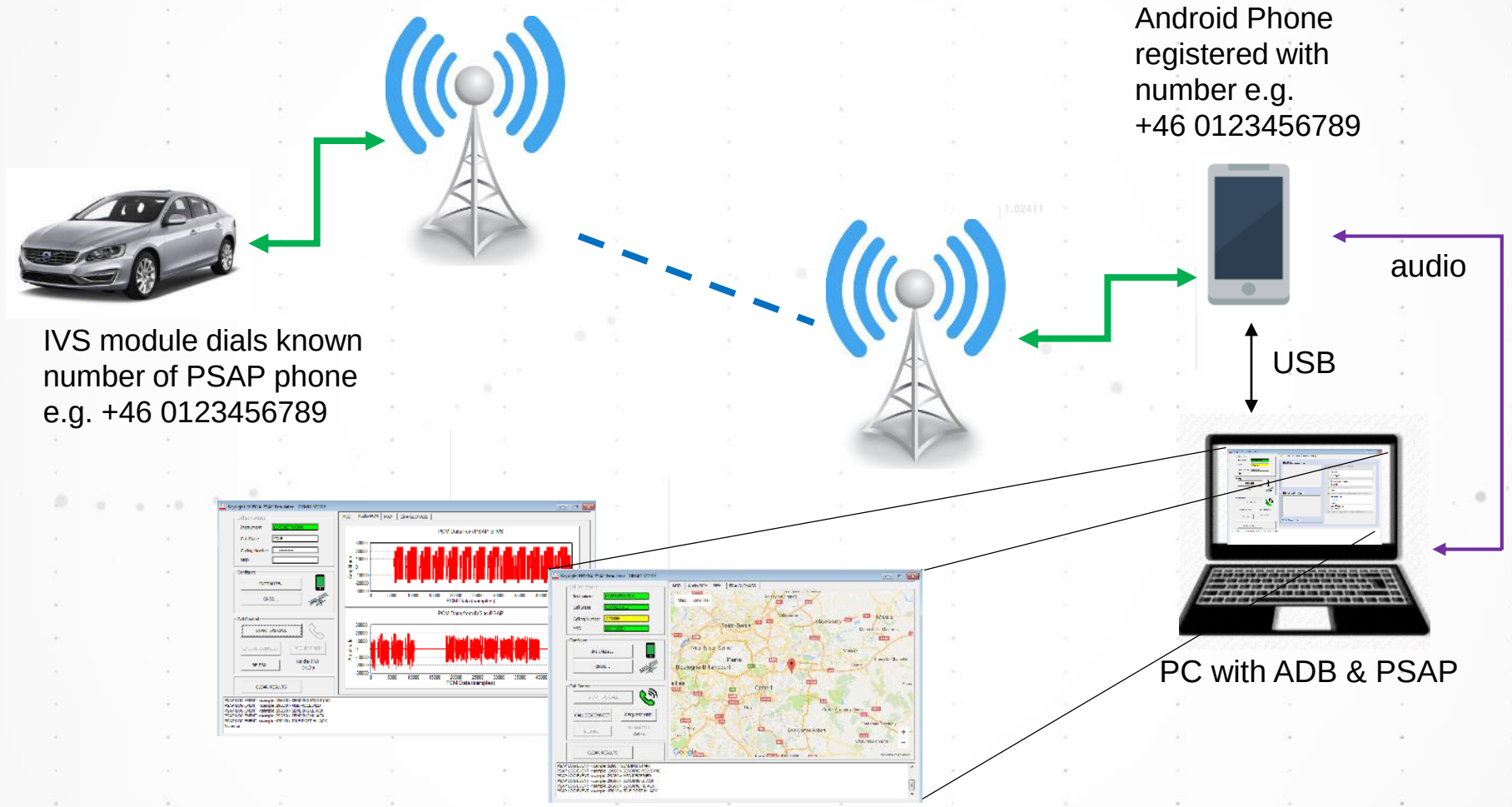
ERA-GLONASS Test Cases
GOST R 33467 ➔ (was R-55530)



eCall scenarios for GNSS testing (**ANNEX VI** of **EU 2017/79** regulation)

- 2.2.2. Assessment of positioning accuracy in autonomous static mode (static).
- 2.2.3. Assessment of positioning accuracy in autonomous dynamic mode (dynamic).
- 2.2.4. Movement in shadow areas, areas of intermittent reception of navigation signals and urban canyons (dynamic).
- 2.2.5. Cold Start time to first fix test (static)
- 2.2.6. Test of re-acquisition time of tracking signals after block out of 60 seconds (static)
- 2.2.7. Test of GNSS receiver sensitivity in cold start mode, tracking mode, and re-acquisition scenario (static).

eCall Live Network Test - PSAP and Android Phone



Test Challenges and Requirement for V2X (DSRC)

Wireless Communications System Lifecycle

WHERE DOES TESTING/MEASUREMENT CONTRIBUTE ?

- Simulation
- Channel Sounding & Modelling
- RF & modulation testing
- Channel Performance testing
- Base Station/ Network Emulation
- Congestion & Load testing
- Pilots/Trials
- Certification
  - Radio Conformance
  - Protocol Conformance
  - Interoperability
- Device Manufacturing Test & Calibration
- Infrastructure Coverage Planning
- Drive Test
- Virtual Drive Test

The Bottleneck and Test Gap of This Industry

KEY CHALLENGES OF V2X TESTING

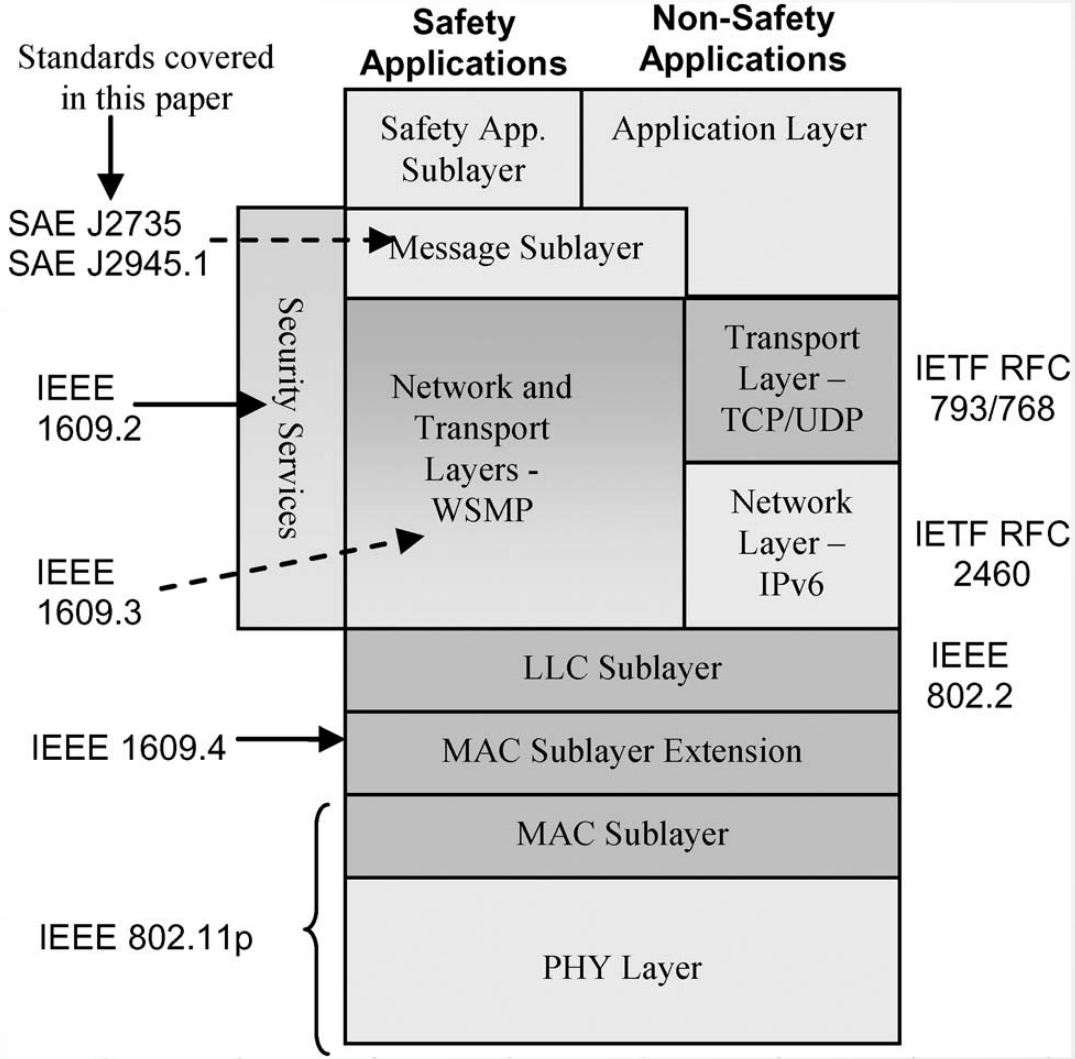
- System performance depends upon consistent implementation of Network Elements
  - Functional & Parametric Test of On Board & Roadside Units
  - Conformance Test : Device Certification
    - Multiple layers of standards : PHY layer to Protocol layer
  - Interoperability Testing
  - Assurance of functionality & performance of OBUs & RSUs through the manufacturing process
- System performance in real life conditions – pilots/trails
  - Field Testing
  - Loading, congestion handling

DSRC Operating Standards

COMMON VEHICLE LANGUAGE

- *SAE J2735 and J2945 define a standardized system of message sets for carrying information between vehicles.
- IEEE 802.11p is an approved amendment to the IEEE 802.11 standard to add wireless access in vehicular environments(WAVE).
- IEEE 1609 is a family of WAVE standards(P1609.0, P1609.1, P1609.2 etc) which supplement 802.11p with high layer messaging.

*SAE International is a U.S. based professional association and standards developing organization. SAE is an acronym for Society of Automotive Engineers. See www.sae.org



DSRC/WAVE

OmniAir CERTIFICATION PROGRAM

- Test OBUs & RSUs against PHY and Protocol Requirements
  - IEEE 802.11p Physical Layer
  - IEEE 1609.2 Security/Certificates
  - IEEE 1609.3 Network (including WSA)
  - IEEE 1609.4 Multi-Channel Operations
  - SAE J2945.1 V-V BSMs Minimum Performance and Message Interoperability

- 'Plugfests' bring OBU & RSU vendors together with Test Labs & Test Equipment providers to verify Interoperability and readiness for Certification, and provide opportunities for testing with SCMS & Field Testing

E6953A DSRC CoC Certification Test Solution

IEEE802.11p, 1609.3,1609.4, 1609.2, J2945/1Tests Cases supported

- Compact PXIe hardware
  - Keysight VXT : RF measurements + GPS source
  - DSRC Transceiver Module
    - CoC Test Cases require only 1 module
    - Configurable as fully functioning OBU/RSU
    - add modules for multiple simultaneous RF channels
  - Keysight PXIe Frame, Controller, Freq Ref
- Software
  - Certification Test Cases in Keysight Test Automation Platform
    - Test Case construction
    - Test Case sequencing
    - Pass/Fail
    - GUI
    - Controls Wave Channel Module & VXT
  - Single platform to be expanded for future V2X test needs
- Hardware & Software options covering
  - full CoC suite
  - RF only
  - Protocol only

Keysight V2X Test Platform

SIMPLIFYING RF TESTING

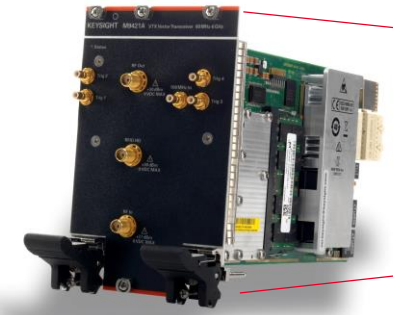
802.11p Test Cases
RF measurements

- using M9421A VXT hardware
  - Vector Signal Analyzer & Source
  - FPGA-Accelerated speed with high density & accuracy
  - Trusted X-Series software: industry tested algorithms, with code compatibility & bench top usability
    - N9077A measurement application
    - Graphical Vector Signal Analyzer
- N7617B Signal Studio
  - Arbitrary Waveform creation

Streamline Compliance Testing

Signal Studio

One-button X-Apps

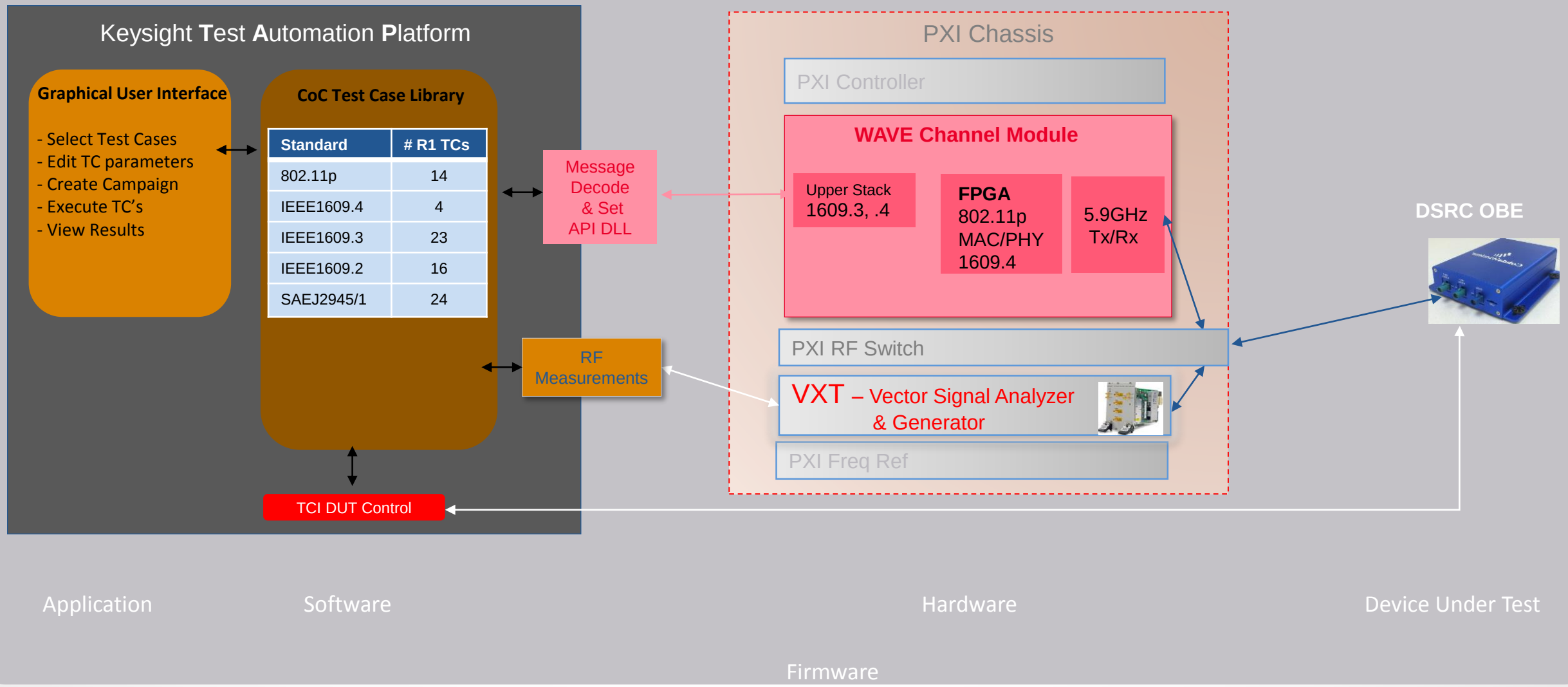


M9421A VXT Key Features	
Frequency	60 MHz to 3.8 or 6 GHz
Bandwidth	40, 80 or 160 MHz
Modulated Output Power	+10 (HD) or +18 dBm
Memory depth	256 or 512 Msa
3 Ports	RF in & out, One Half Duplex (Optional)

Measurement integrity that ensures accurate, consistent results from R&D to Manufacturing

Keysight E6953A DSRC Certification Solution

FUNCTIONAL DIAGRAM



Keysight V2X Test Platform

TEST AUTOMATION PLATFORM

DSRC CoC Test Cases

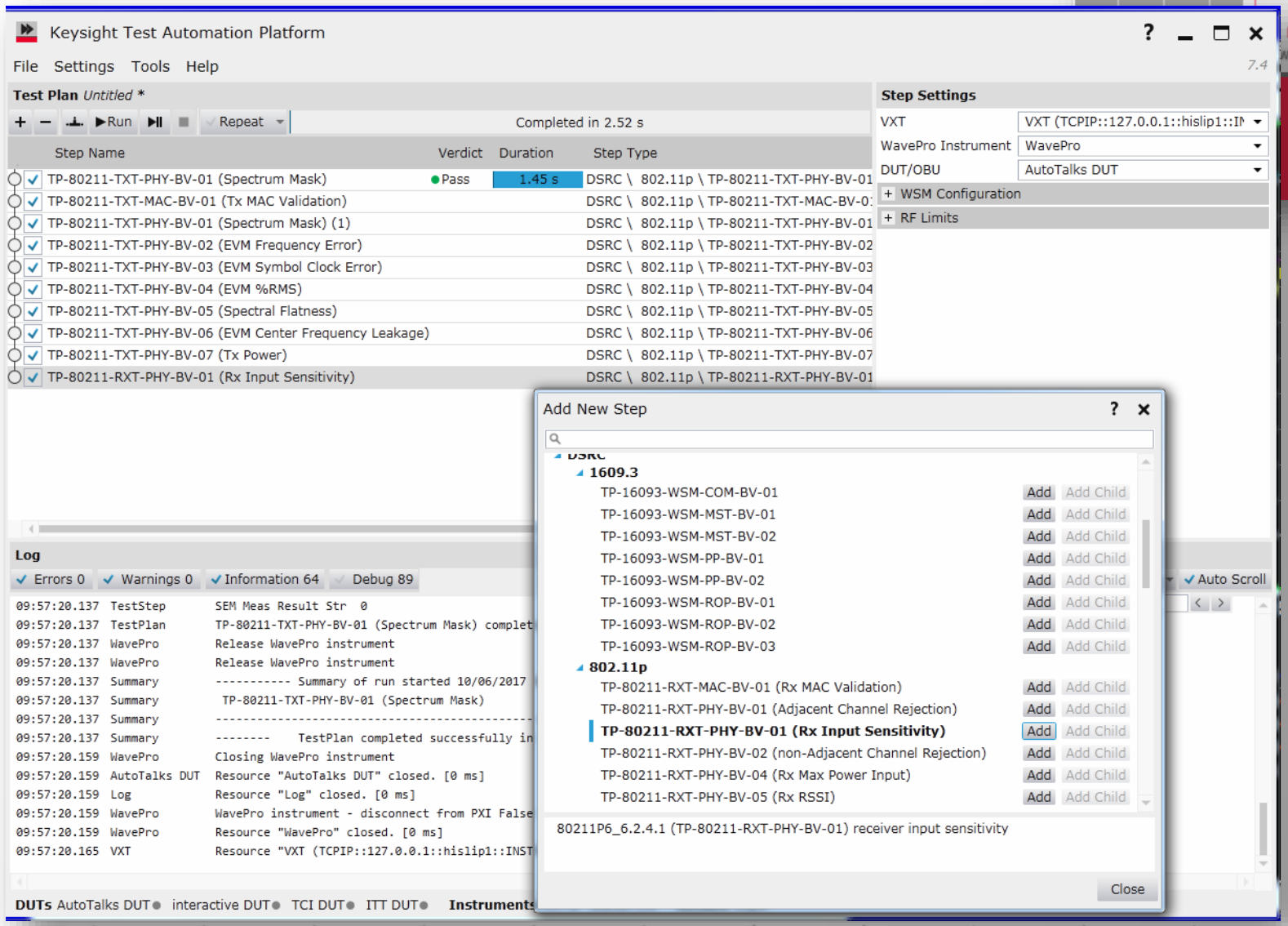
- 802.11p
- IEEE1609.3
- IEEE1609.4
- IEEE1609.2
- J2945/1

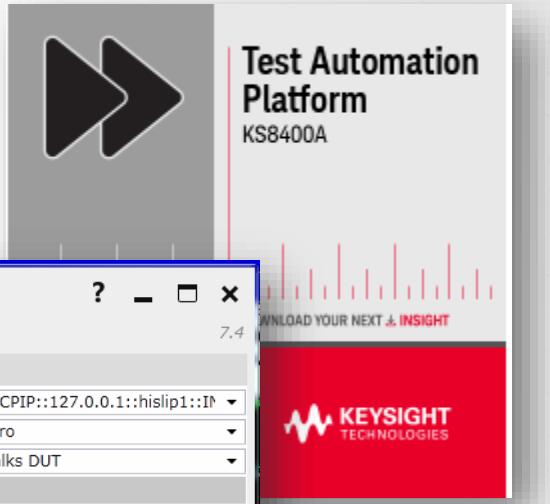
Test Plans

- Parameter Sweep Loop
  - e.g. Channel, Data Rate

Reporting

- Summary and each TC results
- Full ‘raw message’ data
- Detailed & graphical PHY results



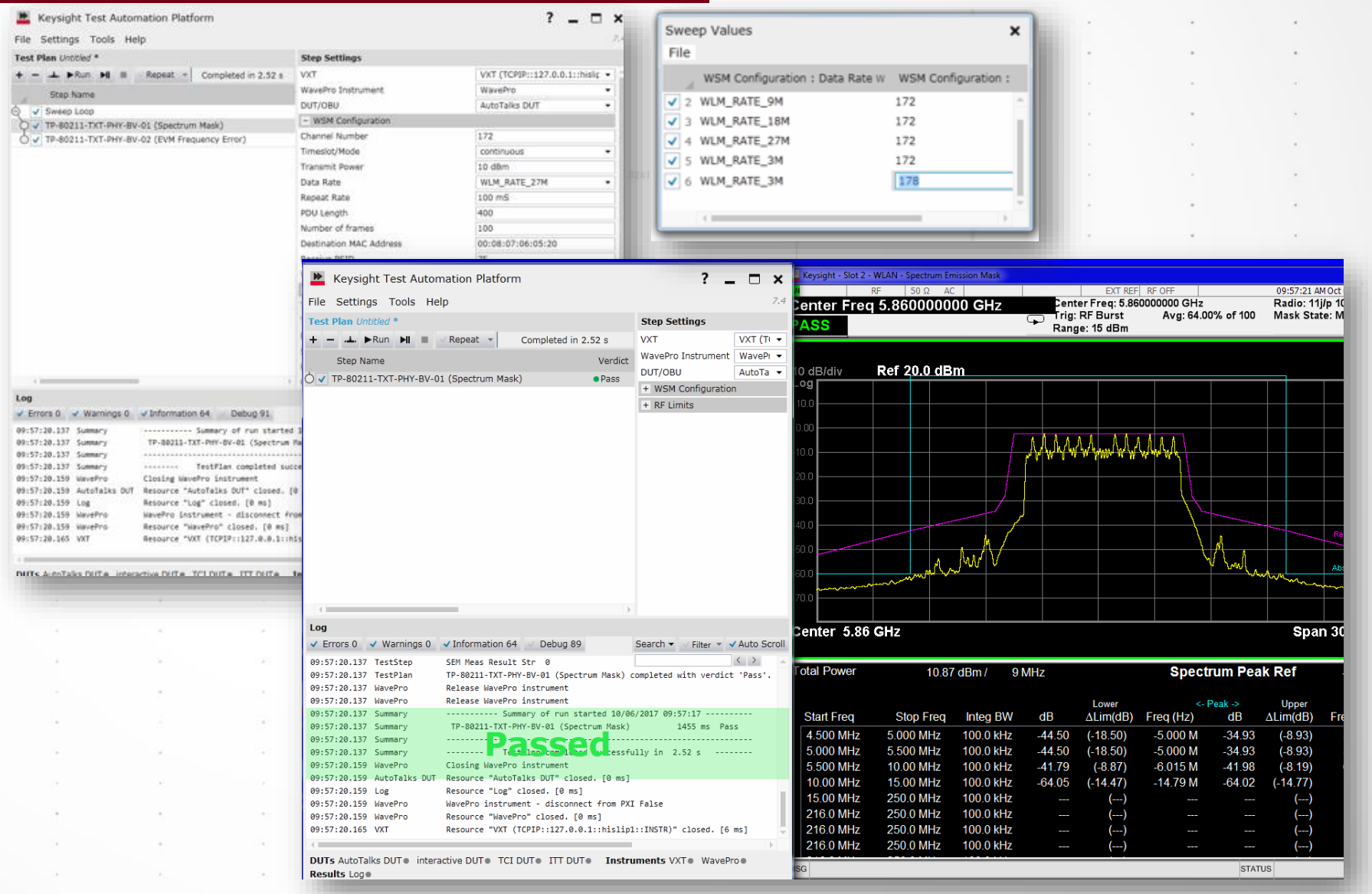


Keysight V2X Test Platform

TEST AUTOMATION PLATFORM

802.11p Test Cases

- RF Measurements
  - Test parameter setting, looping
  - Test Case Pass/Fail
  - Graphical VSA window
- Test Campaign Sequencing, Looping

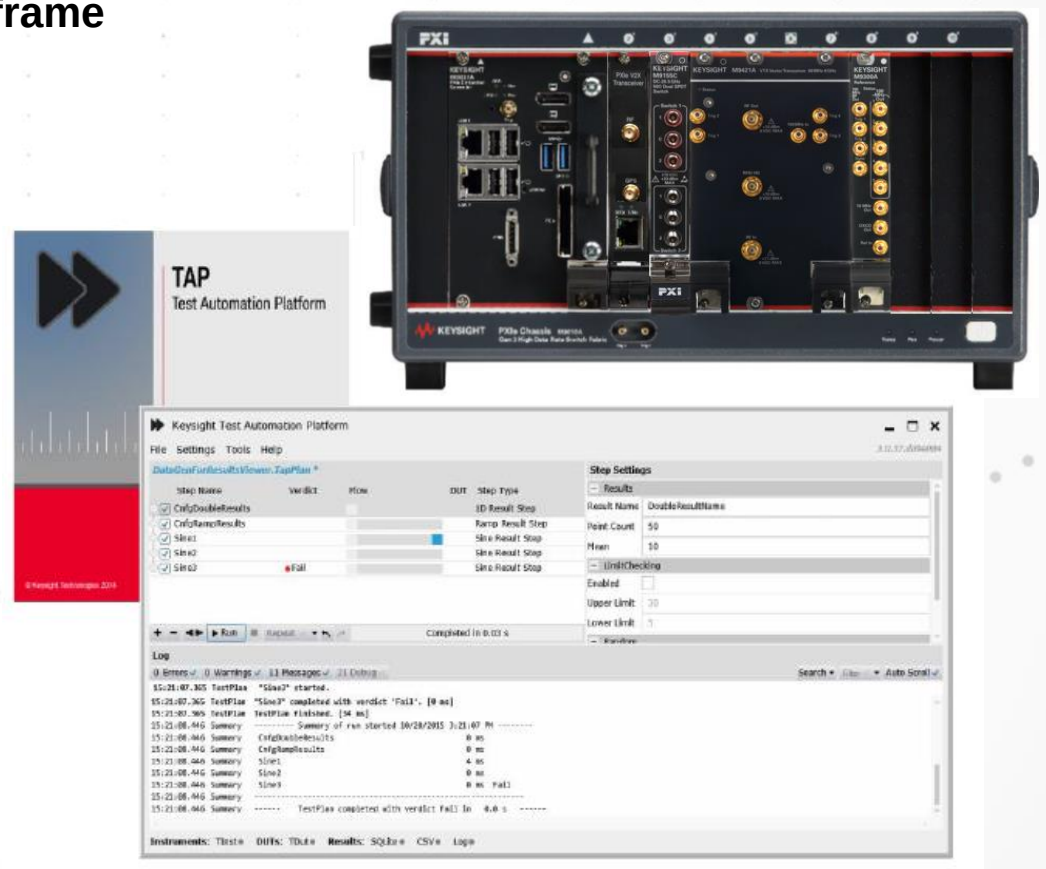


KEYSIGHT TECHNOLOGIES

E6953A Keysight DSRC CoC Certification Tester

Covers all CoC Test Cases in single , integrated PXI frame

- 802.11p
- IEEE1609.3
- IEEE1609.4
- IEEE1609.2
- J2945/1



Up next ……

- Pre-Certification and Design Verification solution
- Parameter flexibility to create new ‘TC’s & scenarios
- Loading, congestion, application testing
- ITS-G5 (optional 18GHz SA for EN 302 571 5.3.4)
- C-V2X

R14 C-V2X is the first step towards 5G NR V2X

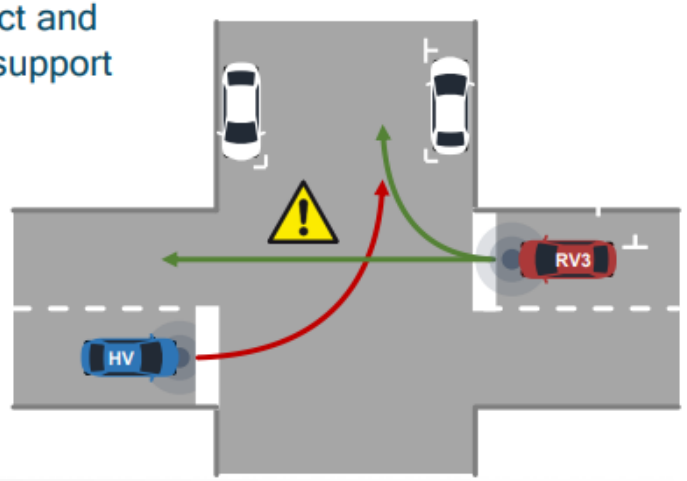
1H17 | 2H17 | 1H18 | 2H18 | 2H20

Rel14 — Rel15 — Rel16

Basic and enhanced safety

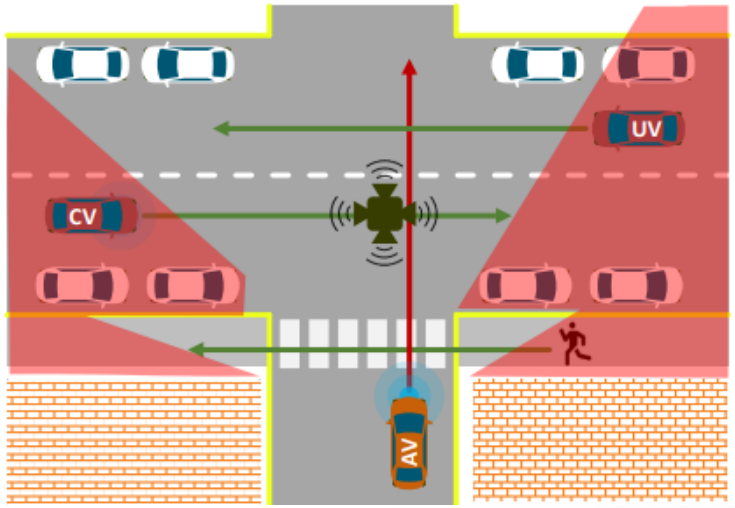
C-V2X R14/R15 with enhanced range and reliability

- Basic safety messaging
- Dual (direct and network) support



Autonomous driving / Automation

5G NR based C-V2X R16



- Backward compatible
- HD sensor and intent sharing

Autonomous Driving

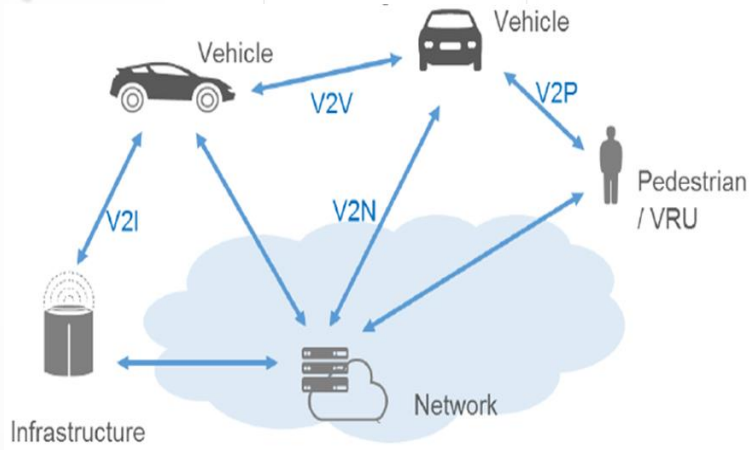
DSRC AND C-V2X COMPARISON

	802.11p DSRC	C-V2X
Readiness	IEEE 802.11p, approved in 2010	3GPP Rel.14, fixed in 2017
Cost Effectiveness		Leveraging the cellular network infrastructure
Network Independency	Ad-hoc	LTE D2D on PS5
Scalability		4G → 5G → …
Latency	Less than 5ms	LTE D2D (5G's goal: 1ms)
Security		Network based
Range		FDM / Turbo Channel Coding, SC-FDM, HARQ
Reliability		Same as above
Positioning	More focused on V2V / V2I / V2R	(V/V) / V2N / V2I / V2R / V2P

C-V2X with 5G

5G AUTOMOTIVE ASSOCIATION (5GAA)

Mission:
"Our mission is to bridge the automotive and telecommunications industries in order to embrace and accelerate the global deployment of intelligent transport and communications solutions. Through this, we aim to address society's connected mobility and transport safety needs."

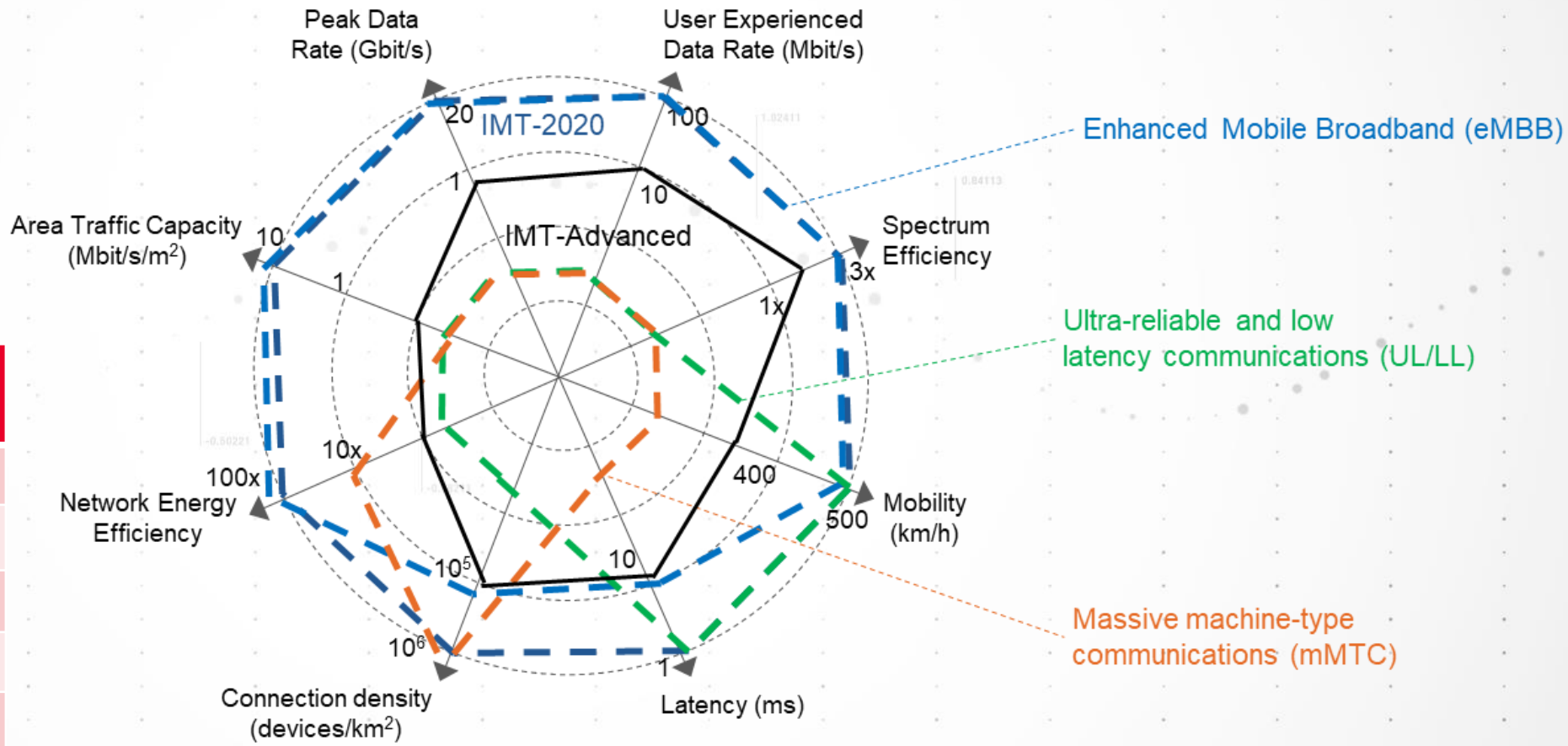


http://www.5gaa.org/

5G Key Performance Indicator from ITU-R : IMT-2020 Vision

KPIS AND PROPOSED 5G USE CASES

Additional KPI for IMT-2020
Reliability
Average spectral efficiency
Mobility interruption time
Bandwidth
5th percentile user spectral efficiency



5G Framework for Automotive

COMBINATION OF ALL THREE

Mobile Broadband Access

- All data, all the time
- 2 billion people on social media

Massive Machine Communication

- 30 billion “things” connected
- Low cost, low energy

Mission-Critical Machine Communication

- Ultra high-reliability
- Ultra-low latency

Very High Data Rate In Congested Areas
Communications Optimized for Machines
High Reliability and Low Latency

5G & V2X Measurement Challenges

OVERALL AND C-V2X

5G Overview

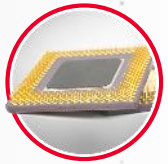
1. Measure, model, and emulate mmWave channels
2. Measure, model, and emulate wideband baseband
3. Measure and characterize chips & devices over-the-air
4. Emulate 5G network and device—characterize spectral efficiency gains
5. Simulate 5G NR signals, protocol stacks—prototype baseband and RF implementation effects to the system
6. Characterize phase, amplitude, and thermal effects of phased arrays
7. Emulate and evaluate end-to-end connections
8. Model, design, and troubleshoot mmWave components and subsystems
9. Characterize and troubleshoot high-speed digital interfaces in circuits and networks (from DigRF all the way to PAM4 and 400G)
10. Characterize interoperability/coexistence of wireless standards

Key Measurements in V2x

- Latency
- Reliability (PER)
- Interference and Co-existence
- Range (Sensitivity)
- Congestion Control
- Maximum Relative Vehicle Speeds
- Dynamic Channel Impairments
- Data Throughput
- GNSS Accuracy
- Interoperability
- Certification Test (Dictated by Policy)
- Security
- Antenna Performance

Keysight Now Provides Insight Across the Entire Stack

Keysight Classic Ixia Anite



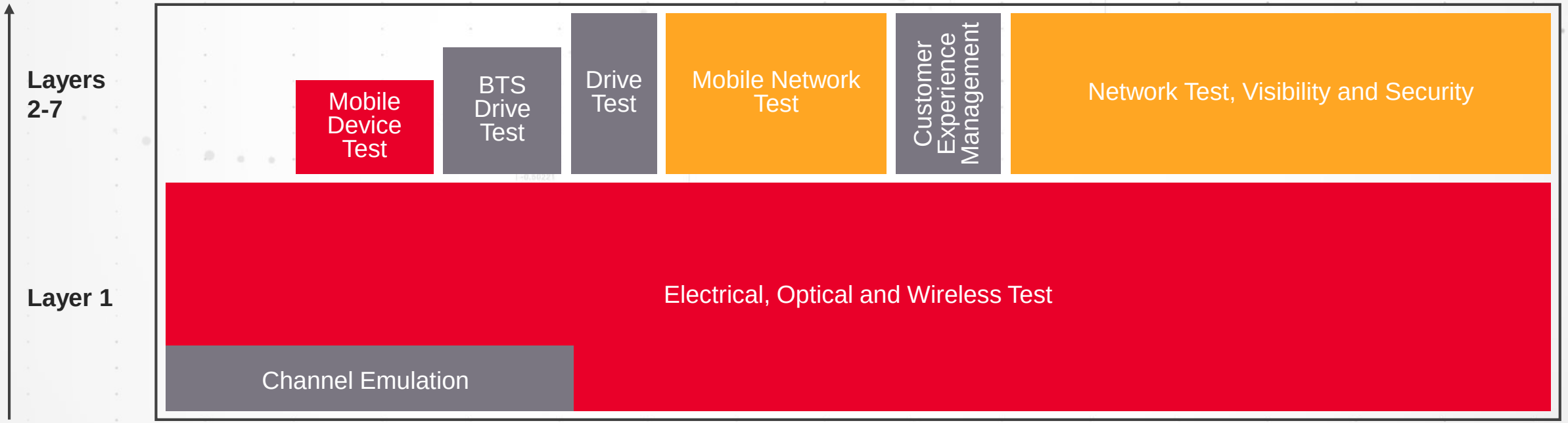
COMPONENTS & CHIPSETS

DEVICES

BASE STATIONS

HYPERSCALE AND DATA CENTERS

ENTERPRISE



Keysight Research Partnership & Collaboration

Value of Keysight #3

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SAMSUNG PORTFOLIO INSIGHTS NEWS & EVENTS OUR BUSINESS

Samsung Electronics and Keysight Technologies Announce 5G Collab

New 5G Test Solutions Accelerate 5G Development

Share

Highlights:

- Samsung Electronics and Keysight announce collaboration on 5G development and testing
- Partnership to cover 5GTF and 3GPP NR

SANTA ROSA, Calif., February 27, 2017 - Keysight Technologies, Inc. (NYSE: KEYS) and Samsung Electronics Corporation today announce
Samsung and Keysight have entered into a technology collaboration to enable design and deployment of 5G devices to support early oper
specifications (www.5gtf.org). Future collaboration will include work being done in 3GPP NR.

With the first set of 5G specifications based on Verizon's 5GTF now in place, first trial networks are now being deployed. Samsung and Keys
align their respective product portfolios around the specification and build an ecosystem of interoperable products. Both companies will c
booth at Mobile World Congress in Barcelona.

"As we begin to transition to a new generation of wireless technologies, it's growing more important that we establish industry alignment.
an area of the radio spectrum that has been a big unknown for the mobile industry," said Woojune Kim, Vice President of Next-Generation

U University Collaboration
P Consortium Research Project
R Regional/Country Consortium

mmWAVE

Mobile N

RCRWireless News
INTELLIGENCE ON ALL THINGS WIRELESS

KEYSIGHT TECHNOLOGIES Keysight 5G Design & Test Solutions

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TEST EQUIPMENT | CARRIERS | NFV | 5G | DAS | SDN | CLOUD COMPUTING | SMALL CELLS | ENTERPRISE | ENTERPRISE IOT INSIGHTS

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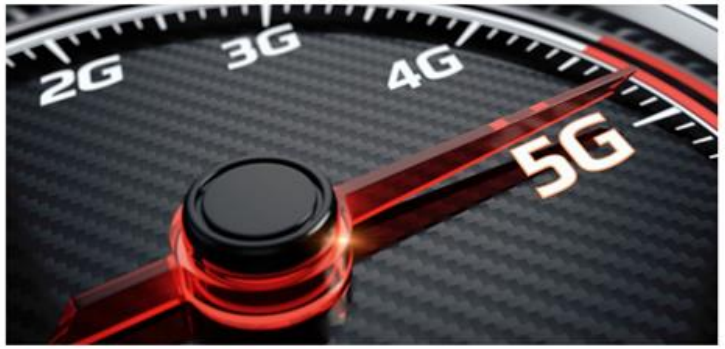

Test and Measurement: Keysight, Qualcomm partner to test 5G chips

By Kelly Hill on JUNE 9, 2017 Test and Measurement

Keysight, Qualcomm will collaborate on testing 5G chips

Qualcomm Technologies will use Keysight Technologies' test equipment and design tools to develop "5G" chips. The two companies announced a collaboration this week on 5G chipset development. Qualcomm will be utilizing Keysight offerings such as its network emulation portfolio (including tis UXM 5G wireless test platform) for validating 5G chips and higher-layer protocols.

Keysight's 5G protocol testing solution was just launched last month to support chipset and device research

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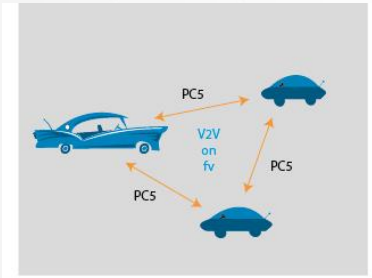
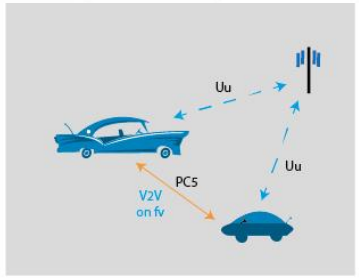
V2X Test Challenges in Real World Scenario

Automotive Use Cases

C-V2X VEHICULAR COMMUNICATIONS

- Test reliability of communications in your lab
- V2V, V2X scenarios
  - Drop the cars on the map
  - Select antennas, multiple per car supported
  - Choose the environment
- Import timestamps, coordinates and power profile from field to simulate movement





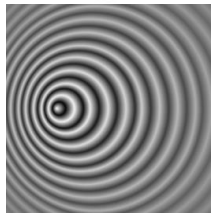
VIRTUAL DRIVE TESTING

- Collect network data with Nemo Outdoor and playback the scenario in you lab
- Test E2E Multi-cell mobility in realistic fading and interference conditions
- Replace expensive field trials by emulating field measured conditions from all continents

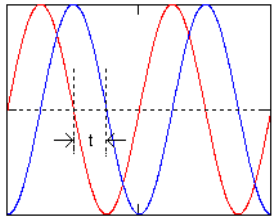
The Bottleneck and Test Gap of This Industry

HOW TO BRING FIELD CONDITIONS TO TEST LAB

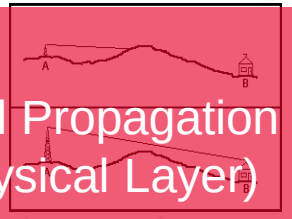
- Testing in field is
  - Expensive
  - Time-consuming
  - Impractical
- How can to create real world RF conditions inside Lab?
  - With V2X standard channel models
  - Field recorded data



High Doppler +/- 700 Hz



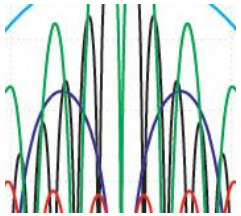
Channel delay rate change +/- 0.3us/s



Extereme Signal Propagation Conditions (Physical Layer)

RMS Power swing 5-30 dB/s

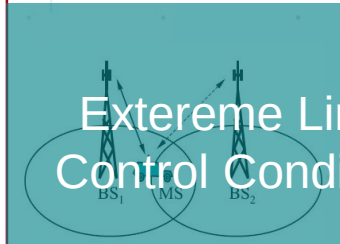
LoS/NLoS up to 30 dB/msec



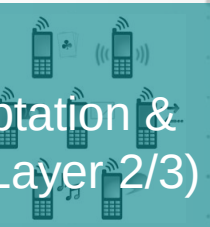
Fast Interference fluctuation

Scheduling Challenges

Multi-RAT HOs

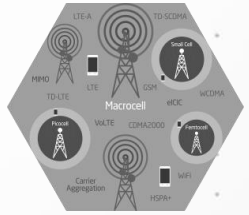


Extereme Link Adaptation & Control Conditions (Layer 2/3)



Fast/Frequent HOs

Fast Group HOs

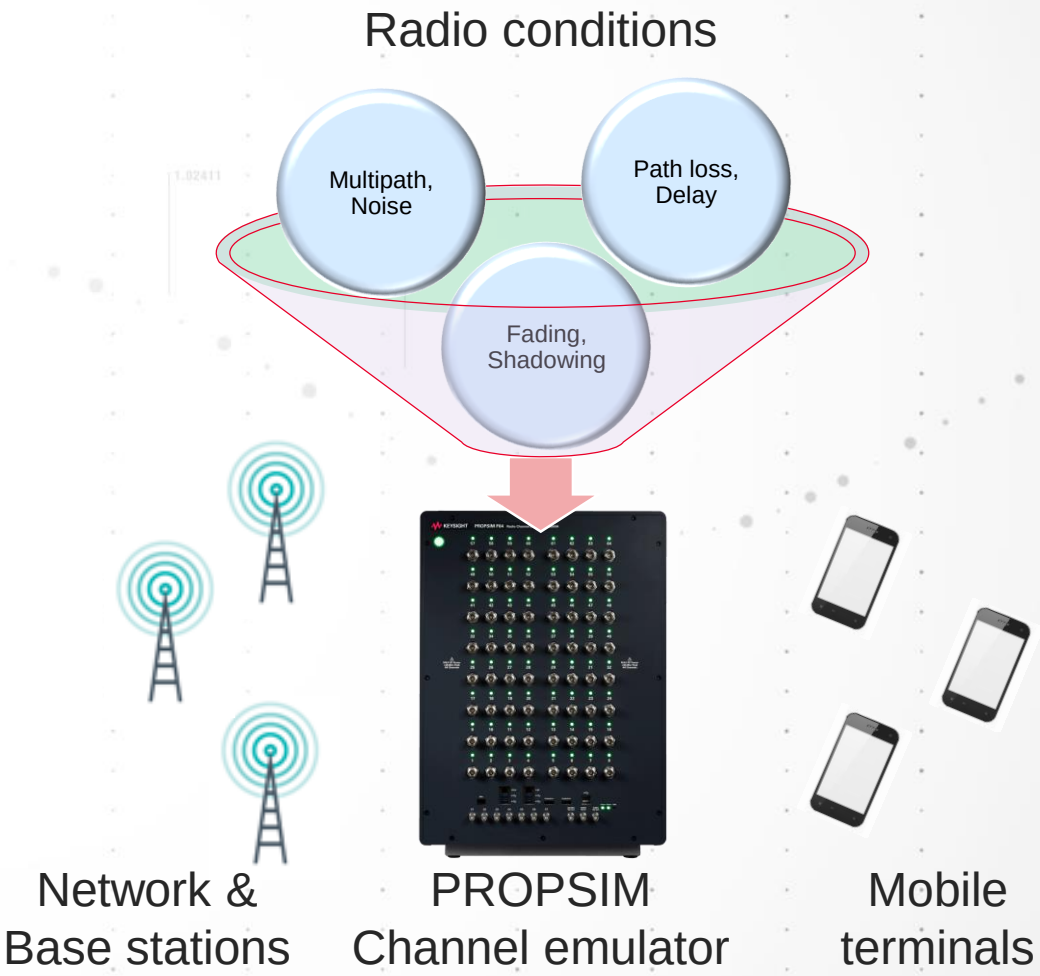


Co-existance of different networks

Introducing Channel Emulator

PROPSIM EMULATES COMPLEX REAL-WORLD RADIO CONDITION IN THE LAB

- Channel Emulator (CE) is a device which replaces wireless links with mathematical model of the radio conditions
  - Control the conditions over multiple test runs
  - Model extreme conditions
- Channel Emulator is used with real Radios
  - First prototypes can be already exposed to realistic field conditions

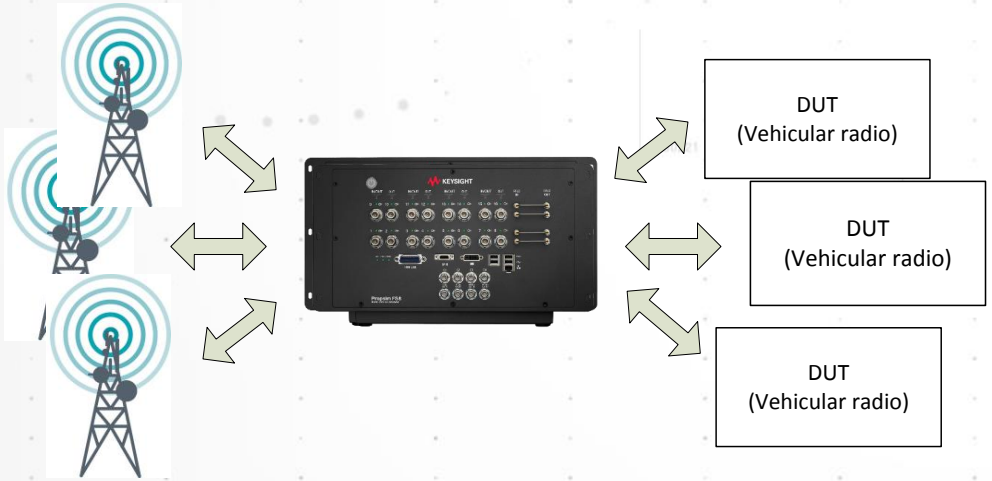


Automotive Use Cases

POTENTIAL TEST SETUPS AND TEST CASES

Test setup with emulated network

- Functional protocol testing
- Link level

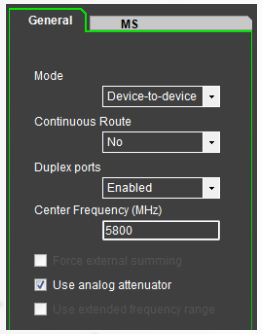


Test setup between real network and user devices

- System level performance verification
- Interoperability
- Network component testing

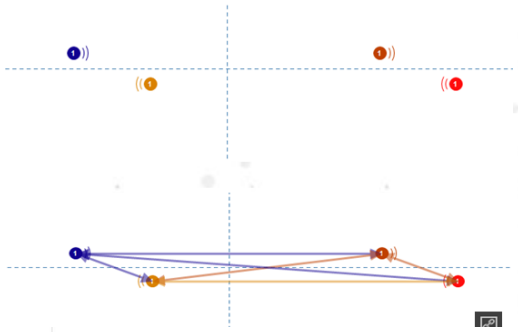
GCM V2X - 3GPP R14 Features for Vehicular Communications (C-V2X)

- Supports scenarios between vehicles, vehicle to pedestrian and vehicle to infrastructure and for communications with networks.



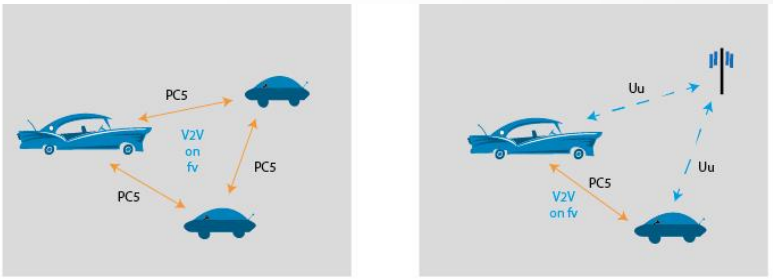
GCM D2D mode

- Combing 5.9GHz ITS band and cellular networks in GCM release 2.8



Scenario ceating in GUI

- 3GPP TR36.885 V2X channel models
- Each radio can have arbitrary antenna configurations
- Connections can be visualized by clicking ”show links” button



3GPP deployment configurations

Test cases: Reliability of communications under speed, interference, high number of nodes w/wo cellular network precense

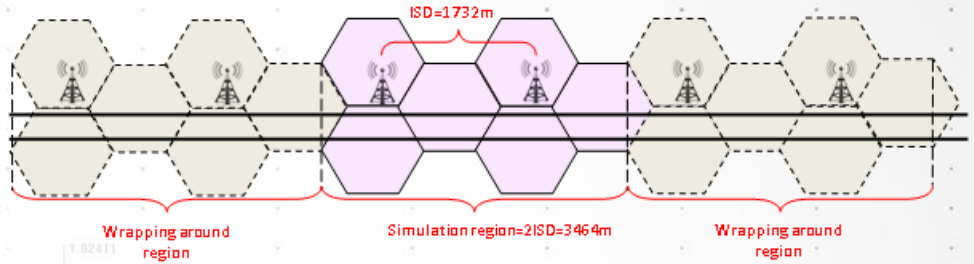
- V2V, Latency critical functions (PC5): Collision warnings and autonomous driving features
- V2N, wide area communications (Uu)
- Combinations of V2V & V2N
- Interoperability between IEEE 802.11p based DSRC technology

V2X Channel Scenario and Channel Models

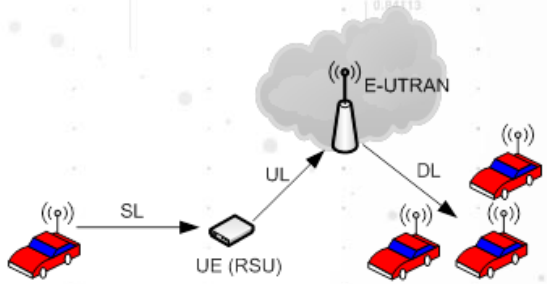
3GPP V2X MODEL TR36.885

- V2X model definitions refer to TR36.843 (Study on LTE Device to Device Proximity Services)
  - Modes for in-coverage, out-of-coverage and partial coverage situations
  - Introduces PC3 and PC5 interfaces for D2D use
- Vehicle to vehicle
  - Fast fading model ITU-R UMi with dual MS topology
  - Pathloss models Winner B1 with different parameters for Freeway and urban scenarios
- Vehicle to eNB
  - 3GPP Spatial Channel Model (SCM) NLOS
  - With specific pathloss and shadowing parameters specified

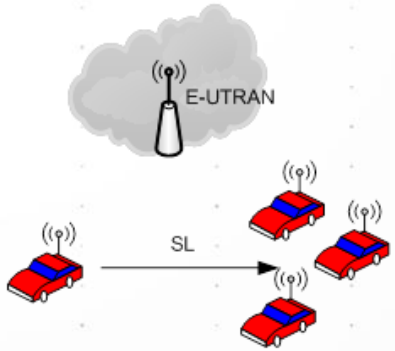
Freeway case

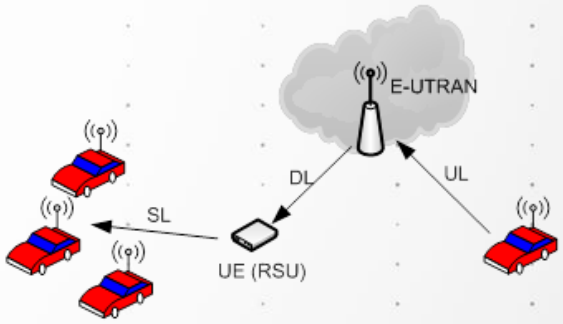


SL = Side Link = PC5
RSU = Road Side Unit (UE)



Different V2V/V2I scenarios from TR36.885

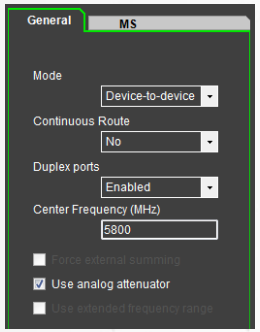




V2V Test Case Example

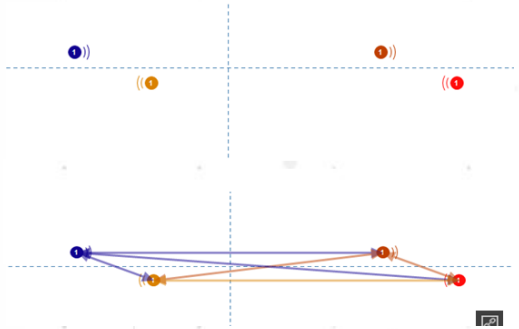
Scenario

Create highway scenario for four cars. Each car has a radio with1 TX and 2 RX antennas



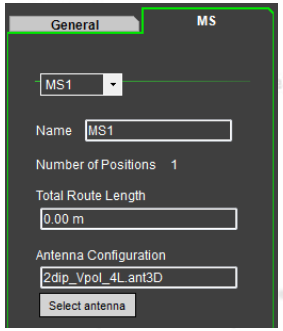
Switch GCM in D2D mode

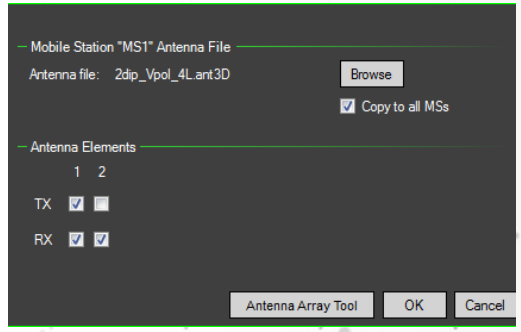
- The mode is selected under general parameters tab
- In case of D2D mode the scenario fequency is also selected here



Drop the cars on the map

- Connections can be visualized by clicking ”show links” button
- In this example static positions and virtual movement is used
- Antenna orientations and direction of movement can be defined under position dialog



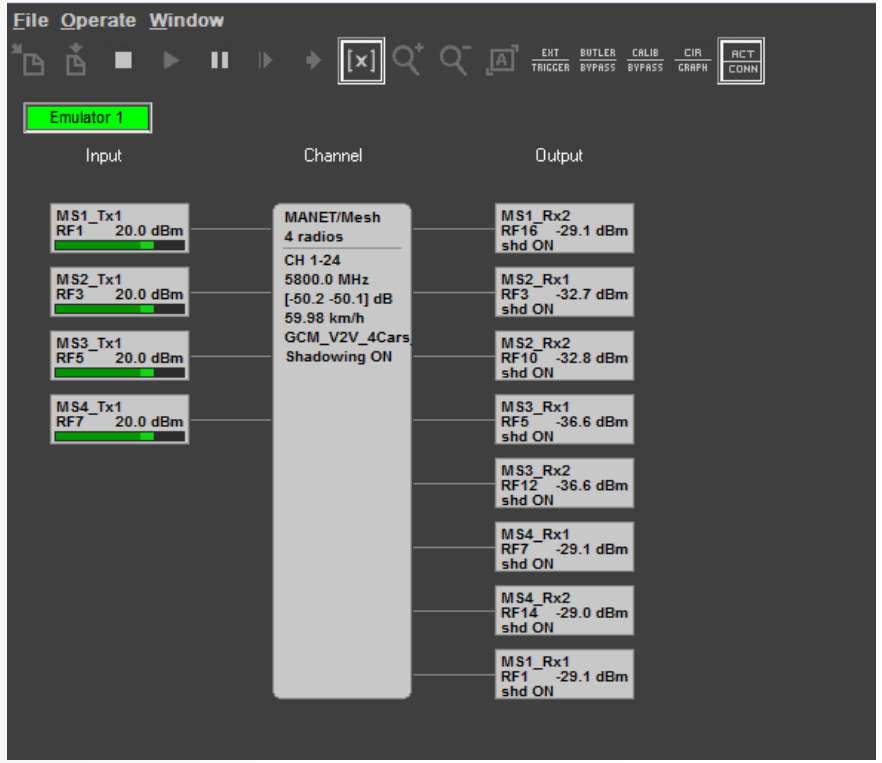


Select antennas

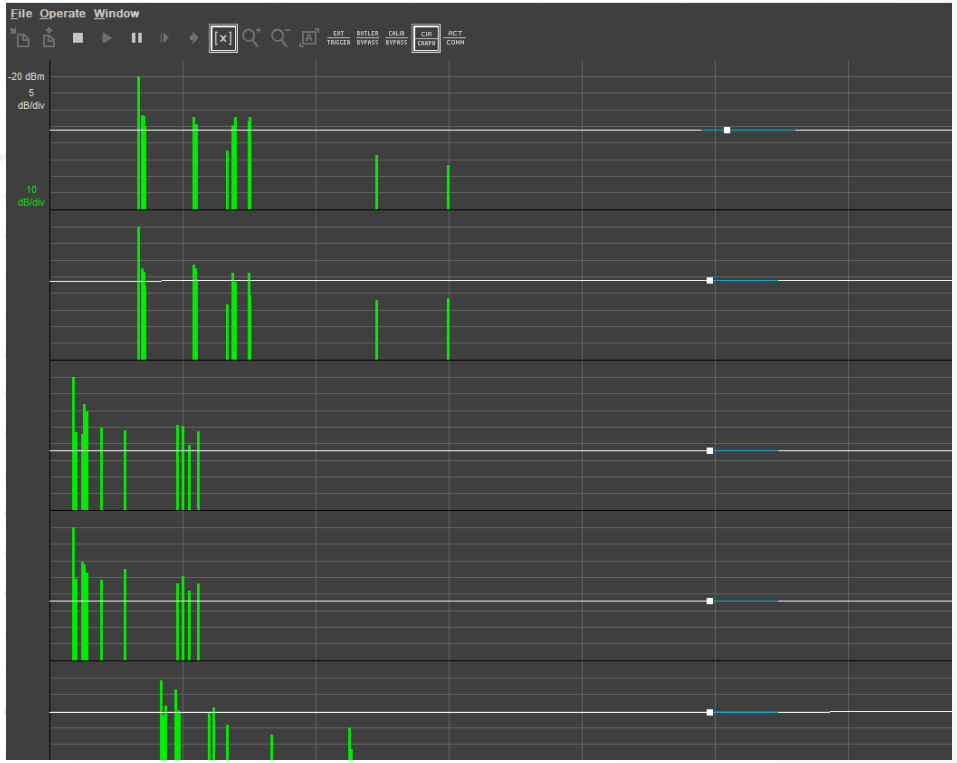
- Two vertical dipoles with 4 lambda spacing are used in this example
- Antenna 1 is TX/RX, antenna 2 is RX only

V2V Test Case Example

Running View



CIR graph



LEADER IN AUTOMOTIVE & ENERGY

Collaborations

ETSI, 3GPP, 5GAA, IWPC, Autotech Council, Car 2 Car, and more

R&D Centers

in Germany, Detroit, , Bay Area, and Singapore

Over **50 Solutions** launched in 2017 alone

Innovations in V2X Design and Test

SUMMARY

- V2X will enable enhanced Safety and Higher Levels of Automation.
- It is our (engineers) roles to create a safer, connected, and better world!
- Keysight provides broadest and most powerful design and test solutions to help engineers become super-heroes and save lives!
  - Value #1- Entire design and test lifecycle solutions
  - Value #2- Connected solution consists of design simulation software and measurement
  - Value #3- Leadership in current and future technologies

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