



Spirent Automotive C-V2X Test Solutions

September 2023

What is V2X ?



Platooning



Extended Sensors



Remote Driving



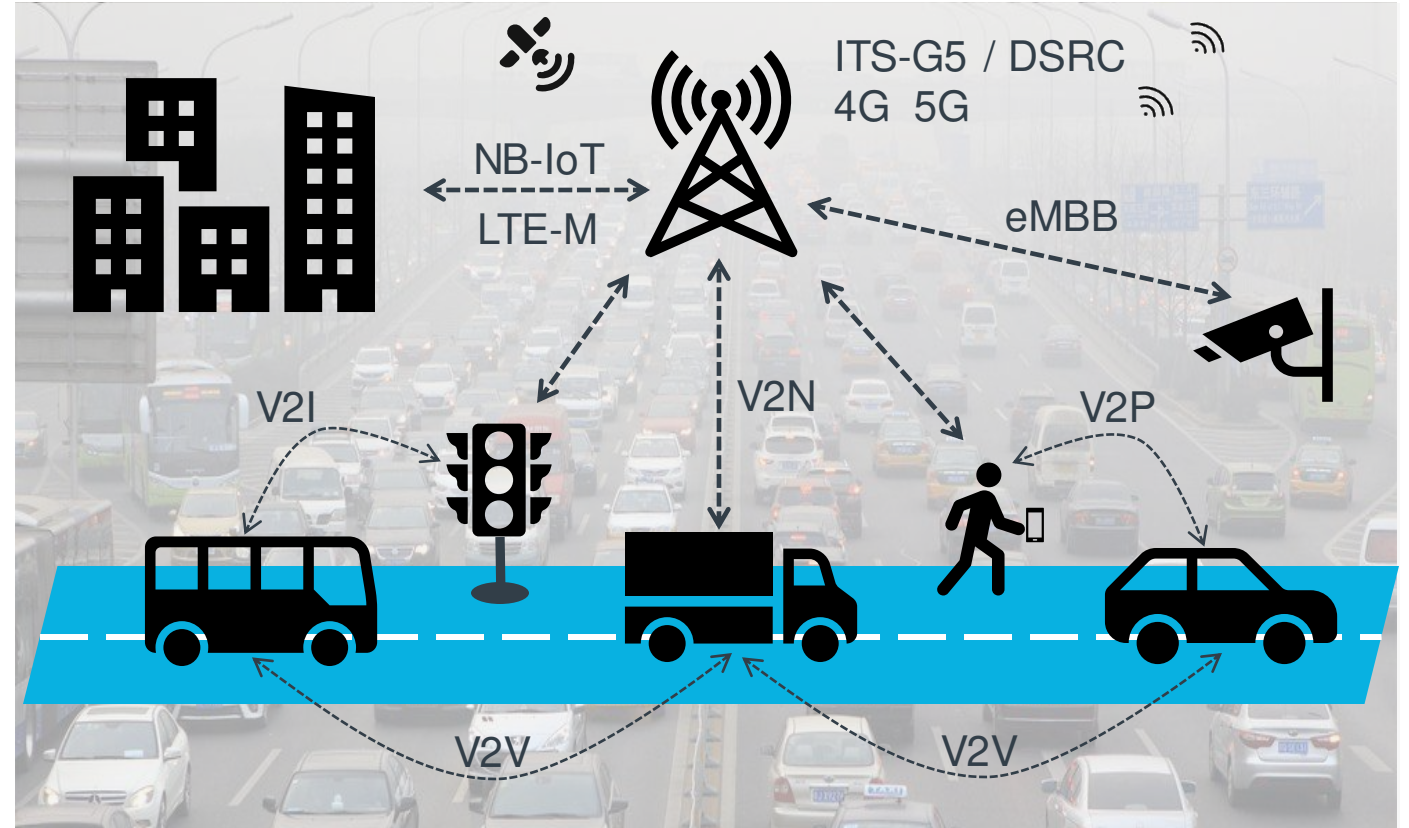
Automated Driving



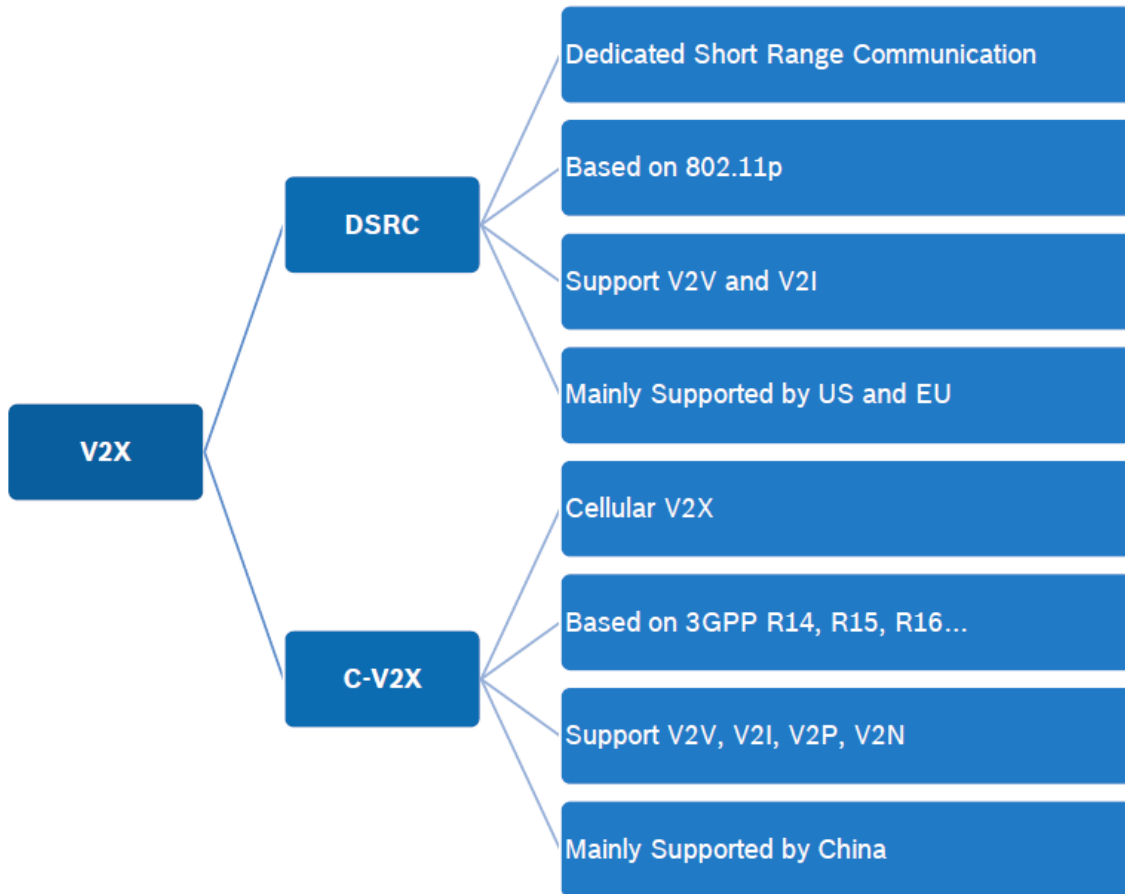
Big Data & AI



HD Maps



~60% REDUCTION IN CO² EMISSIONS
~90% REDUCTION IN TRAFFIC DEATHS



Technology Benchmark Summary

Congestion	Lab Cabled Congestion Control	Pass
Reliability	Lab Cabled Tx and Rx Tests	CV2X better
	Field Line-of-Sight (LOS) Range Tests	CV2X better
	Field Non-Line-of-Sight (NLOS) Range Tests	CV2X better
Interference	Lab Cabled Test with Simulated Co-channel Interference	CV2X better
	Lab Cabled Near-Far Test	Pass
	Field Co-existence with Wi-Fi 80 MHz Bandwidth in UNII-3	CV2X better
	Field Co-existing of V2X with Adjacent DSRC Carrier	Pass

CV2X radio technology consistently outperforms DSRC.





Field Results Summary

Test Procedure	Range at 90% Reliability	
	DSRC	CV2X
Line-of-Sight (LOS) Range	675m	1175m
Non-Line-of-Sight (NLOS) Blocker (5GAA)	125m	425m
Non-Line-of-Sight (NLOS) Blocker (CAMP)	400m (200m) ¹	>1350m (625m)
Non-Line-of-Sight (NLOS) Intersection	375m	875m
Co-existence with Wi-Fi 80 MHz Bandwidth in UNII-3	300m (75m)	625m
Co-existing of V2X with Adjacent DSRC Carrier	400m (100m)	1050m

CV2X radio technology consistently outperforms DSRC.

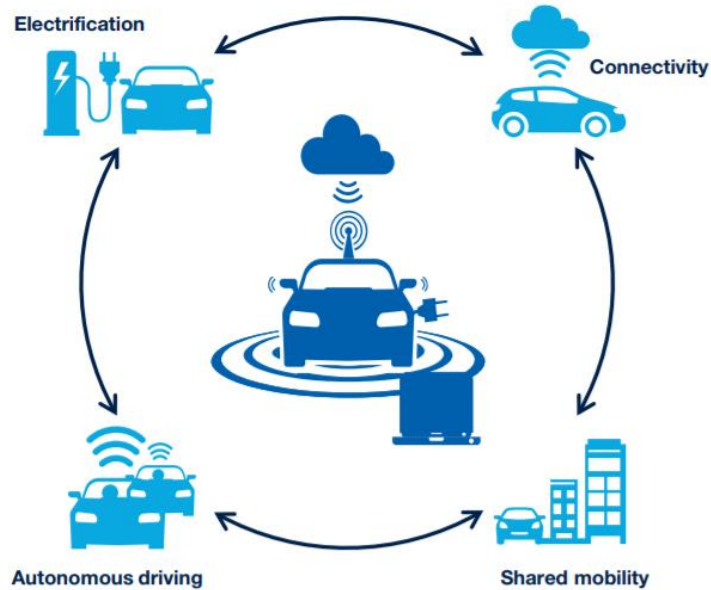
Report from 5GAA

C-V2X: Market Dynamics

 <p>DRIVERS</p>	<ul style="list-style-type: none">▪ Increasing demand for fully autonomous driving and safe vehicles▪ Concerns over environmental pollution▪ Developments in connected car technology and growing collaborations
 <p>RESTRAINTS</p>	<ul style="list-style-type: none">▪ Latency/reliability challenges▪ Lack of infrastructure for proper functioning
 <p>OPPORTUNITIES</p>	<ul style="list-style-type: none">▪ Government support for V2X technology▪ Advancements in 5G technology▪ Developments in autonomous vehicles
 <p>CHALLENGES</p>	<ul style="list-style-type: none">▪ Vulnerability to cyberattacks

Automotive Market Directions

ACES (Autonomous, Connectivity, Electrification, Shared Mobility) Trends



Source: McKinsey, Rewiring car electronics and software architecture for the Roaring 2020s, August 2021

ACES trends	Implications for automotive electronics and software	Relevance
Autonomous driving	Complex and safety-relevant software High-performance computers	64% of customers would switch OEMs for better autonomous-driving capabilities
Connectivity	Performant in-vehicle network (Ethernet) Over-the-air updates Cybersecurity	95% of new vehicles sold in 2030 will be connected
Electrification	New electrical package New powertrain applications	53% of new vehicles sold in Europe in 2030 could be electric vehicles ¹
Shared mobility	Features for individualization Keyless entry	2/3 of US customers expect their shared-mobility usage will increase over the next 2 years

¹Includes battery electric vehicles (EVs), plug-in hybrid EVs, and fuel-cell EVs.
Source: McKinsey analysis

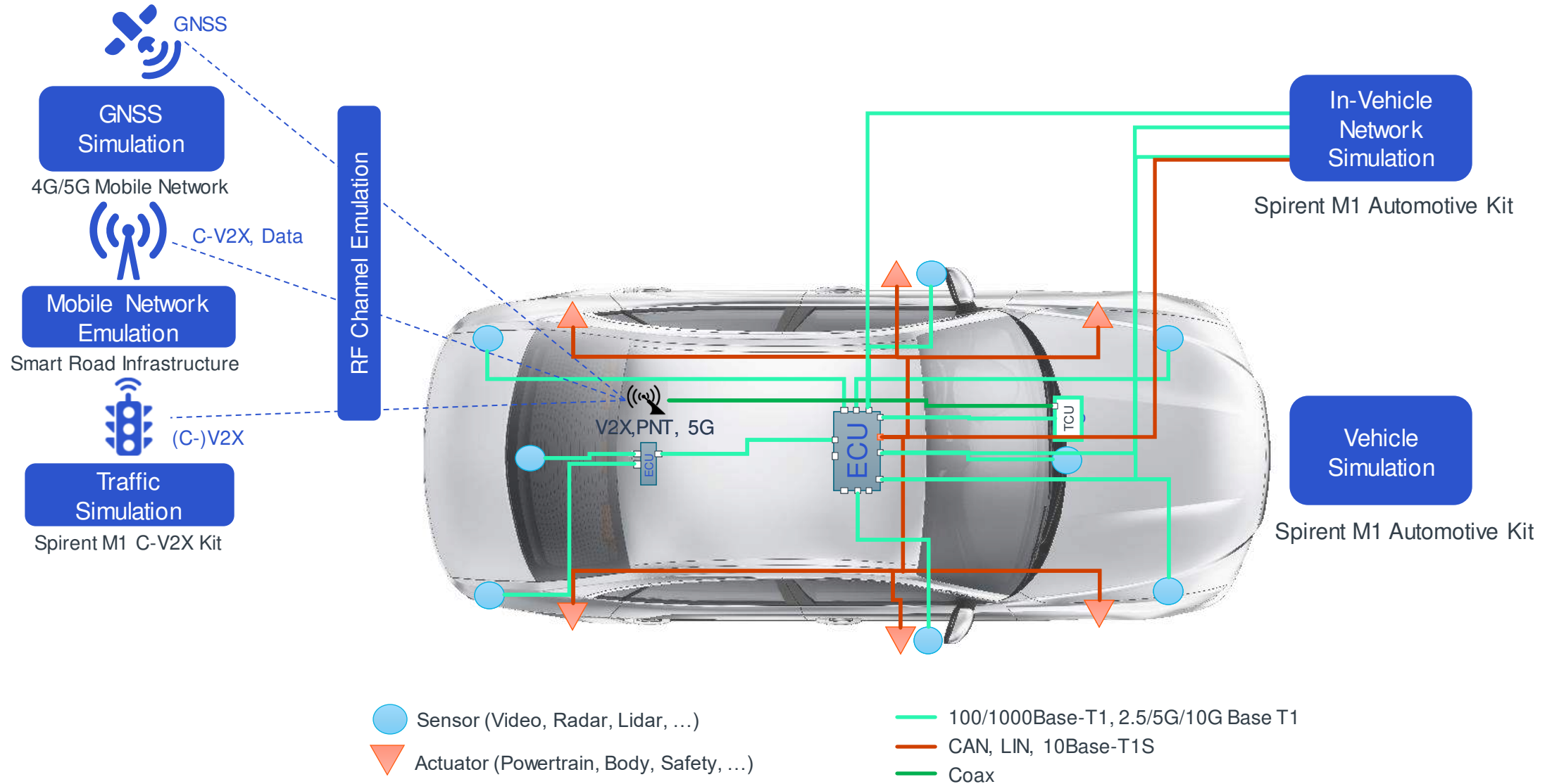
Spirent's Focus Area of Specialization

- Expertise in time critical ethernet testing
- Expertise in wireless communications
- In-house GNSS solution

Offering Complete Portfolio

- AD: V2X Virtual + M1 + GNSS Simulator + Vertex
- Connectivity: STC + GNSS Simulator

Spirent Test Solutions for the Connected Automated Vehicle



Spirent Automotive Test Expertise

Recognized for innovation & leadership to advance tomorrow's technologies



Test Methodologies

Conformance

- Conformance to standard test specifications
 - OmniAir, EU- ITS, CCSA
- Interoperability
- Stability & robustness (negative testing)

Products:

- TTworkbench
- TTsuites

Functional

- Simulation of in-vehicle network components and topologies
- Simulation of road traffic including communication behavior
- Simulated mobility
- Functional validation of ECU under real world conditions

Products:

- V2X Virtual
- M1 Appliance
- GSS7000

Performance

- Scalability testing
- Congested road traffic simulation
- Channel fading testing

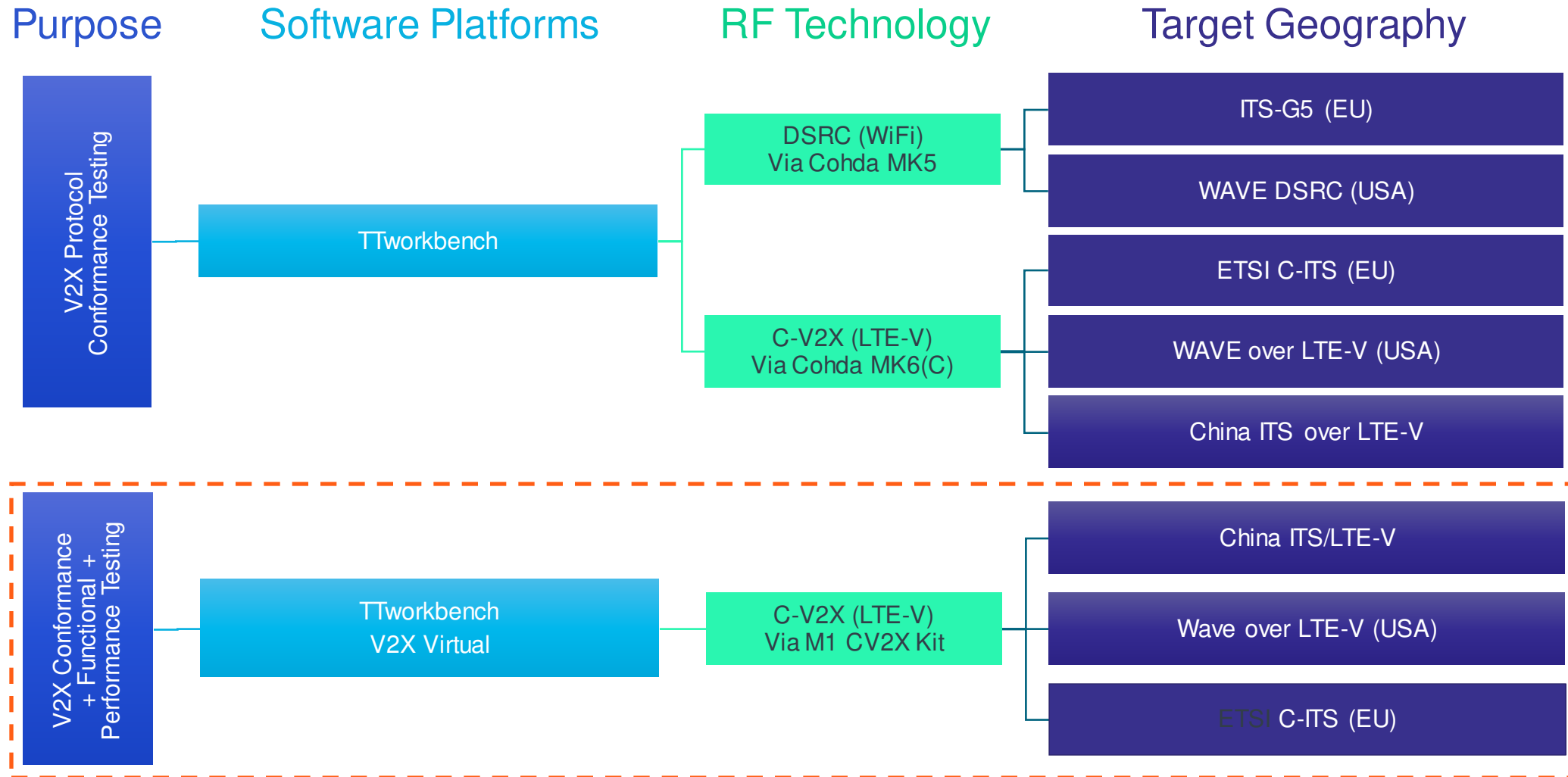
Products:

- V2X Virtual
- M1 Appliance
- GSS7000
- Vertex



Test Automation

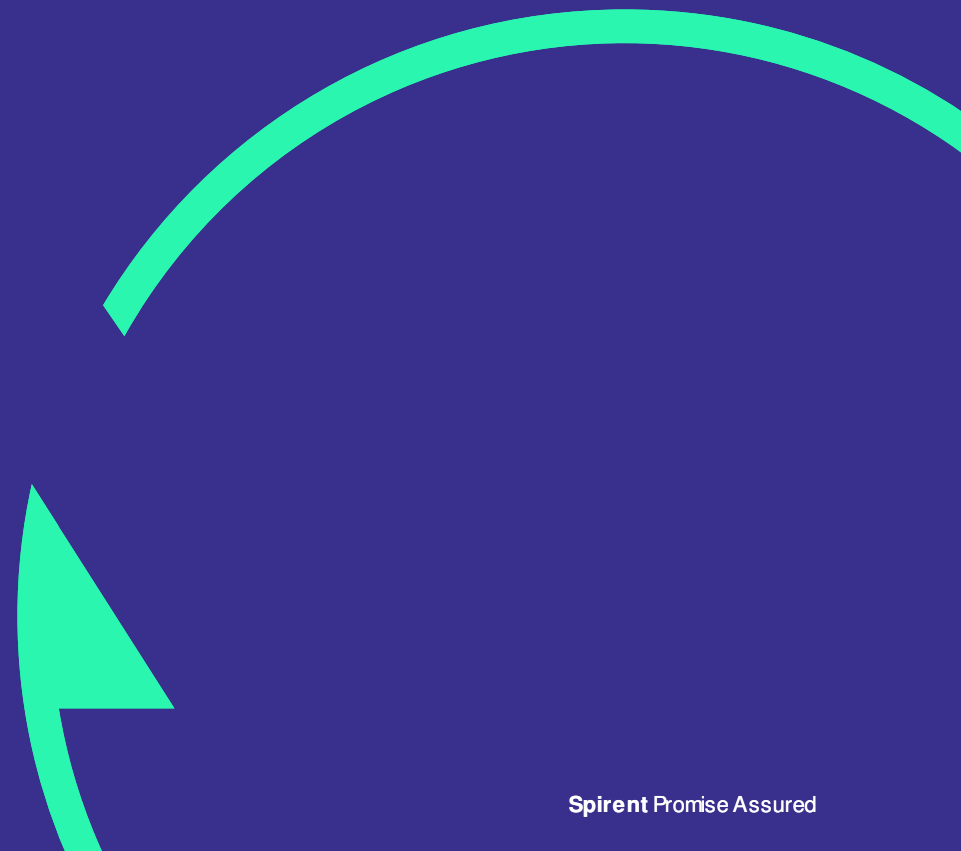
Spirent V2X Products Overview



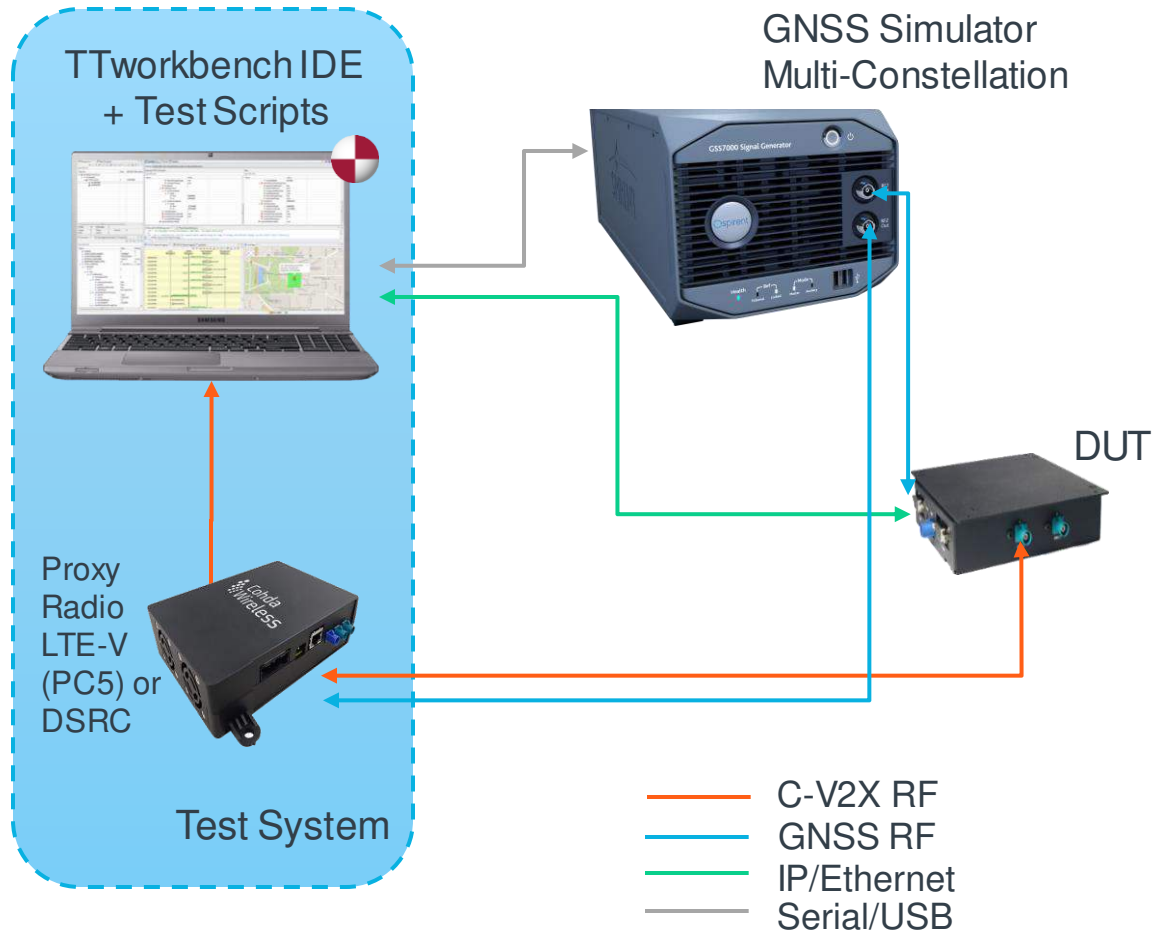
Solutions include other components, e.g. for simulated mobility (positioning & timing)



V2X Conformance Test Solution



Conformance Testing – TTworkbench Features



Common Test Platform: TTworkbench

- Standardized Test Notation & Test Architecture: TTCN-3
- Advanced Toolset for Test Management, Test Automation, Failure Analysis

Multi-Mode Support

- Wireless RF Mode: Proxy HW Device for radio (DSRC with different DCC profiles/LTE-V PC5)
- Wired Mode: Direct over Ethernet

All Test Suites Prepared for Full Test Automation via UDP (Upper Tester) / TCI Support

- TCIv3 Supported

Same Look & Feel Across Different RF Standards (DSRC or LTE-V PC5)

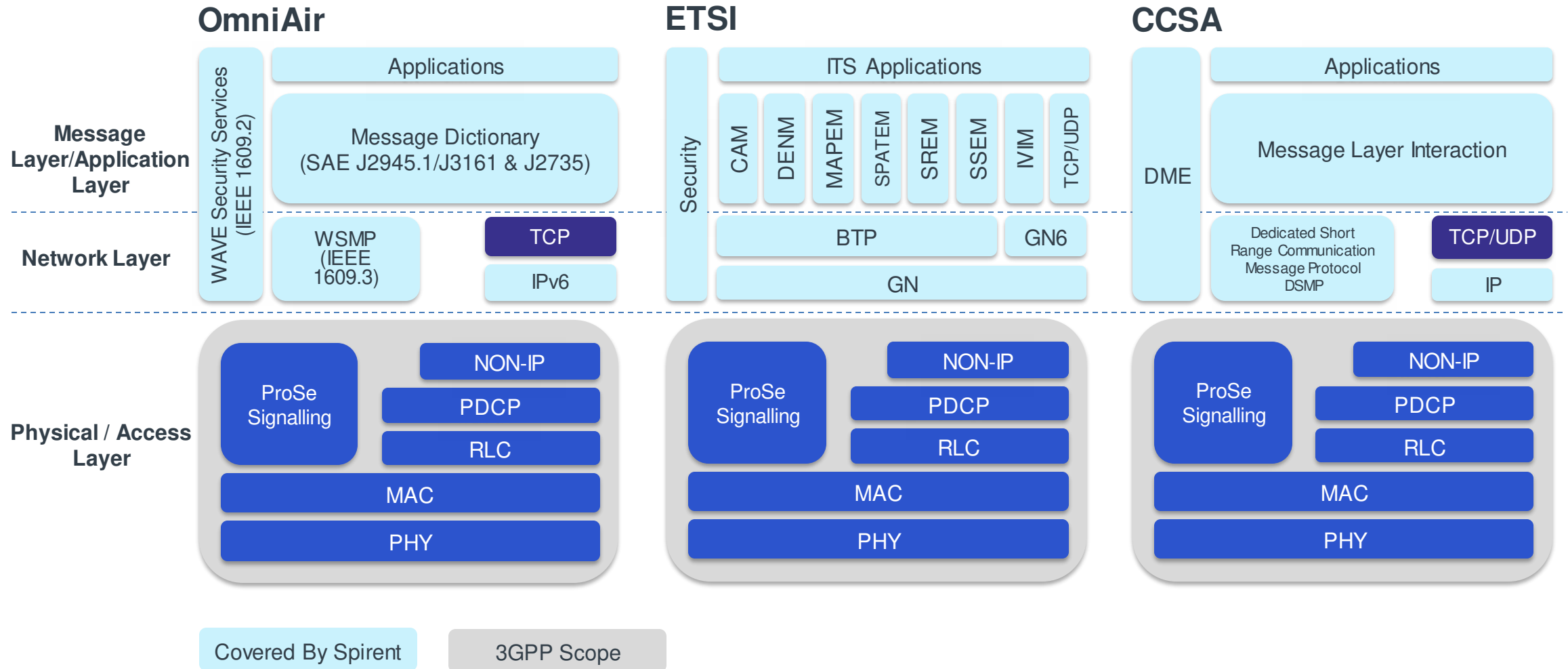
Available for all Regional Standards

- US WAVE
- EU ETSI ITS
- China ITS

Supports OBU & RSU Testing

Open Framework for Customized Message Set and Test Cases

Conformance Coverage



TTworkbench Test Suites: Look & Feel

The screenshot displays the TTworkbench Professional interface, divided into several key sections:

- Management (Top Left):** A table listing test cases and their execution status.

Test Case	Runs	INCONC/FAIL Action	Retries	Module
IEEE_1609_x_TestCases (runs on ttech's TTmanSe)				
WsmPacketValidation				
TC_16093_WSM_MST_BV_01	1	CONTINUE	0	IEEE_1609_3_Te...
TC_16093_WSM_MST_BV_01_01	1	CONTINUE	0	IEEE_1609_3_Te...
TC_16093_WSM_MST_BV_01_02	1	CONTINUE	0	IEEE_1609_3_Te...
TC_16093_WSM_MST_BV_02	1	CONTINUE	0	IEEE_1609_3_Te...
TC_16093_WSM_MST_BV_02_01	1	CONTINUE	0	IEEE_1609_3_Te...
TC_16093_WSM_MST_BV_02_02	1	CONTINUE	0	IEEE_1609_3_Te...
TC_16093_WSM_MST_BV_02_03	1	CONTINUE	0	IEEE_1609_3_Te...
TC_16093_WSM_MST_BV_02_04	1	CONTINUE	0	IEEE_1609_3_Te...
WsmTransmissionParameters				
TC_16093_WSM_ROP_BV_01	1	CONTINUE	0	IEEE_1609_3_Te...
TC_16093_WSM_ROP_BV_01_01	1	CONTINUE	0	IEEE_1609_3_Te...
TC_16093_WSM_ROP_BV_01_02	1	CONTINUE	0	IEEE_1609_3_Te...
TC_16093_WSM_ROP_BV_01_03	5	CONTINUE	0	IEEE_1609_3_Te...
TC_16093_WSM_ROP_BV_01_04	1	CONTINUE	0	IEEE_1609_3_Te...
TC_16093_WSM_ROP_BV_02	1	CONTINUE	0	IEEE_1609_3_Te...
TC_16093_WSM_ROP_BV_02_01	1	CONTINUE	0	IEEE_1609_3_Te...
TC_16093_WSM_ROP_BV_02_02	1	CONTINUE	0	IEEE_1609_3_Te...
TC_16093_WSM_ROP_BV_02_03	1	CONTINUE	0	IEEE_1609_3_Te...
TC_16093_WSM_ROP_BV_02_04	1	CONTINUE	0	IEEE_1609_3_Te...
- Test Data (Top Right):** Shows a match for 'MsgDEVtoUDP: mw_msgInd' at 12:32:44.043. It displays the expected TTCN-3 Template and the actual Data.

Name	Value	Name	Value
MsgDEVtoUDP	?	MsgDEVtoUDP	1476756012518270
time	?	time	
frame		frame	
wiFrame		wiFrame	
channelNumber	?	channelNumber	172
timeSlot	?	timeSlot	2
dataRate	?	dataRate	1
recvPwrAnt1	?	recvPwrAnt1	-40
recvPwrAnt2	?	recvPwrAnt2	0
data		data	03007F0A63DC86F3FAD6D6
match		(decoded)	
(decoded)		subtype	
subtype		nullN	
null		ve 3	
- Code Editor (Middle Right):** Displays a snippet of C code:


```
return FncRetCode {
    var FncRetCode v_ret := e_success;

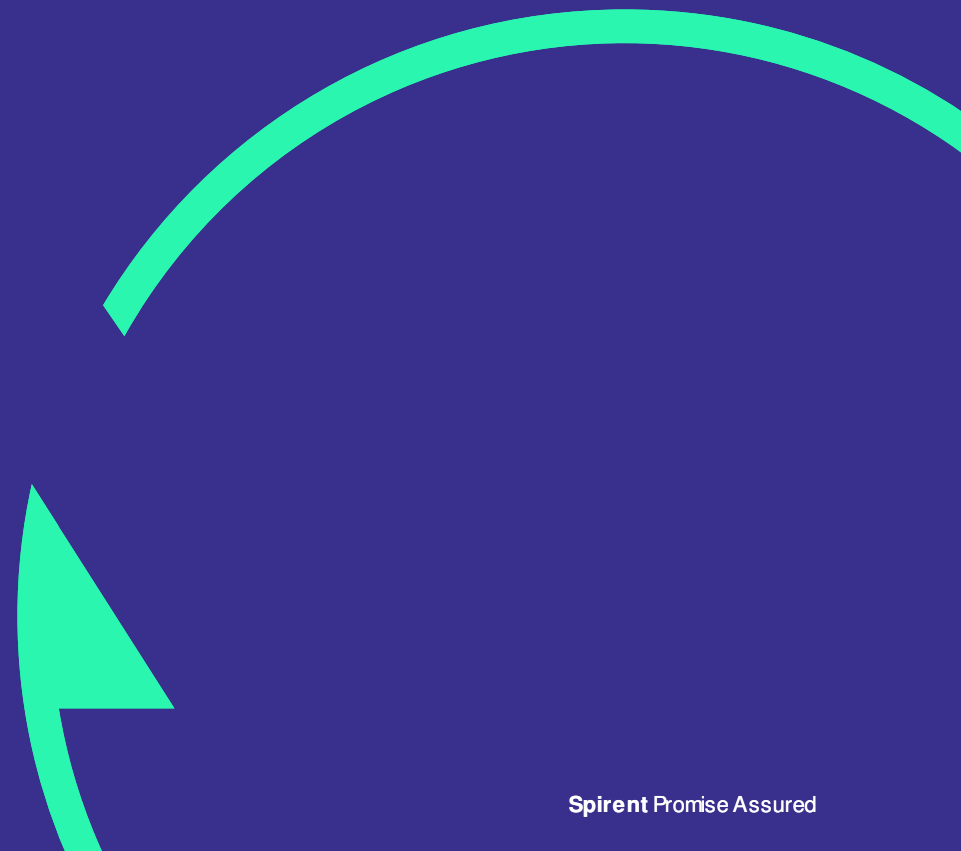
    tc_ack.start(p_waitTime);
    alt {
        [] !tPort.receive(
            mw_msgInd(
                p_data, ...

```
- Parameters (Bottom Left):** A table of test parameters.

Name	Value	Default	Description
Codecs			
DSRCProxyCodec OER1997 ASN.1 Codec	DSRC-Proxy	DSRC-Proxy	Generated ASN...
WSMCodec PER-BASIC-UNALIGNED:1997 AS			Generated ASN...
WSACodec PER-BASIC-UNALIGNED:1997 AS			Generated ASN...
TCICodec OER:1997 ASN.1 Codec	TCI	TCI	Generated ASN...
External functions			
WaveExtFnCs			WAVE External ...
Ports			
UDP Port Provider	IEEE_1609_3_Ty...	IEEE_1609_3_Ty...	Provides comm...
default			
UDP_LOCAL_PORT	5000	5000	Represents the l...
UDP_LOCAL_ADDRESS	"127.0.0.1"	"127.0.0.1"	The IP address ...
UDP_REMOTE_PORT	5001	5001	Represents the ...
UDP_REMOTE_ADDRESS	"127.0.0.1"	"127.0.0.1"	The IP address ...
>utPort			
>UDP_LOCAL_PORT	50001	5000	Represents the l...
>UDP_LOCAL_ADDRESS	"10.73.224.145"	"127.0.0.1"	The IP address ...
>UDP_REMOTE_PORT	30172	5001	Represents the ...
>UDP_REMOTE_ADDRESS	"10.73.224.156"	"127.0.0.1"	The IP address ...
UDP Port Provider	IEEE_1609_3_Ty...	IEEE_1609_3_Ty...	Provides comm...
default			
UDP_LOCAL_PORT	5000	5000	Represents the l...
UDP_LOCAL_ADDRESS	"127.0.0.1"	"127.0.0.1"	The IP address ...
UDP_REMOTE PORT	5001	5001	Represents the ...
- Graphical Logging (Bottom Right):** A sequence diagram showing the interaction between MTC (IEEE 1609...) and SYSTEM (IEEE 1609...).
 - 12:32:43.793: MTC sends TCIMsg to SYSTEM.
 - 12:32:43.794: SYSTEM receives TCIMsg and sends tc_ack(5.0) to MTC.
 - 12:32:43.822: MTC receives TCIMsg.
 - 12:32:43.824: MTC sends tc_ack(0.03) to SYSTEM.
 - 12:32:43.829: SYSTEM receives tc_ack(5.0).
 - 12:32:44.037: MTC receives MsgDEVtoUDP.
 - 12:32:44.038: MTC sends receive to SYSTEM.
 - 12:32:44.046: SYSTEM sends tc_ack(0.215) to MTC.
 - 12:32:44.047: MTC sends pass to SYSTEM with the message: "WSM with the correct version number indicating 3 was transmitted."
 - 12:32:44.053: MTC sends TCIMsg to SYSTEM.
 - 12:32:44.055: SYSTEM sends tc_ack(5.0) to MTC.
 - 12:32:44.061: MTC receives an unexpected message: "*** Received unexpected message. Ignoring! ***"
 - 12:32:44.079: MTC receives TCIMsg.

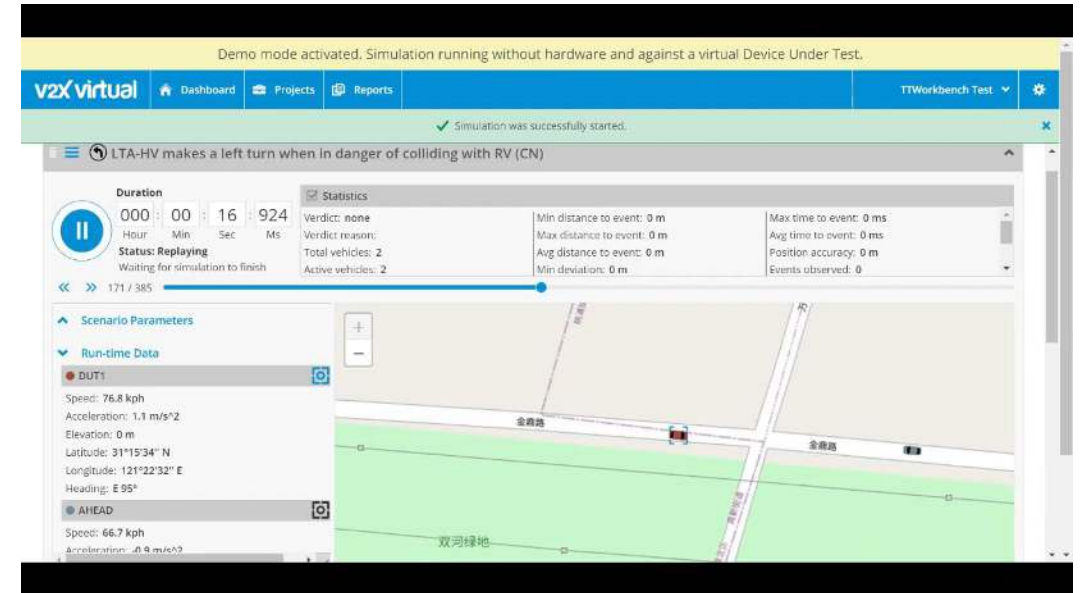


V2X Virtual: Functional and Performance Testing



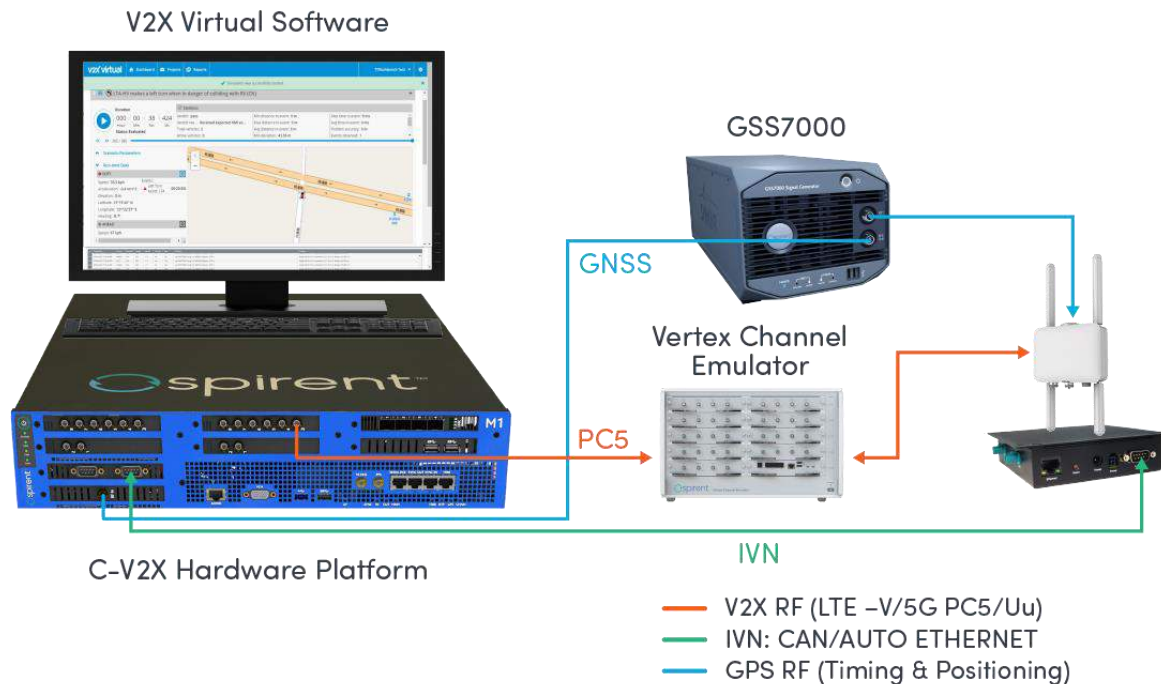
Value Proposition: Testing V2X Apps on the Bench

- Bringing field test to lab
 - No need to install multiple RSU reducing requirement for test site and making operation more convenient
- Baselining the results
 - Simulated test scenarios can be reused for on-road vehicles, allowing for comparison between simulations and real-world test results
- Precision
 - Testing systems can achieve high precision positioning and conduct scenario tests.
- Test large scale scenarios
 - On-road simulation testing can simulate large vehicles, verifying systems ability to handle large amount of data



Spirent V2X Virtual Solution

- C-V2X platform for functional & performance testing



Hardware

- Spirent M1 Appliance
- Multi-RF support (8 Radios)
 - PC5 (V2V, V2I, V2P)
 - Uu (V2N - Roadmap)
 - Multiple Radios realise the parallelism with transmission of signals with different strength, SNR
 - Enables large scale stress and performance testing

C-V2X Emulator Software

- Modular test and automation platform
- Conformance & functional test scenarios
- Open architecture for 3rd party functions (Traffic Sim, Vehicle Sim, GNSS Sim, Test Control)
- Built in protocol stack of different regions (China, US, EU)
- Integration with traffic scenario simulators – IPG CarMaker, Hexagon Virtual Test Drive

V2X Virtual

- Execute predefined test cases for V2X Day 1 applications. Easy interface for creating custom scenarios.
- Easy integration with external traffic simulators to create highly realistic virtual test-driving V2X scenarios
- Test V2X security features of the participating OBUs & RSUs

M1

- Dedicated C-V2X RF equipment with advanced timing accuracy – multi RF with 8 Radios
- In-vehicle Network and Rest-Bus simulation via CAN FD/ Automotive Ethernet for controlling and observing Device

GNSS

- Accurate position simulation for the V2X ECU under test using Spirent's GNSS simulator
- Also simulate various atmospheric conditions that can have an impact on the accuracy of the GNSS receiver of the ECU under test
- Supports upto 256 channels
- Signal accuracy of ± 3 mm pseudo range

Vertex

- Re-create realistic RF channel conditions on the bench using Spirent Vertex Channel Emulator integrated into the test bed

Complete V2X Scenario Emulation

Scenarios &
Test Cases

V2X Scenarios Test Library

V2X Scenarios Emulation Software



Protocol
Emulation

V2X Protocols Interaction Emulation
(Network, Message, Security)

Low Layer
Emulation

GNSS Emulation

In-Vehicle BUS

V2X Communication

V2X Channel Emulation

Supported Scenarios in V2X Virtual

VRUCW: Vulnerable Road User Collision Warning

FCW: Forward Collision Warning

EBW: Emergency Brake Warning

EVW: Emergency Vehicle Warning

ICW: Intersection Collision Warning

GLOSA: Green Light Optimal Speed Advisory

RLVW: Red Light Violation Warning

SLW: Speed Limit Warning

CLW: Control Loss Warning

AVW: Abnormal Vehicle Warning

HLW: Hazardous Location Warning

IVS: In-Vehicle Signage

TJW: Traffic Jam Warning

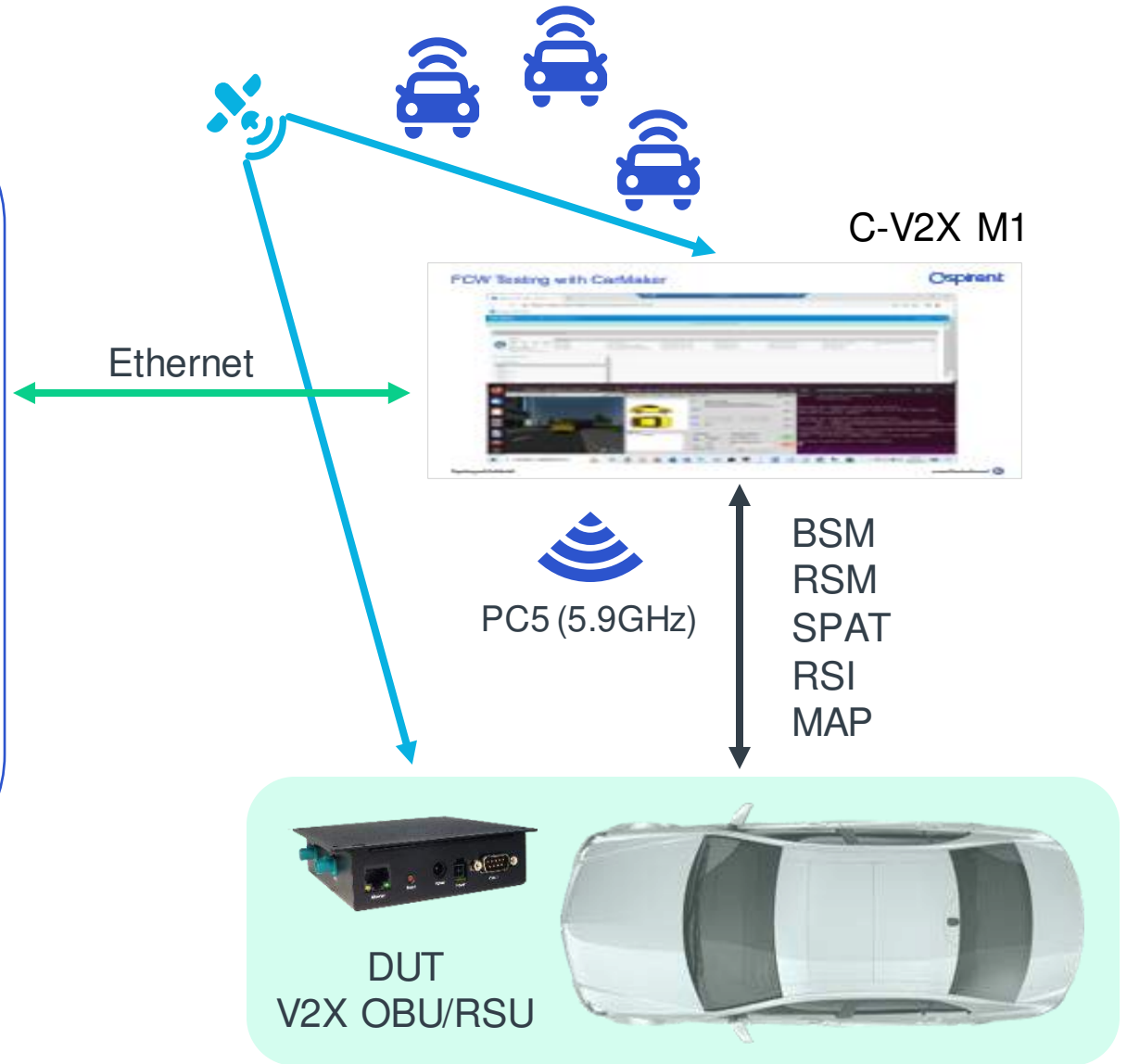
VNFP: Vehicle Near-Field Payment

The screenshot displays the 'Testing Scenarios' section of the V2X virtual interface. It features a grid of 18 scenario cards, each containing an icon, a title, and a brief description of the scenario's purpose. The scenarios are organized into three rows and six columns. The interface also includes a navigation bar at the top with 'v2x virtual', 'Dashboard', 'Projects', and 'Reports' tabs, and a user profile 'V2Virtual User'.

C-V2X HIL – Functional Scenario Simulation



Scenario Simulation Software: LTA



FCW Testing with CarMaker

The image displays a multi-window desktop environment. The top window is a web browser showing the V2X virtual simulation interface. The browser address bar shows `https://10.67.100.41:30221/simulation/1896713078`. The V2X virtual interface includes a navigation bar with 'Dashboard', 'Projects', and 'Reports'. A green notification bar states 'Simulation was successfully started.' The main content area shows simulation details for 'FCW-Same Lane directly in front (CN)'. A timer indicates a duration of 00:00:20.000. A statistics table shows various metrics such as 'Active vehicles: 0', 'Min distance to event: 0 m', and 'Position accuracy: 15.05 m'. Below the statistics are sections for 'Scenario Parameters' and 'Run-time Data'.

The bottom window shows the CarMaker software interface. The left pane displays a 3D simulation of a yellow car on a road. The right pane contains configuration options for the simulation, including 'Car: DemoCar_FCW', 'Trailer: -', 'Tires: Ex..RT_195_65R15', and 'Load: 0 kg'. The 'Simulation' section shows 'Perf.: realtime', 'Status: (1.0x)', 'Time: 20.0', and 'Distance: 328.47'. The 'Storage of Results' section shows 'Mode: collect only' and 'Buffer: 33.6 MB, 482 s'. 'Start' and 'Stop' buttons are visible.

The bottom right window is a terminal window showing the following output:

```
PROXY -> V2X Virtual: Terminating
Simulation done

Awaiting new simulation load from V2X Virtual
V2X Virtual -> PROXY: received 4 bytes from 10.67.100.41:63386
Received termination request

Awaiting new simulation load from V2X Virtual
V2X Virtual -> PROXY: received 83 bytes from 10.67.100.41:39875
buf = /home/spirentdemo/Downloads/CM_Demo/Data/TestRun/FCW_Same_Lane_Directly_In_Front_CN
ScriptControl: LoadTestRun /home/spirentdemo/Downloads/CM_Demo/Data/TestRun/FCW_Same_Lane_Directly_In_Front_CN 1
PROXY -> V2X Virtual: sending 4 bytes to 10.67.100.41:39875

Awaiting simulation start from V2X Virtual
```

Fading – Why this is important in C-V2X testing



Fading – Variation of attenuation of the signal due to multipath propagation or presence of obstacles.

- Signal attenuation
- Doppler deviation
- Signal arrival phase difference

Its important to test safety related data messages are received even under poor transmit conditions and if the tx and rx adhere to the minimum standards.

The Vertex channel emulator operates in several different fading modes.

Channel Models

Classical Channel Models: These channel models are suitable for narrowband technologies.

Geometric Channel Models: These channel models are suitable for wide bandwidth, multiple antenna technologies.

MIMO OTA Channel Models: These channel models are suitable for MIMO over the air chamber tests.

Realism is Key: Multi-RF vs. Single-RF



Typical Multi-RV Scenario:
Each RV needs one dedicated
RF Channel

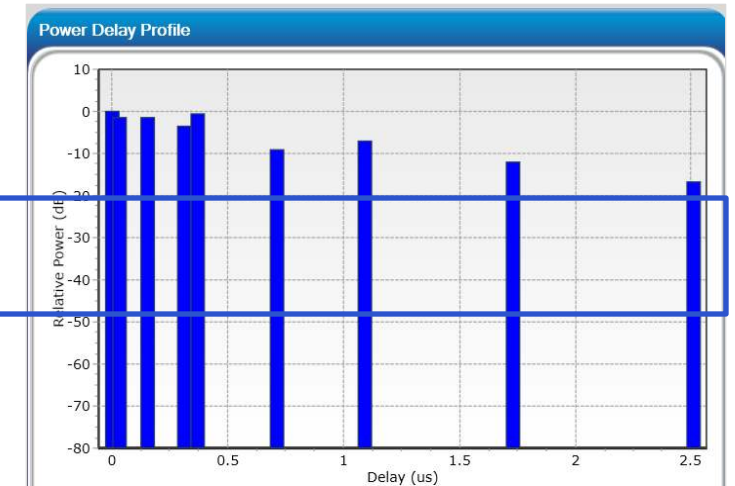
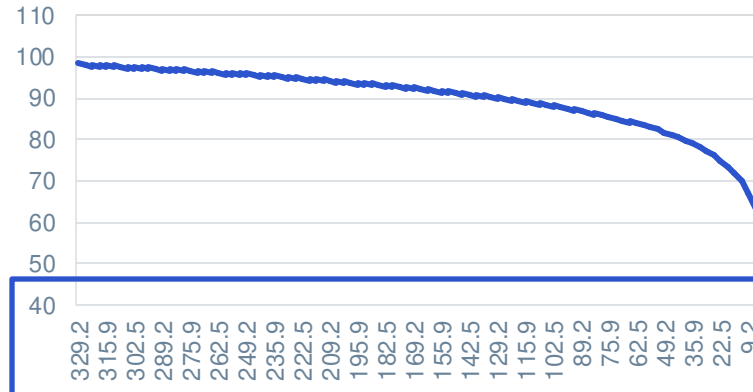


Channel Scenarios Emulation



Build Channel Model based on Scenario Parameters

Pathloss(dB) vs Distance(meter)

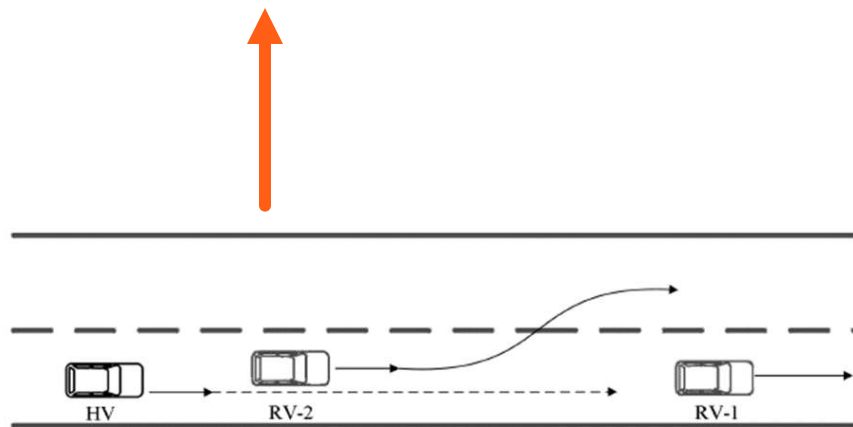


Channel Model

Interactive Propagation Conditions Editor - #1: CV2X_EVA_120kmph

Doppler Preference: Velocity Velocity (km/h): 120 Bulk Delay (us): 6.5 Fading Parameters Fading Mode: Classical Channel Model

Path	Fading Type	Fading Doppler (Hz)	Fading Doppler Vel. (km/h)	Cluster Modeling	Relative Path Loss (dB)	Delay Mode	Delay value (us)	Minimum (us)	Maximum (us)	Rate of Dispersion
1	Rayleigh	657.68	120	<input type="checkbox"/>	0	Fixed	0			
2	Rayleigh	657.68	120	<input type="checkbox"/>	1.5	Fixed	0.03			
3	Rayleigh	657.68	120	<input type="checkbox"/>	1.4	Fixed	0.15			
4	Rayleigh	657.68	120	<input type="checkbox"/>	3.6	Fixed	0.31			
5	Rayleigh	657.68	120	<input type="checkbox"/>	0.6	Fixed	0.37			
6	Rayleigh	657.68	120	<input type="checkbox"/>	9.1	Fixed	0.71			
7	Rayleigh	657.68	120	<input type="checkbox"/>	7	Fixed	1.09			
8	Rayleigh	657.68	120	<input type="checkbox"/>	12	Fixed	1.73			
9	Rayleigh	657.68	120	<input type="checkbox"/>	16.9	Fixed	2.51			



Vertex

Integration Test Result

- Testing result

- The chart shows the distance between HV and RV-1 when HV(DUT) send out the first warning message.
- When adding channel emulation, the distance is shorter, which means that the brake distance may not be enough and cause the collision.

- Conclusion

- When the OBU has big message loss during V2X applications, it will greatly influence the function and performance of the DUT.

Test Time	HV speed=40km/h		HV speed=120km/h	
	Without Channel Emulation	With Channel Emulation	Without Channel Emulation	With Channel Emulation
1	48.29	22.41	137.21	31.63
2	48.36	18.97	137.8	37.46
3	47.59	33.39	136.88	42.15
4	48.15	48.4	136.91	41.09
5	47.78	18.16	131.38	42.97
6	48.66	25.94	130.18	50.68
7	46.32	21.5	136.26	34.06
8	47.12	21.94	137.32	32.54
9	49.22	39.38	135.55	46.24
10	48.55	31.93	133.15	40.85
AVG	48.004	28.202	135.264	39.967

Unit: meter

Complete Scenario Integrated V2X HIL

Functional Scenarios

- FCW
- ICW
- LTA
- BSW/LCW
- ...



Positioning Scenarios

- Urban canyon
- Tunnel
- High bridge
- Open area
- ...

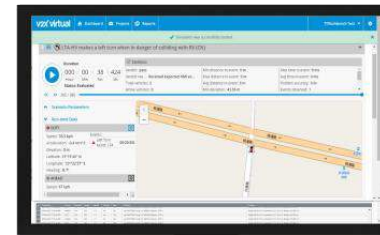


Channel Scenarios

- Urban roads
- Express
- Roundabouts
- Indoor parking
- ...



V2X Virtual Software



C-V2X Hardware Platform

GSS7000



GNSS

Vertex Channel Emulator

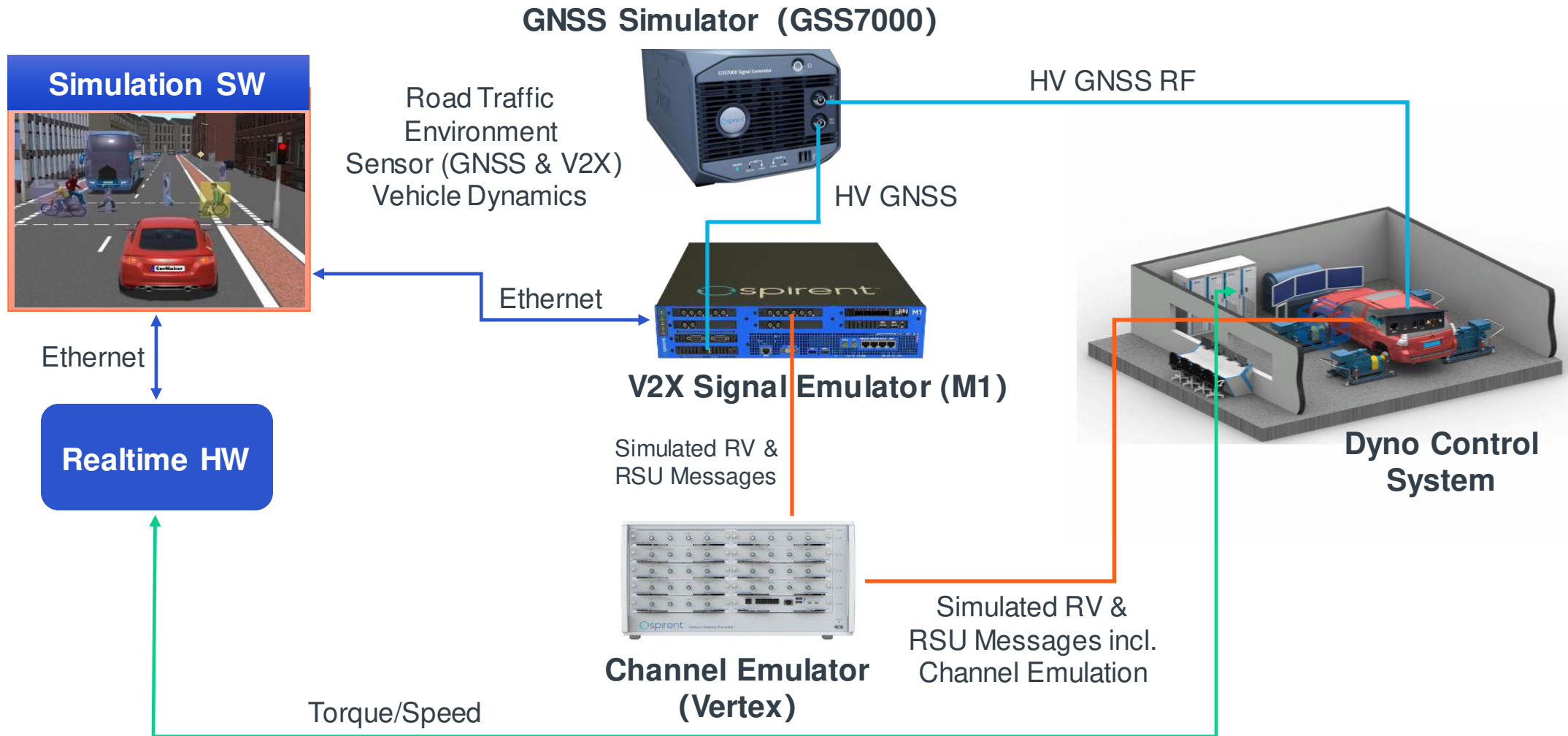


PC5

IVN

- V2X RF (LTE -V/5G PC5/Uu)
- IVN: CAN/AUTO ETHERNET
- GPS RF (Timing & Positioning)

Complete Scenario Integrated V2X VIL(with Dyno)



- Webpage: [Connected Vehicles, V2X & C-V2X](#)
- Datasheet: [V2X Virtual Test System](#)
- Blog: [Putting V2X Drive Tests in the Fast Lane](#)
- Webinar: [Automotive Ethernet & V2X Validation](#)
- White Paper: [How should the automotive industry test V2X systems?](#)
- Solution Brief: [V2X Testing](#)

- For more details, please contact support@spirent.com

AUTOMOTIVE

Putting V2X Drive Tests in the Fast Lane

By: Bhargavi Srinivasan
June 28, 2023 · 5 min read

Test, Validate and Benchmark Connected Vehicles, V2X & C-V2X

Bring your connected devices to market faster by testing real-world traffic scenarios in the lab.

Overview | Testing Approaches & Best Practices | V2X Standardization | Featured Resources | Features & Datasheets

OVERVIEW

Reduce Expensive and Time-consuming Field Testing

DATASHEET

Spirent V2X Virtual Test System

Overview

Spirent V2X Virtual Test System is a solution for accelerating testing and for functional validation and performance testing of devices and systems implementing V2X applications. The integrated and scalable development and testing environment is designed for testing all applications of any stage of the product development cycle, from early prototyping to pre-production.

The solution supports the evaluation of safety-critical scenarios in the laboratory as a virtual environment that replicates construction project-level behavior. This can help optimize costs and only test when necessary, thus increasing efficiency and speed.

Benefits

- Speed to market in the lab
- Prohibit and isolate test vehicles
- Open V2X test environment and testing flexibility on the open OTC (Open Testbed) in the Cloud (OTC) test environment
- Reduce development, operation and maintenance costs
- Supporting the efficient testing and validation of V2X safety applications
- Flexible, scalable, and secure V2X test environment for C-V2X

V2X Components

- V2X Protocol (IEEE 802.11p) Emulation
- Flexible test platform for functional and performance evaluation of V2X and V2V safety applications
- Customizable Functional Test scenarios
- Open architecture for V2X applications (Traffic Sim, MANET Sim, C-ITS Sim, Test Control)
- Scalable and distributed Cloud Testbeds for:
 - C-ITS (C-ITS-3GPP-LTE-MANET)
 - C-V2X (C-V2X-3GPP-LTE-MANET)
- 4G LTE Testbed
- 5G NR Testbed

V2X Virtual Software

C-V2X Hardware Platform

- V2X BY (LTE-V2X POC) (U)
- 5G NR C-V2X (5G NR V2X)
- 4G LTE (Orange & Red)

WEBINAR

Automotive Ethernet & V2X Validation

Get insights on standardized Automotive Ethernet ECU, TSN, and V2X communication testing.

The logo features a circular icon on the left composed of three curved arrows forming a clockwise cycle. To the right of this icon is the word "spirent" in a lowercase, rounded, sans-serif font. A small "TM" trademark symbol is positioned at the top right of the letter "t".

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