Application Note

C-V2X SCENARIO SIMULATION WITH R&S CMW500 WIDEBAND RADIO COMMUNICATION TESTER

Products:

- R&S® CMW500
- R&S® CMW-KAX550
- R&S® SMBV100B
- Vector® CANoe
- Vector® CANoe.Car2x

Rainer Wagner | GFM341 | Version 2e | 12.2021

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https://www.rohde-schwarz.com/appnote/GFM341

Contents

1 Overview

This application Note is based on CMW500, SMBV100B and Vector CANoe.Car2x Software and guides to how to simulate the specific Cellular Vehicle-to-Everything (C-V2X) wireless environment in respect to road transport scenarios and transmitted messages around the Device Under Test (DUT) like a Telematics Control Unit (TCU). It shows how to verify and validate the C-V2X application of the DUT in laboratory environment. The virtual simulation scenario is not limited to the requirements of CSAE53-2017 specification, and it could be modified by user according to this operating guide with CANoe.

Vehicle-to-everything (V2X) is a new generation of information and communications technologies that connect vehicles to everything. The objective of V2X is to increase road safety and manage traffic efficiently.

C-V2X is designed to offer low-latency vehicle-to-vehicle (V2V), vehicle-to-roadside infrastructure (V2I) and vehicle-to-pedestrian (V2P) communications services to add a new dimension to future advanced driver assistance systems (ADAS). C-V2X as one communications standard defined by 3GPP in Release 14 uses LTE technology as the physical interface for communications. The standard describes two types of communications. The vehicle-to-network (V2N) communications type, exploits the cellular Uu interface, uses traditional cellular link to enable cloud services to be integrated into end-to-end solutions, e.g. to allow road and traffic information for a given area to be distributed to the vehicles.

The second type is referred to as direct or PC5/Sidelink (V2V, V2I, V2P) communications, where data transmission takes place over the PC5 interface. In that type, C-V2X does not necessarily require a cellular network infrastructure. It can operate without a SIM and without network assistance and uses GNSS as its primary source for time synchronization.

Verifying system functionality and performance exclusively by field testing in a real-world environment can be time-consuming, costly and very challenging. Requirements regarding functionality, and consequently the required assistance functions, are constantly changing. Due to this fact, test solutions are needed during the development and introduction phase to verify compliance with the standards. The PC5 direct communications type allows exchange of time sensitive and safety relevant information. Using a mobile communication tester like the R&S® CMW500 together with a C-V2X scenario simulation tool delivers reproducible test scenarios. This is essential for the standardization of verification processes for C-V2X in order to obtain reliable and comparable results, and it helps to demonstrate that end-to-end functionality between two C-V2X devices from different vendors works properly.

2 Test solution

The R&S®CMW500, R&S®SMBV100B, along with Vector CANoe.Car2x software provides the necessary tools to develop use cases and verify end-to-end C-V2X functionality on the PC5/Sidelink. The tool set supports the Chinese, U.S., and European intelligent transportation system (ITS) stack versions, making it easier for teams who are working on TCUs that will end up inside vehicles in all three regions. The R&S®CMW500 uses a C-V2X software package to simulate the 3GPP stack including the physical layer in order to transmit and receive data over the PC5 radio interface (see Figure 1).

2.1 Simulation, Development and Test of V2X-based Communication Applications

The V2X application testing combines emulation of the V2X scenario described by higher layers such as the ITS profiles with the radio protocol including RF layer emulation to test the RF link in combination with the

ITS application. The R&S®CMW500 option R&S®CMW-KAA550 C-V2X LTE application adapter from the LTE V2X Test Suite R&S® CMW-KAX550 links the Vector test tool CANoe with the RF connectivity emulated by the R&S®CMW500 mobile radio tester (see Figure 1).

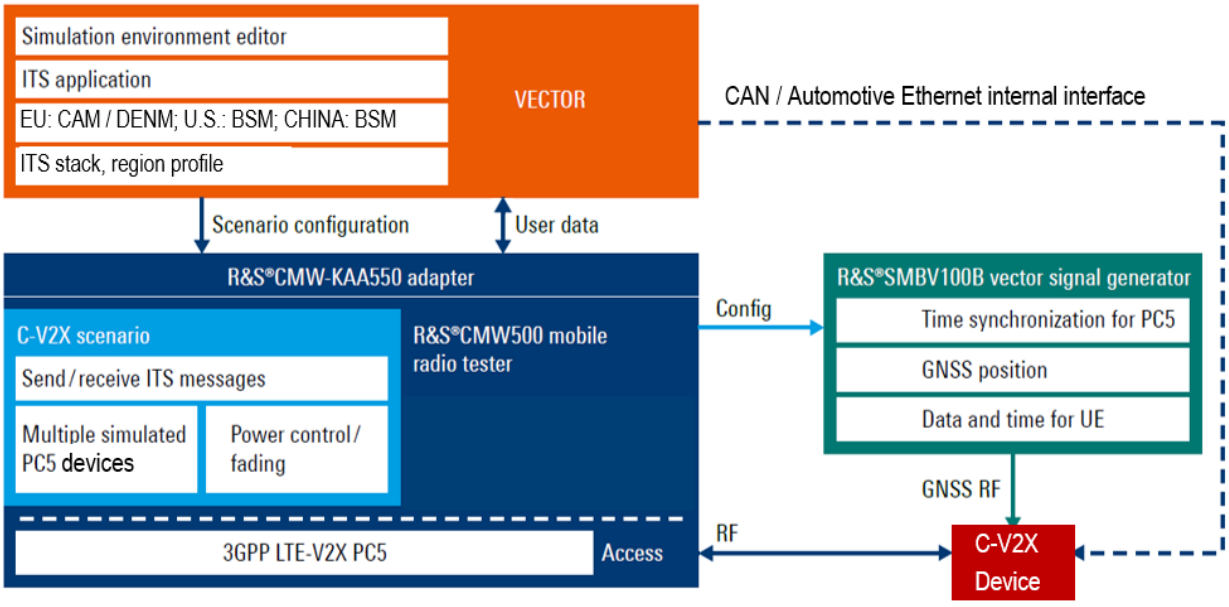


Figure 1 : C-V2X application and RF test solution.

The Vector's CANoe.Car2x is a software tool for development, testing and analysis of entire ECU networks and individual ECUs. It supports the entire development process – from planning to startup of entire distributed systems or individual ECUs. CANoe's versatile functions and configuration options are used by network designers, developers and test engineers at OEMs and suppliers. Time-critical sequences are processed in the real-time area. The CANoe option .Car2x is particularly suitable for application and function development of ECUs that receive their information on the basis of C-V2X application messages. CANoe .Car2x offers a range of functions designed to configure and run traffic scenarios so that the functions of the ECU can be tested comprehensively. This allows you to stimulate your C-V2X capable TCU according to the situation and test the implemented functions in a targeted manner. The tool that is completely adapted to the requirements of the C-V2X domain. Therefore CANoe .Car2x supports the most common standards and protocols published by IEEE (US), ETSI (EU) and CCSA (China) worldwide. This includes application messages such as CAM, DENM, SPaT, MAP, IVIM and BSM, as well as the underlying protocols such as GeoNetworking for the EU, IEEE 1609 (WAVE) for the US and DSRC Short Message Protocol (DSMP) for China.

The incoming bus data is read via a bus interface, provided with a time stamp there, and then processed promptly. Transmission of data to the bus also takes place in the real-time area. Users can create and simulate detailed traffic situations to verify C-V2X connectivity including security and certificate management for the intended application. An easy to handle graphical scenario editor helps users create traffic scenarios. When a scenario is started CANoe .Car2x generates the corresponding ITS communications messages based on the configured test scenario using the relevant ITS stack variant for the target market (North America, Europe, China) inline with specifications.

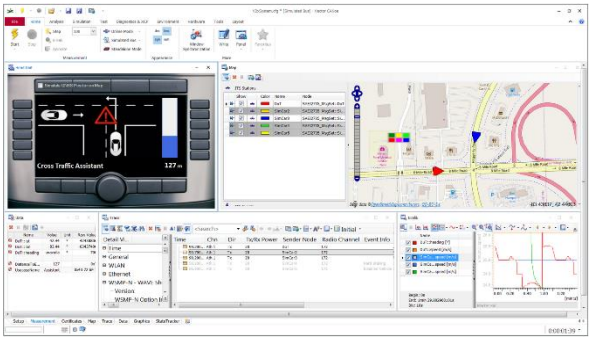
The messages and route information for that scenario are forwarded to the R&S®CMW500 and the SMBV100B via the R&S®CMW-KAA550 C-V2X LTE application adapter for Vector which is included in the CMW® -KAX550 LTE V2X Test Suite, providing the radio access layer to the DUT. This allows stimulating a TCU in line with the particular situation and to test the implemented functions such as:

- ► Intersection Collision Warning (ICW）
- ► Emergency electronic brake light (EEBL)
- ► Left-turn assist (LTA)
- ► Intersection movement assist (IMA)
- ► Congestion control – stimulated with multiple simulated cars

2.2 Brief introduction of the used instruments and tools

R&S®CMW500 functional radio communication tester that provides signaling test solutions for multiple technologies like LTE, WCDMA, GSM, WLAN, Bluetooth etc. It provides high quality, customized, automated test environment for functional tests. It enables developers and test teams to simulate radio access networks and includes a fully integrated end-to-end data solution. R&S®CMW500's RF hardware supports all 3GPP-defined bandwidths up to 6 GHz. The R&S®CMW500 offer dedicated measurement for C-V2X testing using multiple test scenarios to verify trans-mission and reception of C-V2X direct communications (PC5) based on 3GPP Release 14.

The R&S® SMBV100B vector signal generator provides a frequency range from 8 kHz to 3 GHz or 6 GHz. It supports signal generation for all major digital communication standards including 5G NR, LTE, and WLAN. It also supports GNSS simulation with support for GPS, Glonass, Galileo, BeiDou and QZSS/SBAS



CANoe from Vector is the comprehensive software tool for development, test and analysis of individual ECUs and entire ECU networks. It supports network designers, development and test engineers throughout the entire development process – from planning to system-level test. The option .Car2x is particularly suitable for application and function development of ECUs that receive their information on the basis of V2X application messages. The option Car2x offers a range of functions designed to configure and run traffic scenarios so that the functions of the ECU can be tested comprehensively. This allows you to stimulate your Car2x control unit according to the situation and test the implemented functions in a targeted manner.

3 Test setup for the V2X simulation system

Figure 2 shows the necessary components for the V2X application testing:

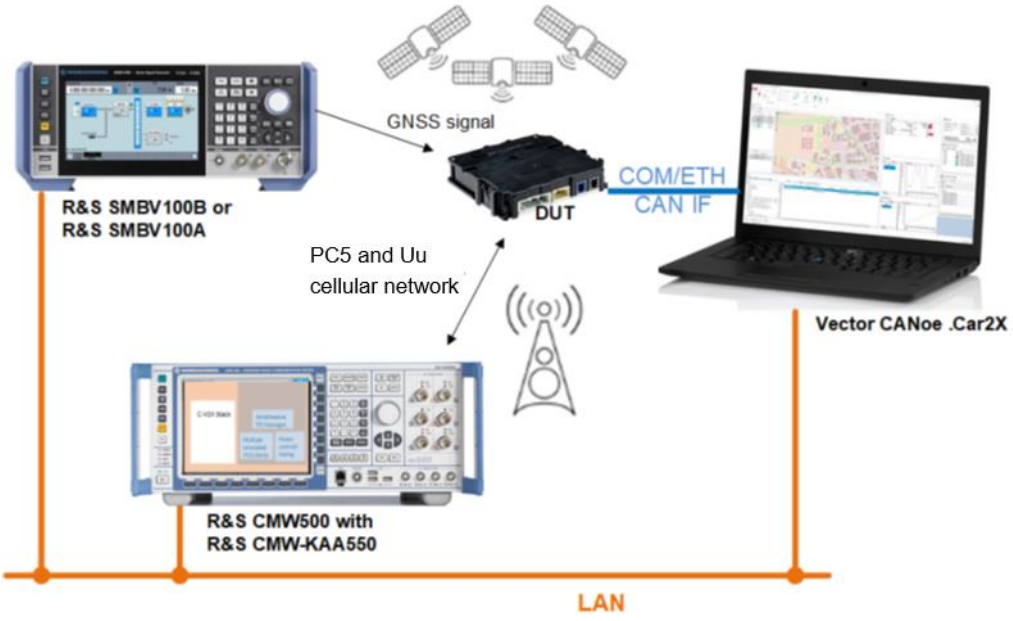


Figure 2: general connection of components for the C-V2X simulation system

The C-V2X simulation system consist of the following components:

- R&S® CMW500: simulates multiple vehicles and covering the access layer（PHY， MAC， PDCP, RLC).
- R&S® SMBV100B: simulates the GNSS signal, which is used by DUT for time synchronizing and navigating.
- Vector CANoe software with Option Car2x：used for network, transport and application layer tests of the ITS protocol stack. It can also be used to simulate kinds of C-V2X application scenarios.
- PC: runs the Vector CANoe .Car2x software. The performance of the test solution depends mainly on the right PC configuration. The recommended configuration will follow in the next update of this application note.

3.1 Hardware setup

3.1.1 R&S Instrument connection

Figure 3 shows the necessary rear panel connections between the R&S® CMW500 and the with an R&S® SMBV100B:

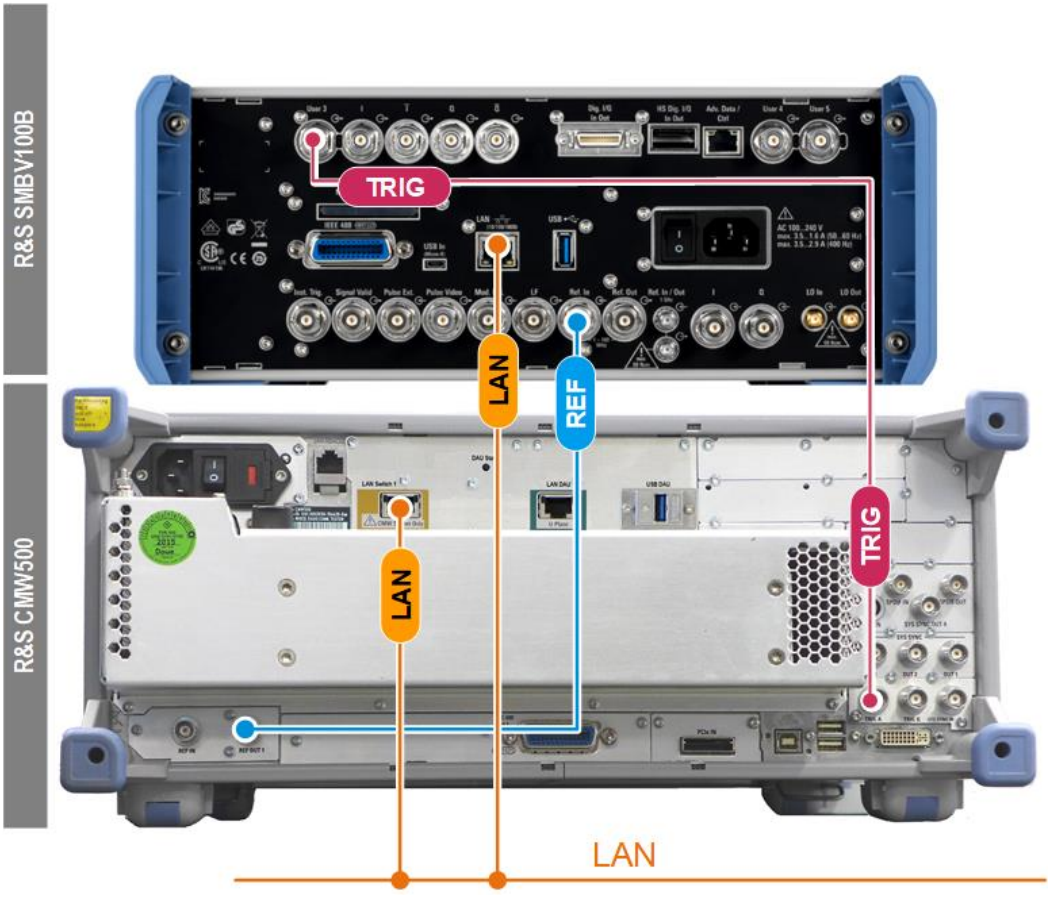


Figure 3: Rear panel connections with R&S SMBV100B

REF = Reference frequency (10 MHz)

LAN = Local area network connections

TRIG = Trigger; synchronization

The R&S®CMW500, R&S® SMBV100B and PC communicate via a gigabit Ethernet connection. The R&S®CMW500 is the master for reference frequency ("REF OUT1") and trigger. The two signals synchronize the R&S® SMBV100B via the connectors Ref. In and User 3.

- ► Connect the R&S® CMW500 *TRIG A* port with the R&S® SMBV100B *User3 port*
- ► Connect the R&S® CMW500 SWITCH port with R&S®SMBV100B LAN Port,
- ► Connect the Vector CANoe.Car2x PC also via LAN

3.1.2 Device under test connection

Figure 4 shows the front panel connections of the DUT with the R&S® CMW500 and the R&S®SMBV100B:

Figure 4: Front panel RF connections with R&S SMBV100BSoftware setup

DUT = device under test, typically a TCU

RF GNSS = RF connection for the positioning satellite signal

RF V2X = LTE V2X RF connection (PC5)

- ► Connect the DUT to the bidirectional "RF 1 COM" connector on the front panel of the R&S® CMW500.
- ► For GNSS signals, connect the PC5 interface of the DUT to the RF 50 Ω output connector on the front panel of the R&S® SMBV100B.

3.1.3 CMW500 Adapter configuration

- ► On the R&S® CMW500 start the R&S® CMW-KAA550 C-V2X application adapter and select the folder *Scn Execution parameters*
- ► Configure the IP address or UDP ports of the R&S® SMBV100B and the CANoe.Car2x PC (Figure 5).

  Example: SMBV100B IP: 10.33.0.67, CANoe.Car2x PC IP: 172.22.1.240
- ► Choose the right settings for the GNSS Configuration (Figure 5)

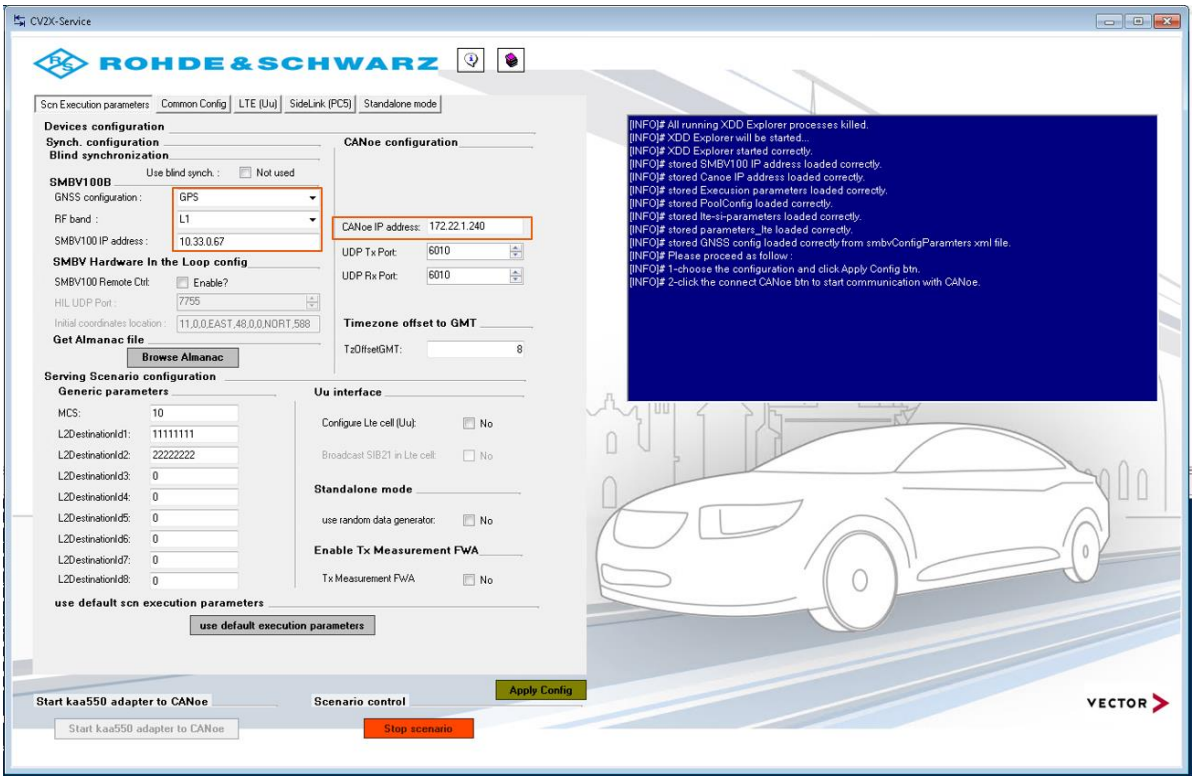


Figure 5: Configuration of Scn execution parameters

► Choose the *Common Config* folder and set pools configuration compatible to the used DUT (example see Figure 6)

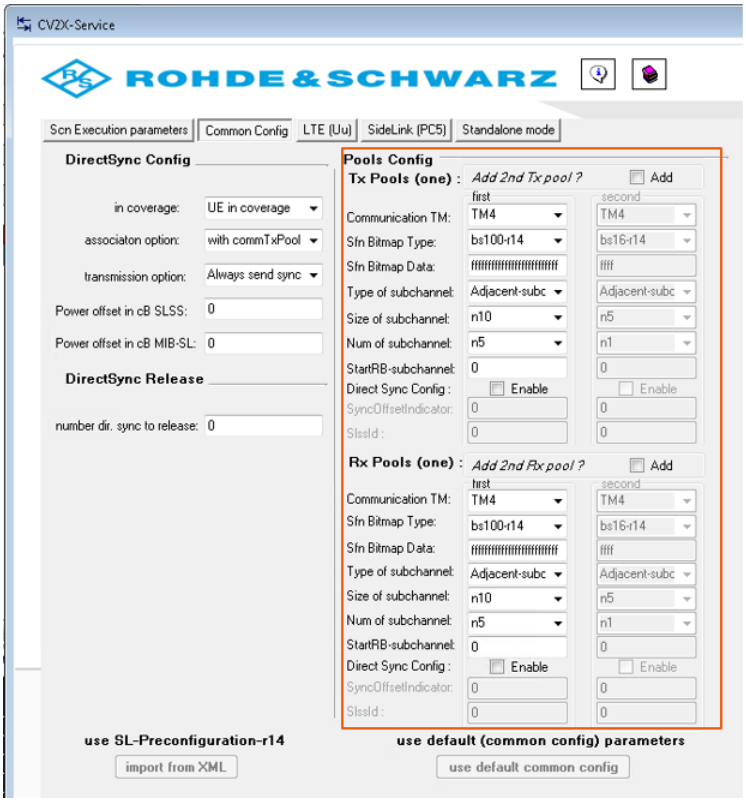


Figure 6 DUT pools configuration

► Choose the *SideLink (PC5)* folder and configure the PC5 parameters of the DUT (see example in Figure 7Figure 7)

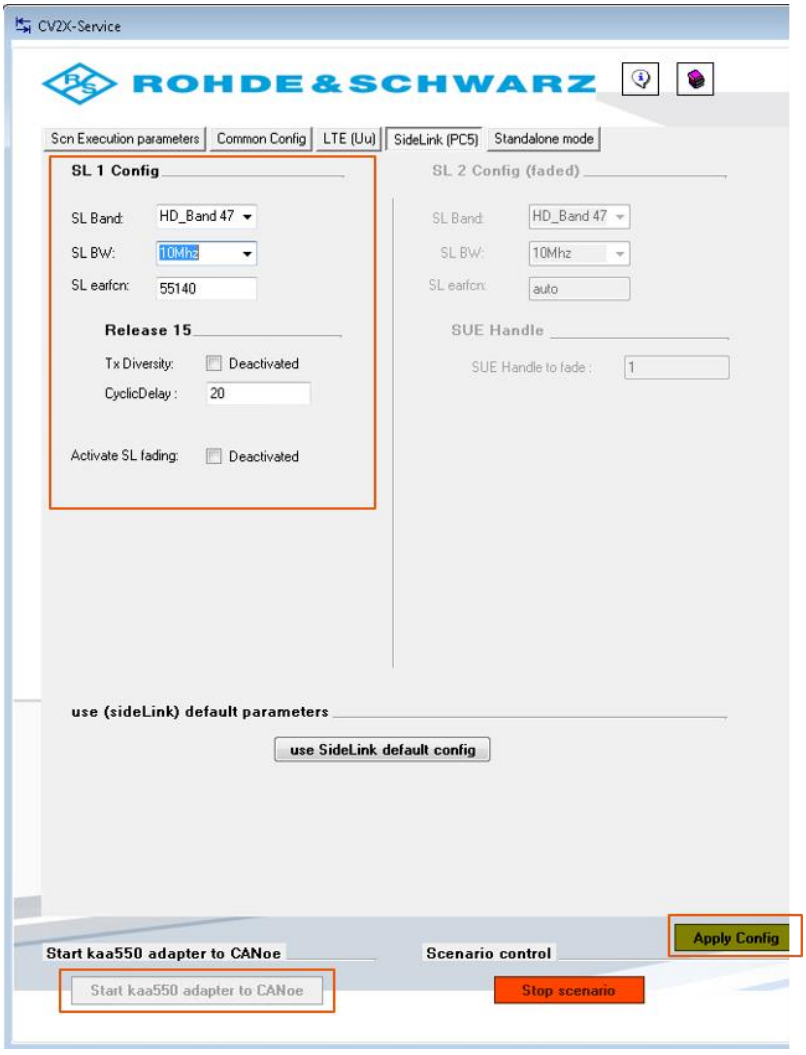


Figure 7: PC5 configuration

► After all the parameters are filled in, Apply Config and Connect CANoe (Figure 7)

4 Creation of a V2X virtual test scenario

4.1 Scenario definition – example intersection collision warning

Intersection Collision Warning (ICW) means, that the Host Vehicle (HV) is approaching an intersection and there is a risk of collision with a Remote Vehicle (RV), the ICW application will alert the driver of the HV. This application is applicable to the warning of collision risk at the intersection of ordinary roads and highways in urban and suburban areas, the entrance of ring road, the entrance of expressway and other intersections.

4.2 Scenario description - intersection collision warning

Intersection collision warning mainly includes warning for vehicles in the area on the left or right of the intersection (Figure 8). HV can have two states of starting and driving, so it can be composed of four or more scenarios. The RV (left of intersection) and HV (starting at the intersection) scenarios are selected to described here.

- HV stops at the intersection, RV-1 drives to the intersection from the left side of HV, and the sight of HV may be blocked by RV-2 that stopped at the intersection;
- HV and RV-1 should have CV2X wireless communication capability. Whether RV-2 has CV2X wireless communication capability does not affect the effectiveness of the scene;
- when the HV is starting to enter the intersection, the ICW application would put out an early warning to the HV driver to remind the driver of the risk of collision with the incoming lateral vehicle RV-1;
- the time of warning shall ensure that HV drivers have enough time to avoid collision with RV-1 after receiving the warning.

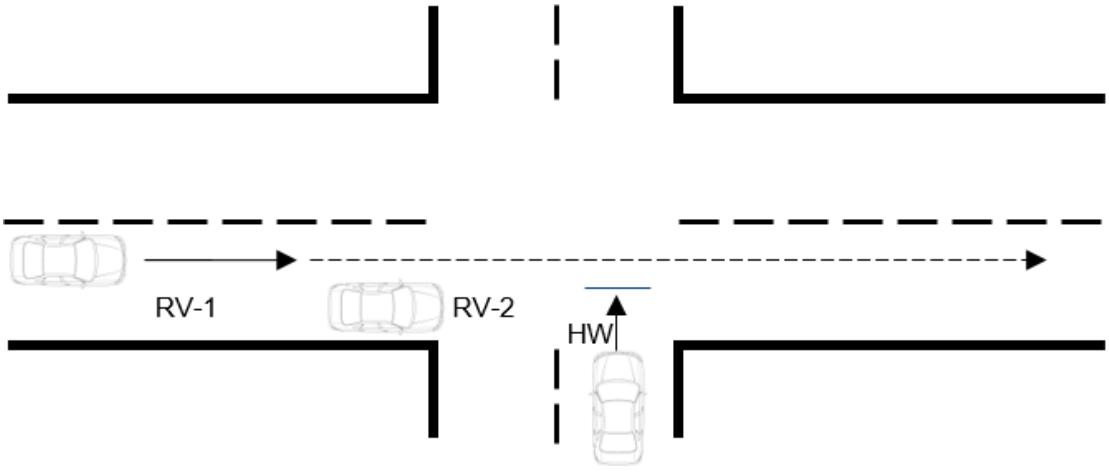


Figure 8: Scenario description

4.3 Scenario Creation -CANoe (Car2x Scenario Editor)

- Install the Vector CANoe Software as described in die CANoe user manual.
- Download the base configuration for a fast ramp-up. The configuration contains the base modules to connect the CMW500 and CANoe .Car2x.
  https://kb.vector.com/entry/1648/

- There are already demo examples included in the delivery which shows, how a configuration can be setup.
- The Online Help of CANoe provides details about how to use the features.
- Use the CANoe software to open the CANoe project, and open the Car2x Scenario Editor tool in the Tools toolbar (Figure 9):

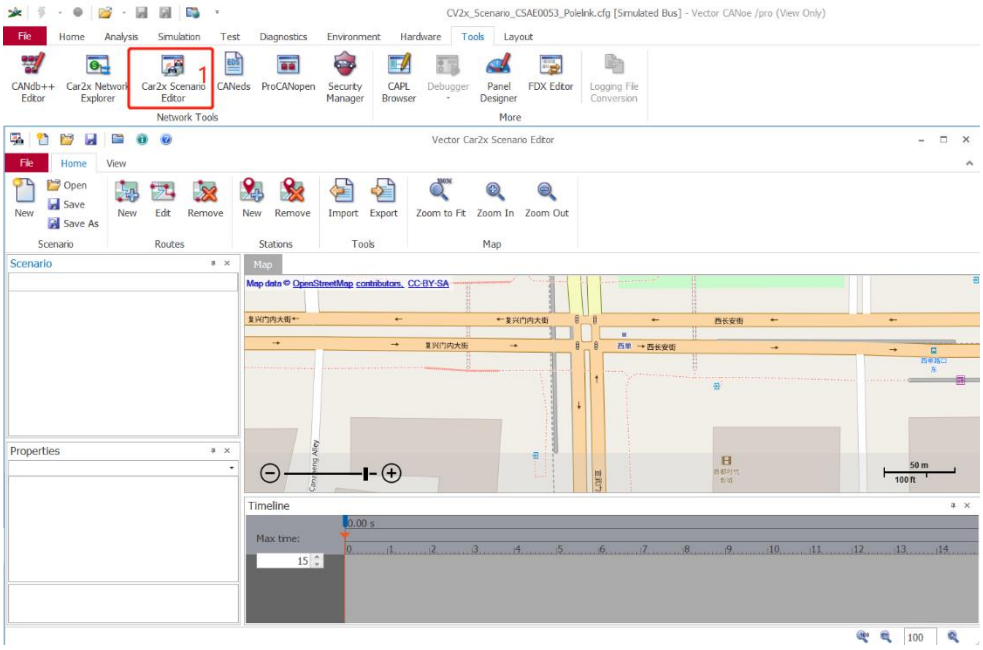


Figure 9: Car2x Scenario Editor

- Scale the map and select an appropriate intersection, click New Routes, and add 2 traffic paths (Figure 10)

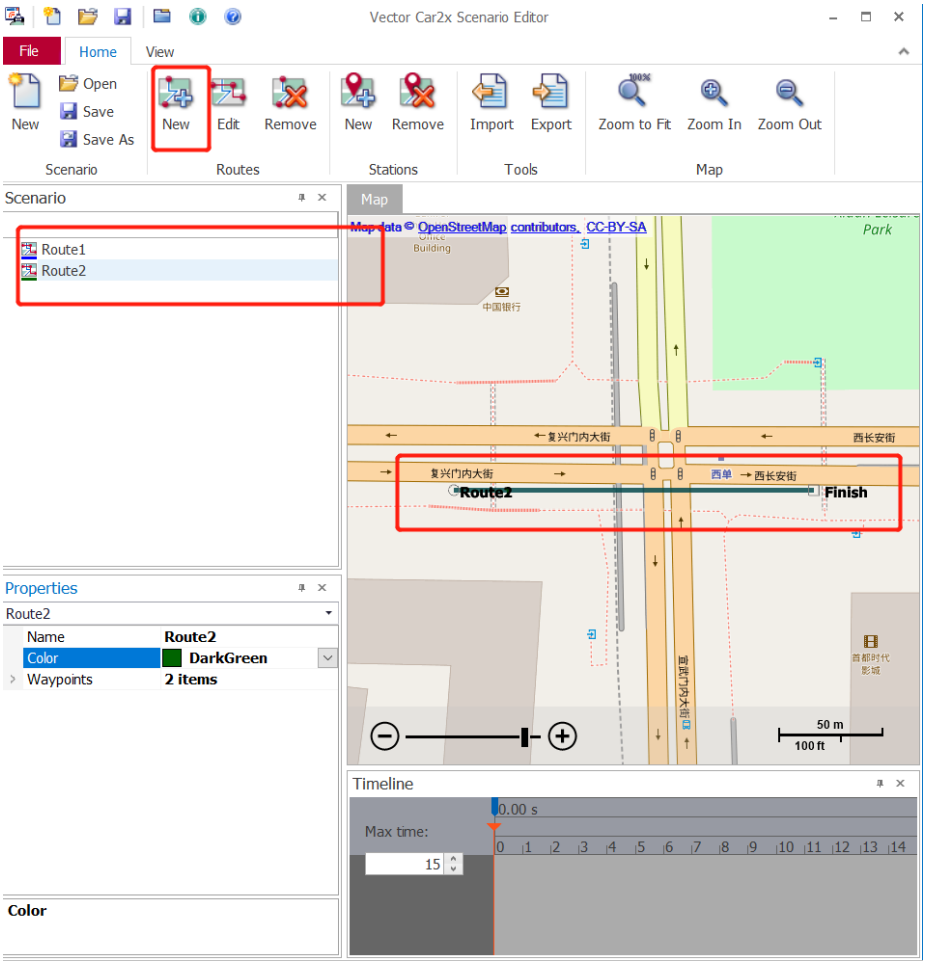


Figure 10 : Add new routes

- ► Edit Route1 to match the driving path of RV-2 in the ICW scene
- ► Edit Route2 to match the driving path of RV-1 in the ICW scene, and configure the properties of route1/2 (color, etc.)

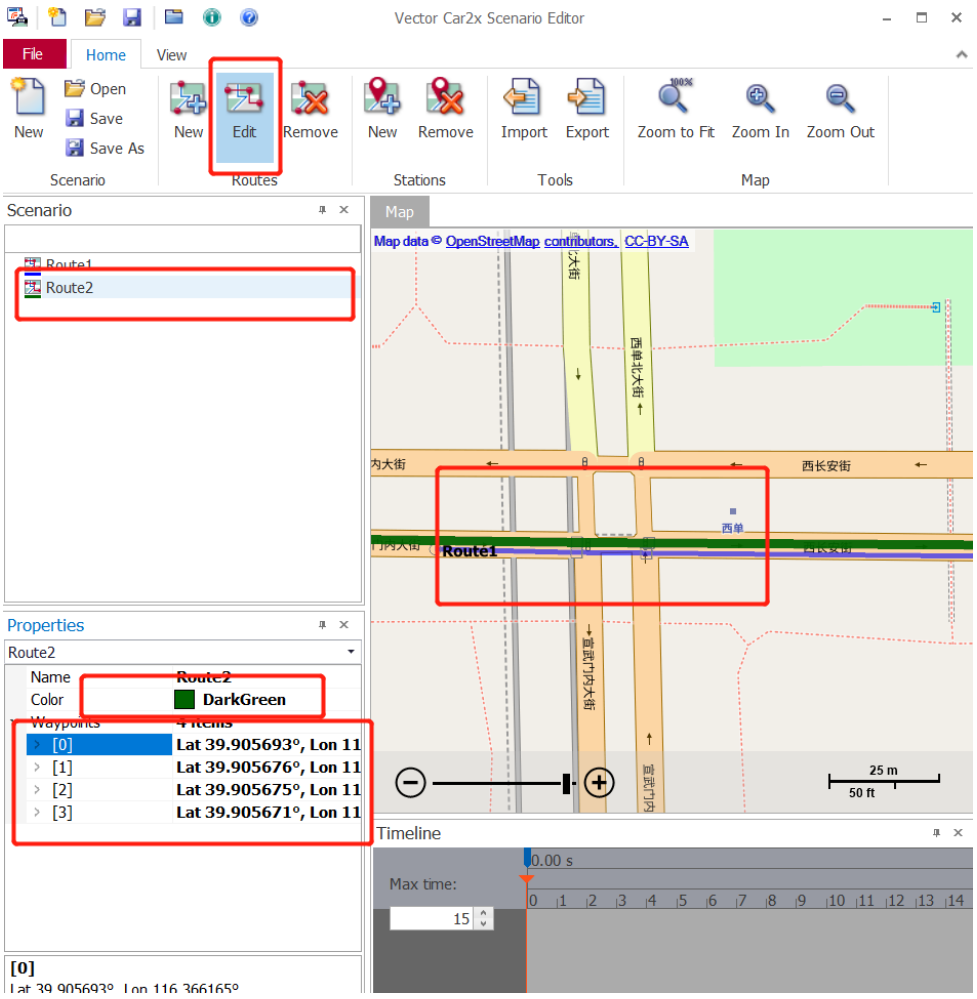


Figure 11: Edit Routes

► Add a new longitudinal vehicle route and edit it to fit the HV's path in the ICW scenario (Figure 12).

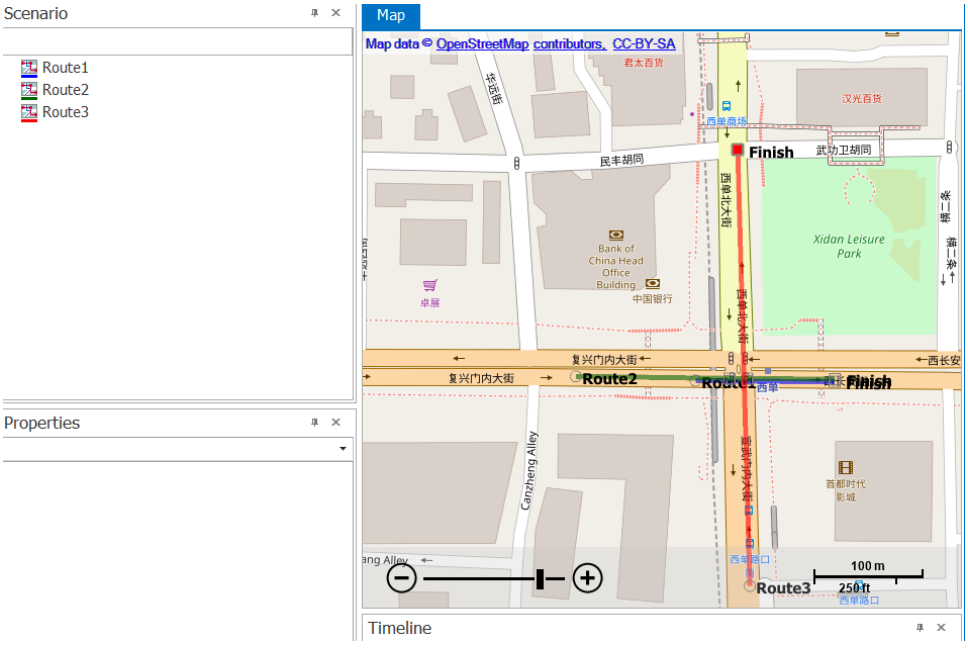


Figure 12: Add a new longitudinal route

► Click *New Stations*, add 1 vehicle node for each route, and edit its color and name referring to the name of each vehicle simulation node in the CANoe project. HV is named DUT, RV-1 is named CarY, and RV-2 is named CarX (Figure 13, Figure 14).
New notes have also be configured in the database. Therefore, the Car2x Network Explorer has to be used. The notes in the simulation setup have to be connected to the database notes (right mouse click on the note | Configuration | Network node).

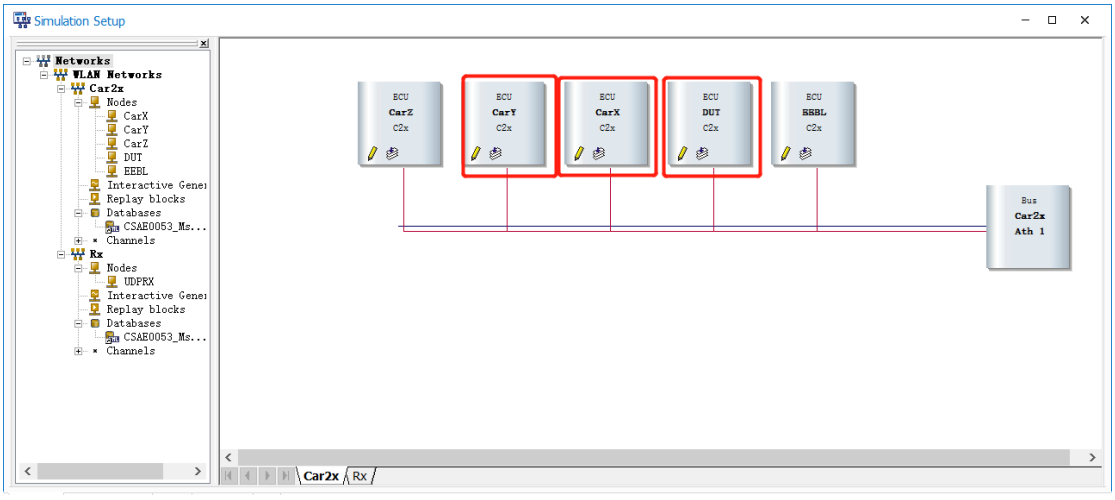


Figure 13: Vehicle simulation node

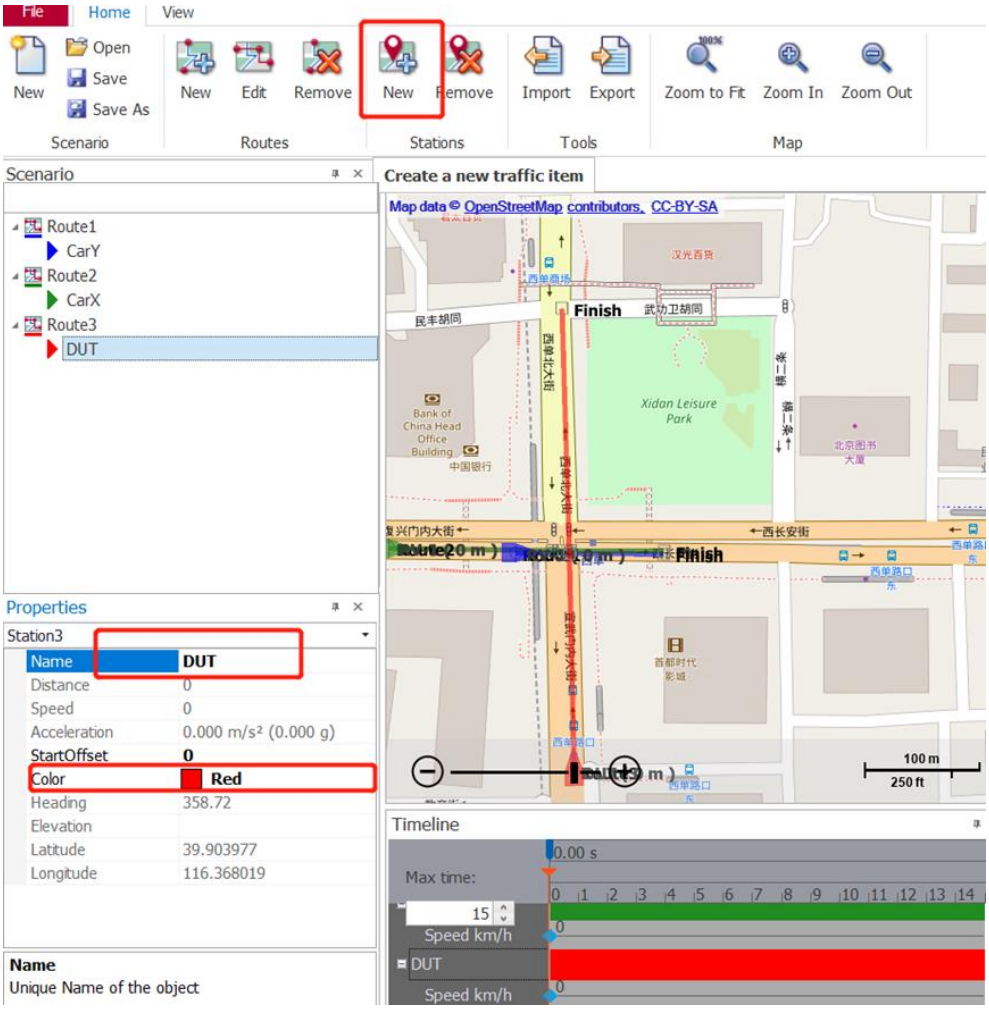


Figure 14: Edit the node name

► Configure CarX (RV-2) to simulate a stationary vehicle: drag the CarX in the Map and place it at the intersection to block the DUT (HV) line of sight, and edit the speed parameter in the timeline window to be 0 (Figure 15).

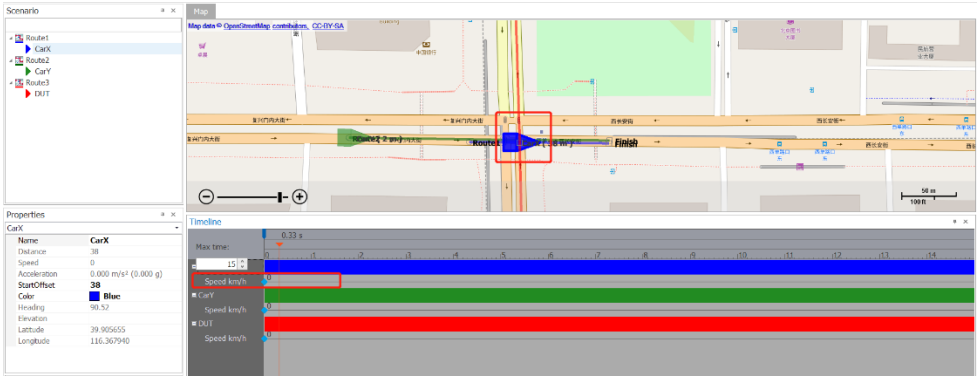


Figure 15: edit the speed parameter

► If CarX is required to send event data (for other V2V communication scenario simulation), the message attributes can be added by right-clicking on the vehicle in the timeline window. Figure 16 shows: at 10 seconds, CarX sends an alarm event message;

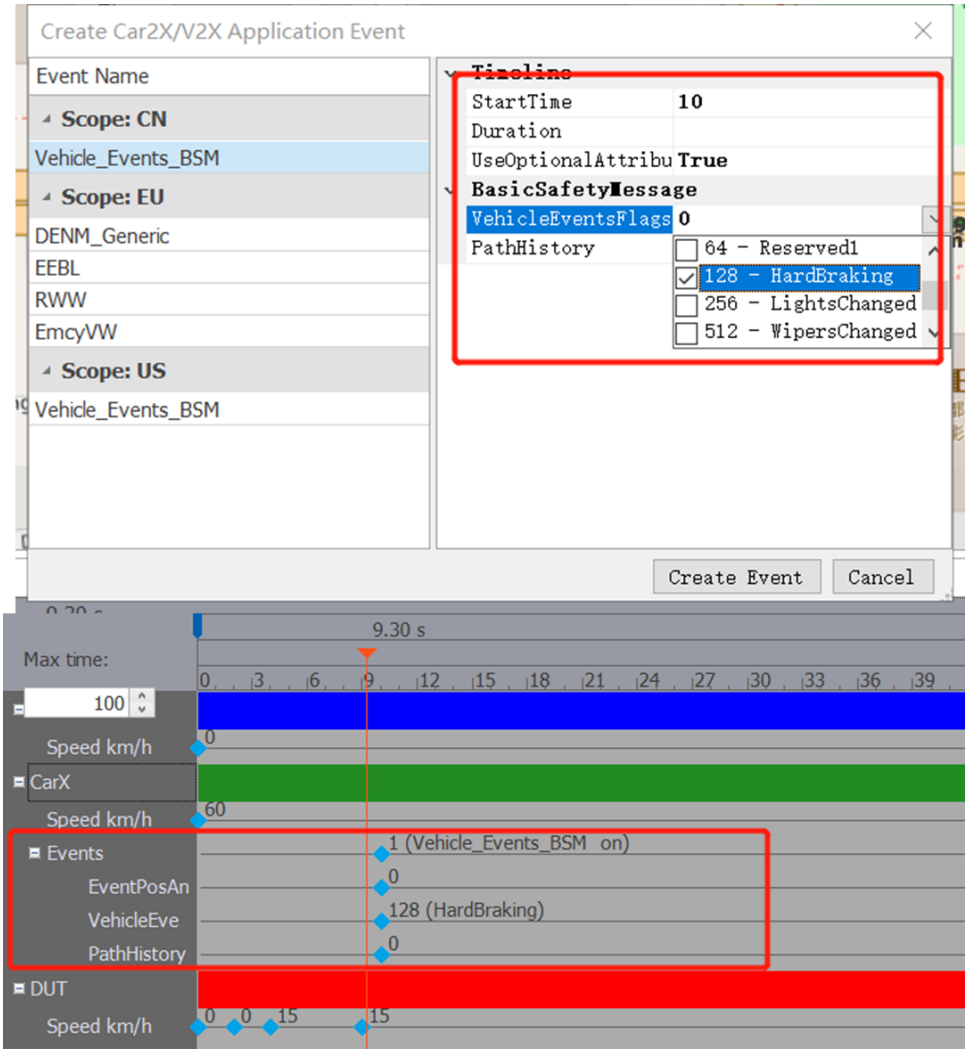


Figure 16: Edit events parameter

► Drag the DUT in the map at the intersection as the initial position. In the timeline window: edit the vehicle waypoint to simulate the starting of the HV. （0s-0km/h;2s-0km/h;4s-15km/s,9s-15km/h) (Figure 17).

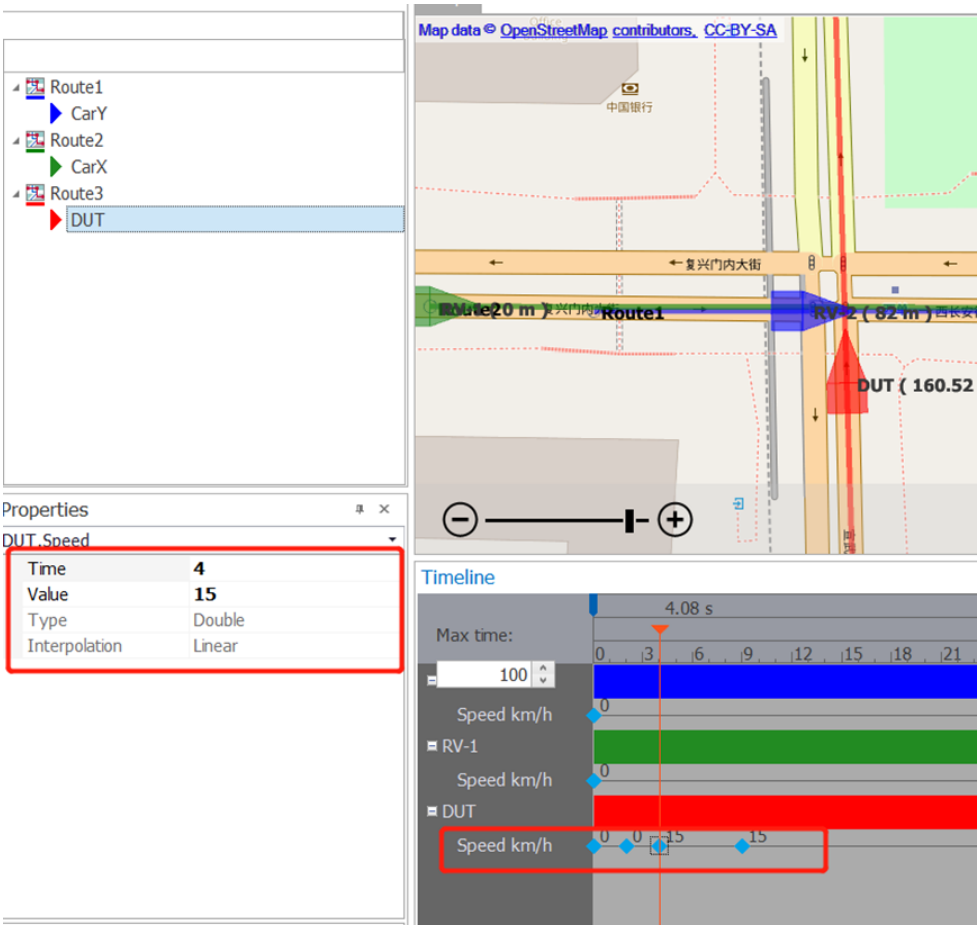


Figure 17: Edit HV parameter

► In order to simulate driving vehicles edit CarY(RV-1) to the right in the left area, the initial position is the starting point of Route2. In the Timeline window, the initial Speed of the vehicle is set 60km/h. Slide the timeline cursor to see the relative position of each vehicle (Figure 18).

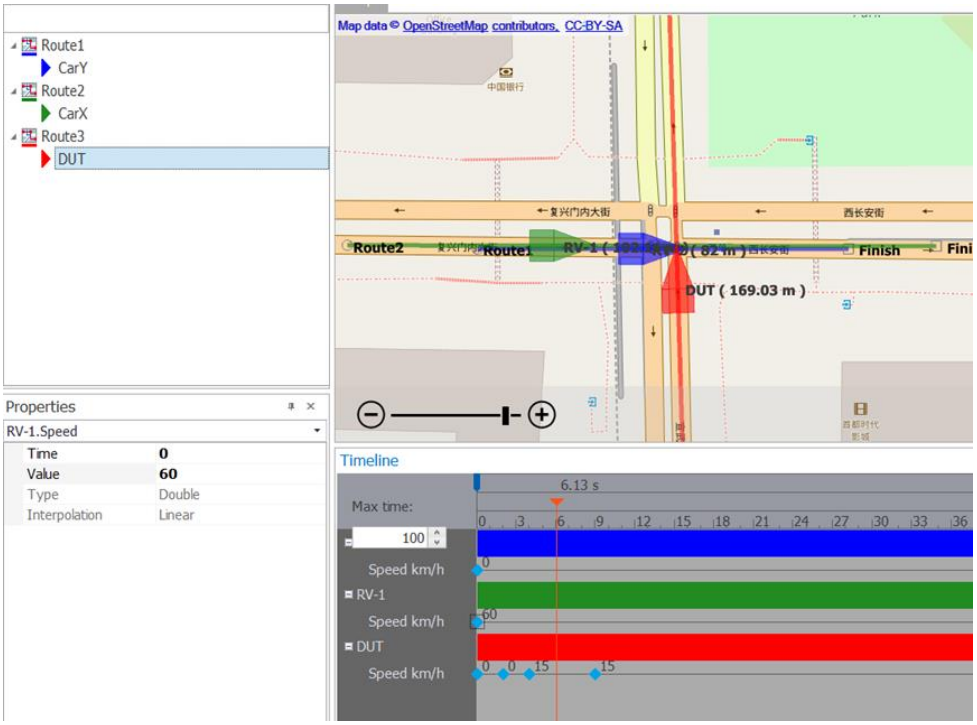


Figure 18: Edit RV-1 parameter

- ► Save the scene file for subsequent simulation. The ICW scenario file (ICW Scenario (Temp).scn) is attached to this application note.
- ► For other scenarios in CSAE53, please refer to this guide or consult R&S partner: Shanghai Polelink co., LTD. At the same time Polelink provides 3D V2X scenario simulation consultation service based on CarMaker +CANoe + R&S instrument.

4.3.1 GNSS Waypoint file generation

- ► Use the CANoe software to open the Project attached to this guide and, and open the Scenario Manager tool to import the previously constructed C-V2X scenario file：ICW Scenario (Temp).scn (Figure 19)

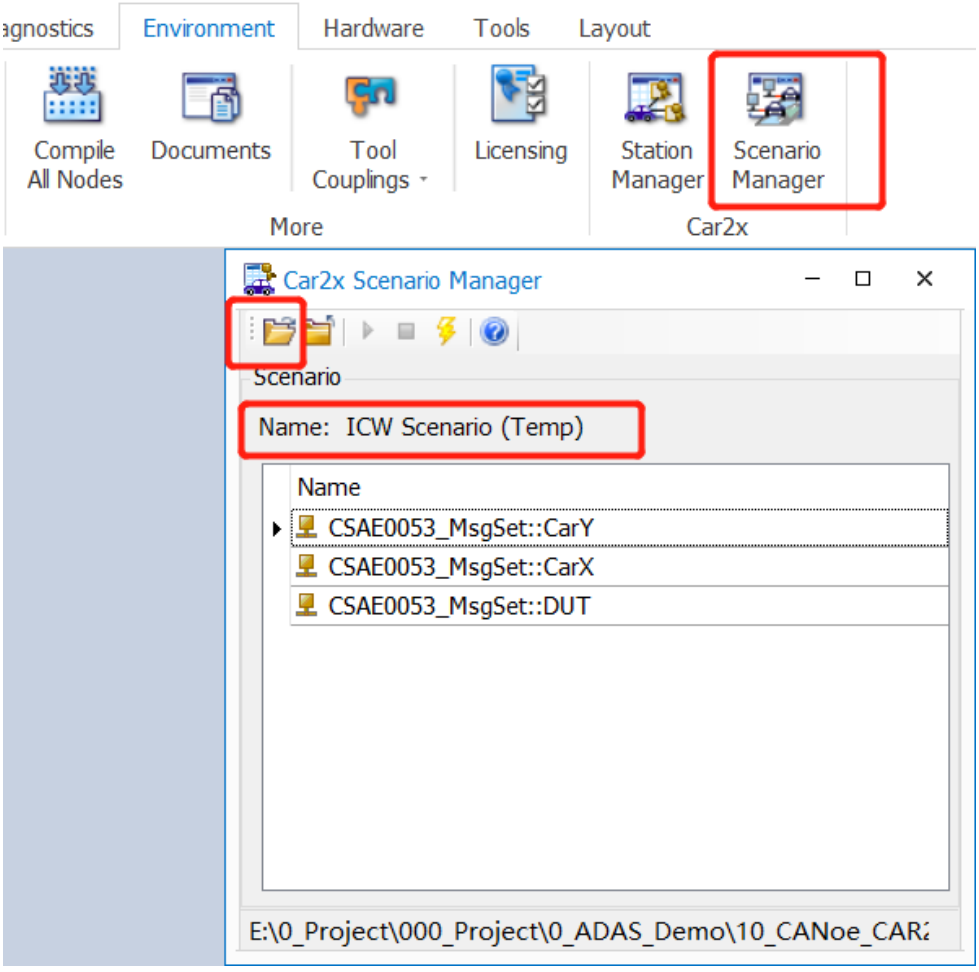


Figure 19: Import V2X of scenario file

► Run the CANoe program and open the Scenario front panel. Configure the start time of GNSS simulation, as shown in the example (Figure 20)

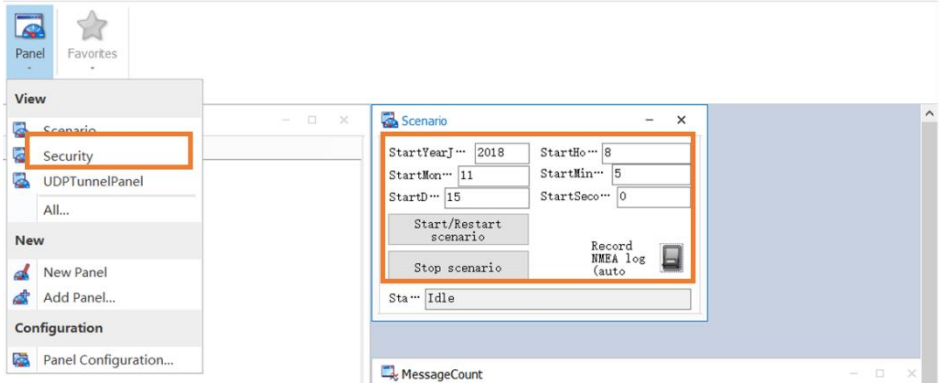


Figure 20: configure GNSS parameter

► Click the *Start Scenario* button. Then click the Record NMEA and switch to trigger the system to record the waypoint of DUT. When the status bar is displays “running” it means that the NMEA file is generated successfully, and the NMEA file can be found in the CANoe project folder. Note: the same scenario, you only need to generate the GNSS waypoint file once.

4.3.2 Run the scenario with CMW500

► Open your project with the CANoe software. Start the Scenario Manager tool and import the previously constructed C-V2X scenario file：ICW Scenario (Temp).scn (Figure 20)

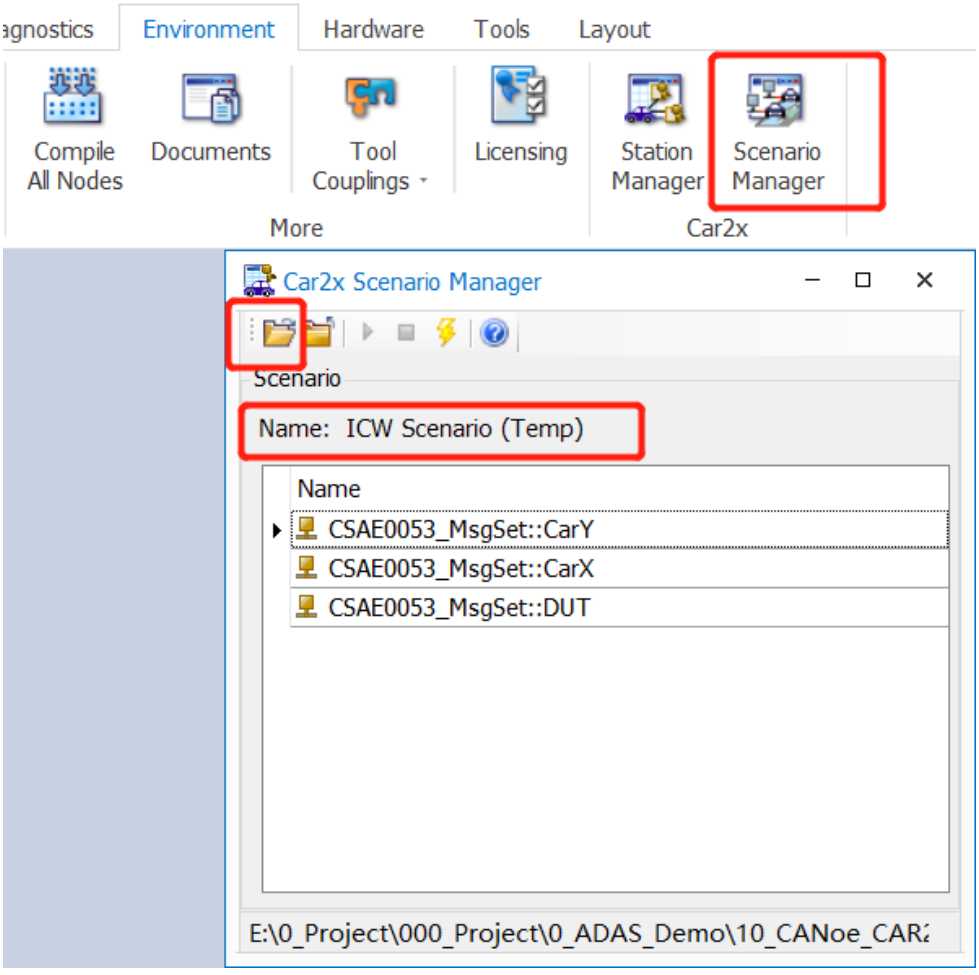


Figure 21: import V2X scenario file

► Run the CANoe program, open the Scenario front panel, and configure the start time of GNSS simulation, as shown in the example (Figure 22).

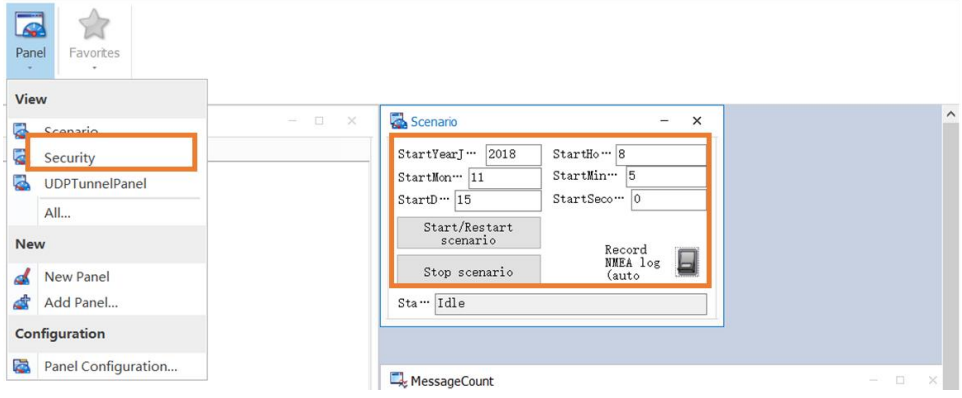


Figure 22: Starting the scenario

► Click the *Start Scenario* button and wait until the communication between CANoe and CMW500 is established (Figure 23). As soon as the DUT has received the satellite synchronization information, you can see the corresponding information sent by the DUT in CANo.

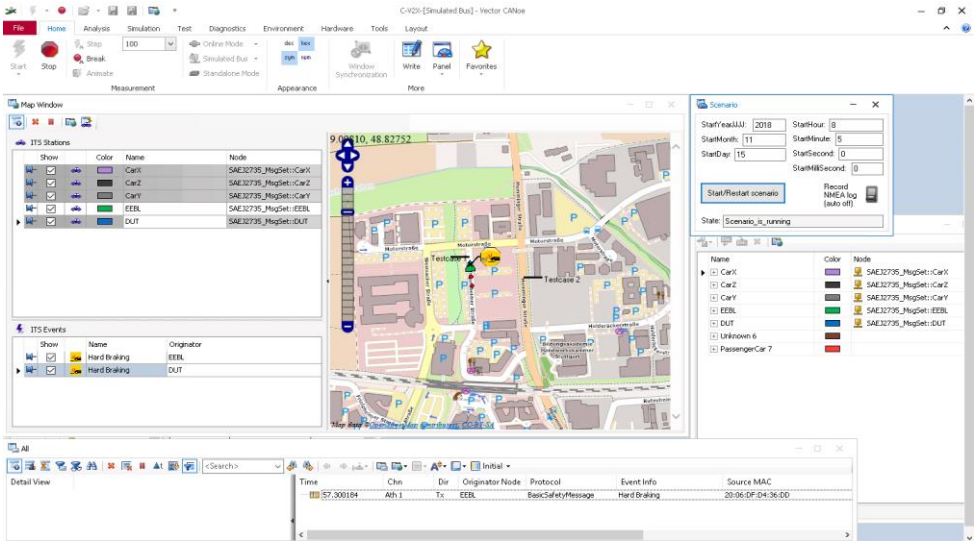


Figure 23: Running simulation

CANoe supports multiple communication networks, such as CAN, LIN, MOST, FlexRay and vehicle ethernet. Therefore, the alert message sent by DUT could be monitored by VECTOR CAN card or Ethernet card. CANoe also could simulate bus nodes of the vehicle and setup the hardware-in-loop test environment.

5 Summary

The test solution presented in this application note allows testing safety-critical C-V2X applications in a lab environment, providing reliable and repeatable results. The Vector CANoe .Car2x software tool in combination with Rohde & Schwarz instruments provides the ability to create complex and reproducible C-V2X scenarios to stimulate a C-V2X capable TCU in line with the configured situation and to test the implemented functions in a targeted manner. The test solution is a future-ready investment, with the option to be extended with an R&S®CMX500 radio communication tester to accommodate future C-V2X releases, including 5G New Radio (5G NR), to keep up with the latest developments of C-V2X.

6 Literature

[1] R. Stuhlfauth, *White Paper: Wireless Communications for Automotive Applications,* Rohde & Schwarz, 2021.

[2] *Application Card: Scenario Based Testing of Safety-critical Cellular V2X Applications in a Lab Environment,* PD 3609.3059.92, Version 01.01: Rohde & Schwarz, 2019.

7 Ordering Information

Designation	Type	Order No.
R&S CMW500 “5G ready"	R&S®R&S CMW500	n.a,
IoT Enabler	R&S®CMW-KP030	1211.1847.02
LTE V2X test suite	R&S®CMW-KAX550	1211.5007.02
LTE R14 PC5 measurement	R&S®CMW-KM570	1211.3010.02
Vector signal generator, base unit incl. ARB (64 Msamples, 120MHz RF bandwidth)	R&S®SMBV100B	143.1003.02
Frequency range 9 kHz to 3.2 GHz	R&S®SMBVB-B103	1423.6270.02
Baseband real-time extension	R&S®SMBVB-K520	1423.7676.02
GPS	R&S®SMBVB-K44	1423.7753.02

Vector CANoe :

Designation	Type	Order No.
Software tool for creation and execution of simulation, communication analysis and testing of ECUs in distributed systems. Supports bus system CAN.	CANoe	55000[1)]
Upgrades CANoe with Car2x functionality	CANoe.Car2x option	55013[1)]

[1)] please contact your local Vector representative

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