NIST Technical Note
NIST TN 2315

C-V2X Interoperability Testing Datasets: Description and Use

Eugene Song
Davide Pesavento
Ya-Shian Li-Baboud

This publication is available free of charge from:
https://doi.org/10.6028/NIST.TN.2315

NIST NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
U.S. DEPARTMENT OF COMMERCE

NIST Technical Note
NIST TN 2315

C-V2X Interoperability Testing Datasets: Description and Use

Eugene Song
Davide Pesavento
Smart Connected Systems Division
Communications Technology Laboratory

Ya-Shian Li-Baboud
Software and Systems Division
Information Technology Laboratory

This publication is available free of charge from:
https://doi.org/10.6028/NIST.TN.2315

November 2024

U.S. Department of Commerce
Gina M. Raimondo, Secretary

National Institute of Standards and Technology
Laurie E. Locascio, NIST Director and Under Secretary of Commerce for Standards and Technology

NIST TN 2315
November 2024

NIST Technical Series Policies

Publication History
Approved by the NIST Editorial Review Board on 2024-11-13

How to Cite this NIST Technical Series Publication
Eugene Song, Davide Pesavento, Ya-Shian Li-Baboud (2024) C-V2X Interoperability Testing Datasets: Description and Use. (National Institute of Standards and Technology, Gaithersburg, MD), NIST Technical Note (TN) NIST TN 2315. https://doi.org/10.6028/NIST.TN.2315

Author ORCID iDs
Eugene Song: 0000-0002-1737-2121
Davide Pesavento: 0000-0002-7136-1888
Ya-Shian Li-Baboud: 0000-0003-3234-4345

Abstract

This paper introduces a set of cellular vehicle-to-everything (C-V2X) datasets collected at the National Institute of Standards and Technology (NIST) Internet of Thing (IoT) Devices Interoperability Testbed. These datasets can be used to examine, analyze, and assess C-V2X compatibility and interoperability among commercial on-board units (OBUs) and road-side units (RSUs) based on IEEE 1609.2, 1609.3, and SAE J2735 standards.

Keywords

C-V2I; C-V2V; C-V2X; Communication; Compatibility; Connectivity; Dataset; GPS; Interoperability; OBU; LTE/5G PC5; RSU; Sidelink.

Table of Contents

List of Tables

List of Figures

1. Introduction

An Internet of Things (IoT) system is a network of devices containing sensing and actuation that are connected to exchange data and information [1]. IoT devices are physical devices that may have zero or more transducers (sensors or actuators) for interacting directly with the physical world and at least one network interface (e.g., Ethernet, Wi-Fi, Bluetooth) for interfacing with the digital world [2]. Interoperability for the IoT is the ability of different IoT devices from various vendors or manufacturers to exchange information and use the information that has been exchanged based on standardized communication protocols to achieve the functions or goals of the IoT devices and systems [3][4].

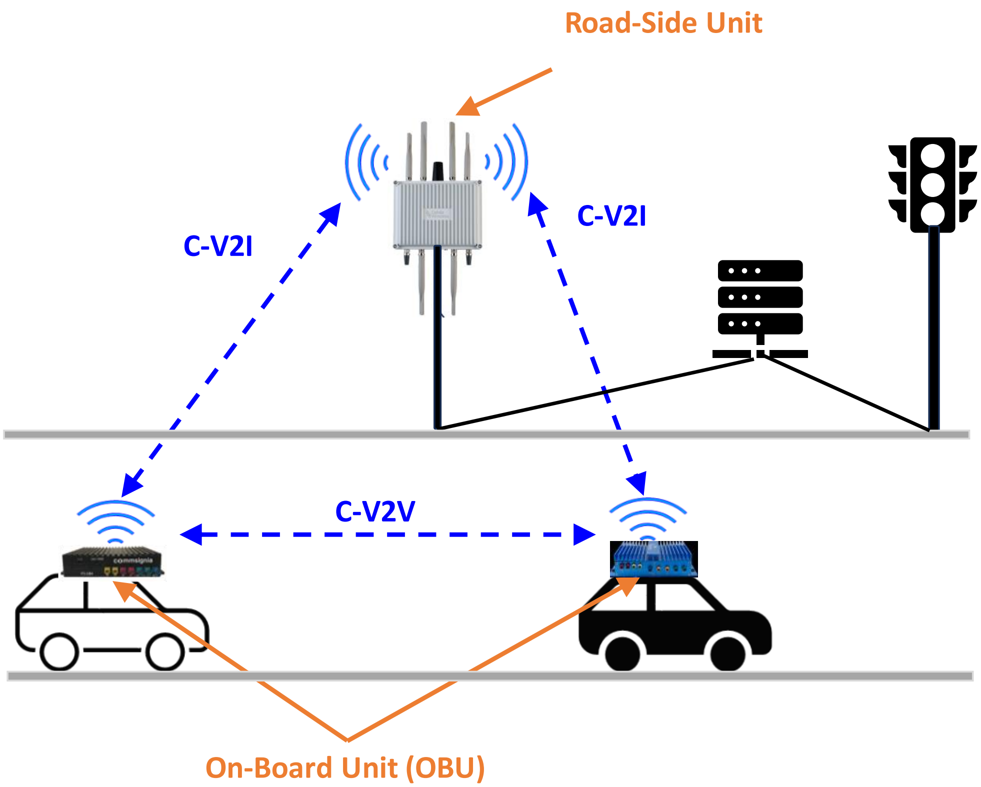

Figure 1.1. Scenario of approach and departure at signalized intersection.

Intelligent Transportation Systems (ITS) aim to use modern computers and communications to make travel smarter, faster, safer, and more convenient [5]. ITS uses IoT devices with cutting-edge technologies, including advanced sensing, wireless communication, and data analytics, to improve transportation efficiency and safety. Figure 1.1 shows a scenario of approach and departure at a signalized intersection [6], which consists of several IoT devices such as on-board units (OBUs) inside vehicles and road-side units (RSUs) installed along the road and at the intersection. ITS rely on these IoT devices to gather real-time data and provide critical information for traffic monitoring and control, which is essential for improving and achieving the efficiency and safety goals of ITS.

The interoperability challenges of these IoT devices in ITS include:

- diverse vehicle-to-everything/cellular V2X (V2X/C-V2X) connectivity, e.g., 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE), Fourth Generation (4G), Fifth Generation (5G) New Radio (NR), Institute of Electrical and Electronics Engineers (IEEE) 802.11p/Dedicated Short-Range Communications (DSRC),
- multiple V2X standardized communication protocols (e.g., Society of Automobile Engineers (SAE) J2735 [7], IEEE 1609.2 [8] and 1609.3 [9] standards),
- diverse vendors and manufacturers of devices such as OBUs and RSUs,
- device heterogeneity,
- diverse use cases and contexts, and
- lack of quantitative measurement and assessment methodology of interoperability.

Solutions to overcome these IoT devices interoperability challenges include developing robust and interoperable standards, as well as test, measurement, and assessment methodologies of IoT devices interoperability based on these standards. This paper introduces C-V2X interoperability testing datasets that have been collected at the National Institute of Standards and Technology (NIST) IoT Devices Interoperability Testbed.

2. C-V2X Interoperability Testing Dataset Descriptions

2.1. IoT Devices Interoperability Testbed Setup

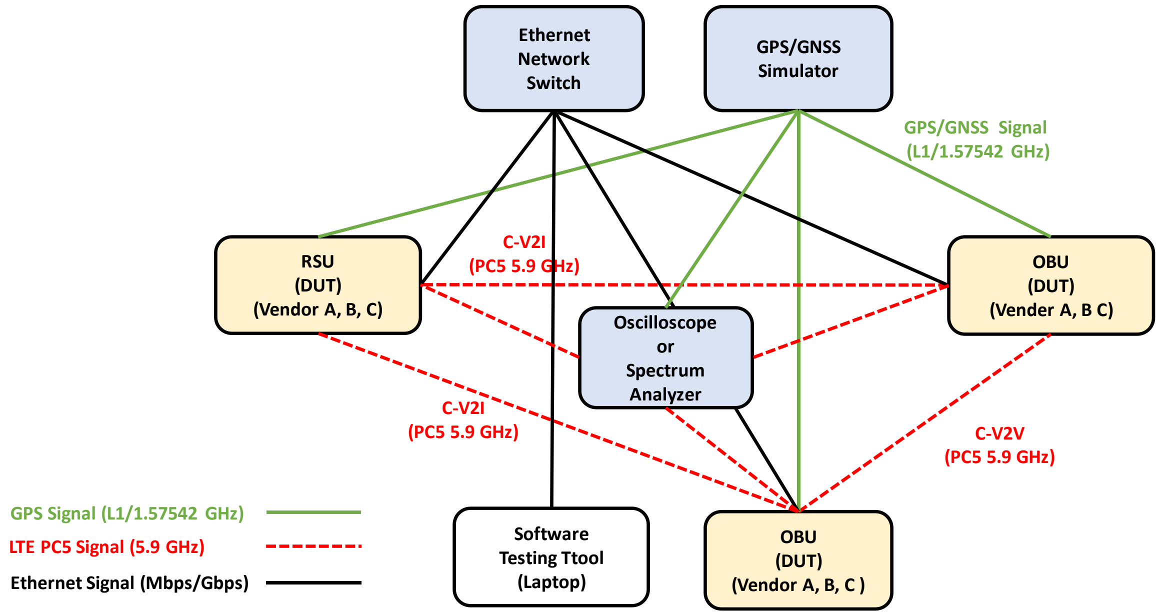

Figure 2.1. IoT devices interoperability testbed.

Figure 2.1 shows the IoT devices interoperability testbed that consists of a Global Positioning System/Global Navigation Satellite System (GPS/GNSS) simulator (GSG-5) [10], a GPS splitter (GPS410 [11]), an Ethernet network switch, one RSU (Cohda MK6 RSU [12]), two OBUs (Cohda MK6 OBU [13]), an oscilloscope (Tektronix MDO4104B-6 Mixed Domain Oscilloscope [14]), a real-time spectrum analyzer (Tektronix RSA306B [15]), and a laptop with Cohda Mk6 software development kit (SDK) [16] software tool.

2.2. C-V2X Interoperability Testcases and Dataset Descriptions

The three C-V2X interoperability testcases studied include cellular vehicle-to-vehicle (C-V2V, OBU-to-OBU), cellular vehicle-to-infrastructure (C-V2I, OBU-to-RSU), and C-V2X (both V2V and V2I). The dataset files are named based on the pattern in Table 1.

Table 1. Dataset file naming method.

Test Case	Year	Month	Day	Testing setup	Transmit or receive	Device under test	Dataset No.	Data file format
C-V2V, C-V2I, C-V2X	yyyy	mm	dd	ts1 or ts2	tx or rx	obu1, obu2, rsu	0, 1, 2	PCAP or PDML
C-V2V	2024	07	23	ts1	tx	obu1	0	pcap

For example, the file `C-V2V-2024-07-23-ts1-tx-obu1-0.pcap` can be described as follows:

- C-V2V testcase
- Data collected on July 23, 2024
- Testing setup 1 (ts1)
- Transmitted packets (tx)
- Data transmitted from OBU1
- Dataset number 0 (first dataset)
- Data file format is packet capture (PCAP) [17]

2.2.1. C-V2V Interoperability Testcase and Datasets

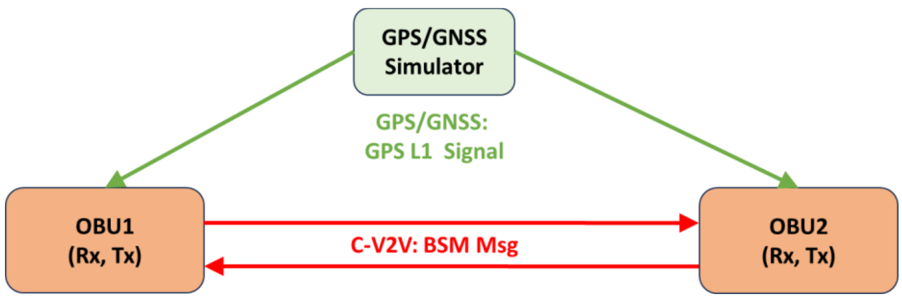

Figure 2.2. C-V2V interoperability testcase.

Figure 2.2 shows a C-V2V interoperability testcase that includes one SGS-5 GPS/GNSS simulator and two OBUs (OBU1 and OBU2). The GSG-5 GPS simulator provides the GPS L1 signal to the two OBUs. Based on the GPS L1 signal provided by the GSG-5 simulator, OBU1 and OBU2 can communicate with each other via cellular network sidelink (LTE PC5) using the IEEE 1609.3 Wireless Access in Vehicular Environments (WAVE) Short Message Protocol (WSMP) and SAE J2735 messages and leveraging the IEEE 1609.2 security services.

Table 2. C-V2V datasets in PCAP format.

Test case	C-V2V PCAP Datasets		
	0	1	2
C-V2V	C-V2V-2024-07-30-ts1-tx-obu1-0.pcap C-V2V-2024-07-30-ts1-rx-obu1-0.pcap	C-V2V-2024-07-30-ts1-tx-obu1-1.pcap C-V2V-2024-07-30-ts1-rx-obu1-1.pcap	C-V2V-2024-07-30-ts1-tx-obu1-2.pcap C-V2V-2024-07-30-ts1-rx-obu1-2.pcap
	C-V2V-2024-07-30-ts1-tx-obu2-0.pcap C-V2V-2024-07-30-ts1-rx-obu2-0.pcap	C-V2V-2024-07-30-ts1-tx-obu2-1.pcap C-V2V-2024-07-30-ts1-rx-obu2-1.pcap	C-V2V-2024-07-30-ts1-tx-obu2-2.pcap C-V2V-2024-07-30-ts1-rx-obu2-2.pcap
	C-V2V-2024-07-30-ts2-tx-obu1-0.pcap C-V2V-2024-07-30-ts2-rx-obu1-0.pcap	C-V2V-2024-07-30-ts2-tx-obu1-1.pcap C-V2V-2024-07-30-ts2-rx-obu1-1.pcap	C-V2V-2024-07-30-ts2-tx-obu1-2.pcap C-V2V-2024-07-30-ts2-rx-obu1-2.pcap
	C-V2V-2024-07-30-ts2-tx-obu2-0.pcap C-V2V-2024-07-30-ts2-rx-obu2-0.pcap	C-V2V-2024-07-30-ts2-tx-obu2-1.pcap C-V2V-2024-07-30-ts2-rx-obu2-1.pcap	C-V2V-2024-07-30-ts2-tx-obu2-2.pcap C-V2V-2024-07-30-ts2-rx-obu2-2.pcap

Both OBU1 and OBU2 transmit and receive SAE J2735 Basic Safety Message (BSM) messages to/from each other. Table 2 and Table 3 shows the resulting set of C-V2V testing datasets in the PCAP and packet details markup language (PDML) [18] formats, respectively.

Table 3. C-V2V datasets in PDML format.

Test case	C-V2V PDML Datasets		
	0	1	2
C-V2V	C-V2V-2024-07-30-ts1-tx-obu1-0.pdml C-V2V-2024-07-30-ts1-rx-obu1-0.pdml	C-V2V-2024-07-30-ts1-tx-obu1-1.pdml C-V2V-2024-07-30-ts1-rx-obu1-1.pdml	C-V2V-2024-07-30-ts1-tx-obu1-2.pdml C-V2V-2024-07-30-ts1-rx-obu1-2.pdml
	C-V2V-2024-07-30-ts1-tx-obu2-0.pdml C-V2V-2024-07-30-ts1-rx-obu2-0.pdml	C-V2V-2024-07-30-ts1-tx-obu2-1.pdml C-V2V-2024-07-30-ts1-rx-obu2-1.pdml	C-V2V-2024-07-30-ts1-tx-obu2-2.pdml C-V2V-2024-07-30-ts1-rx-obu2-2.pdml
	C-V2V-2024-07-30-ts2-tx-obu1-0.pdml C-V2V-2024-07-30-ts2-rx-obu1-0.pdml	C-V2V-2024-07-30-ts2-tx-obu1-1.pdml C-V2V-2024-07-30-ts2-rx-obu1-1.pdml	C-V2V-2024-07-30-ts2-tx-obu1-2.pdml C-V2V-2024-07-30-ts2-rx-obu1-2.pdml
	C-V2V-2024-07-30-ts2-tx-obu2-0.pdml C-V2V-2024-07-30-ts2-rx-obu2-0.pdml	C-V2V-2024-07-30-ts2-tx-obu2-1.pdml C-V2V-2024-07-30-ts2-rx-obu2-1.pdml	C-V2V-2024-07-30-ts2-tx-obu2-2.pdml C-V2V-2024-07-30-ts2-rx-obu2-2.pdml

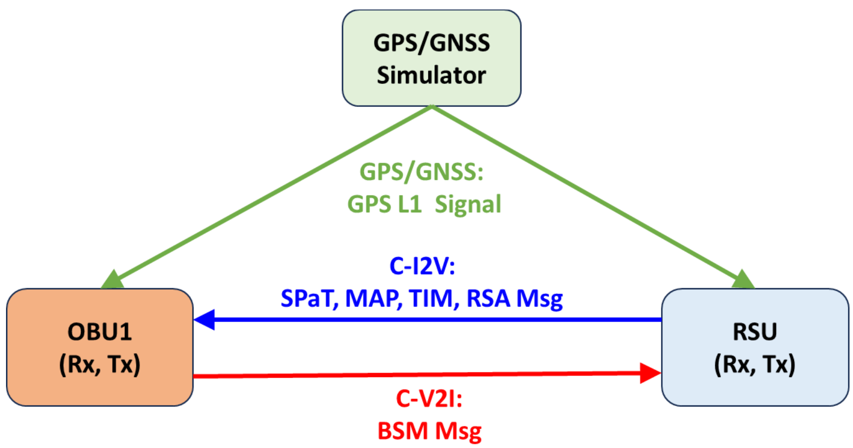

Figure 2.3. C-V2I interoperability testcase.

2.2.2. C-V2I Interoperability Testcase and Datasets

Figure 2.3 shows a C-V2I interoperability testcase that consists of one SGS-5 GPS/GNSS simulator, one OBU and one RSU. The GSG-5 GPS simulator provides the GPS L1 signal to the OBU and RSU. Based on the GPS L1 Signal provided by the GSG-5 simulator, OBU1 and RSU can communicate with each other via cellular network sidelink (LTE PC5) using IEEE 1609.3 WSMP and SAE J2735 messages and leveraging the IEEE 1609.2 security services.

- The OBU1 can transmit the SAE J2735 BSM message and receive Signal Phase and Timing (SPaT), Traveler Information Message (TIM), Road-Side Alert (RSA), and Map (MAP) messages from the RSU.
- The RSU can receive the SAE BSM message from the OBU1 and transmit SpaT, TIM, RSA, and MAP messages.

Table 4. C-V2I datasets in PCAP format.

Test case	C-V2I PCAP Datasets		
	0	1	2
C-V2I	C-V2I-2024-07-30-ts1-tx-obu1-0.pcap C-V2I-2024-07-30-ts1-rx-obu1-0.pcap	C-V2I-2024-07-30-ts1-tx-obu1-1.pcap C-V2I-2024-07-30-ts1-rx-obu1-1.pcap	C-V2I-2024-07-30-ts1-tx-obu1-2.pcap C-V2I-2024-07-30-ts1-rx-obu1-2.pcap
	C-V2I-2024-07-30-ts1-tx-rsu-0.pcap C-V2I-2024-07-30-ts1-rx-rsu-0.pcap	C-V2I-2024-07-30-ts1-tx-rsu-1.pcap C-V2I-2024-07-30-ts1-rx-rsu-1.pcap	C-V2I-2024-07-30-ts1-tx-rsu-2.pcap C-V2I-2024-07-30-ts1-rx-rsu-2.pcap
	C-V2I-2024-07-30-ts2-tx-obu1-0.pcap C-V2I-2024-07-30-ts2-rx-obu1-0.pcap	C-V2I-2024-07-30-ts2-tx-obu1-1.pcap C-V2I-2024-07-30-ts2-rx-obu1-1.pcap	C-V2I-2024-07-30-ts2-tx-obu1-2.pcap C-V2I-2024-07-30-ts2-rx-obu1-2.pcap
	C-V2I-2024-07-30-ts2-tx-rsu-0.pcap C-V2I-2024-07-30-ts2-rx-rsu-0.pcap	C-V2I-2024-07-30-ts2-tx-rsu-1.pcap C-V2I-2024-07-30-ts2-rx-rsu-1.pcap	C-V2I-2024-07-30-ts2-tx-rsu-2.pcap C-V2I-2024-07-30-ts2-rx-rsu-2.pcap

Table 5. C-V2I datasets in PDML format.

Test case	C-V2I PDML Datasets		
	0	1	2
C-V2I	C-V2I-2024-07-30-ts1-tx-obu1-0.pdml C-V2I-2024-07-30-ts1-rx-obu1-0.pdml	C-V2I-2024-07-30-ts1-tx-obu1-1.pdml C-V2I-2024-07-30-ts1-rx-obu1-1.pdml	C-V2I-2024-07-30-ts1-tx-obu1-2.pdml C-V2I-2024-07-30-ts1-rx-obu1-2.pdml
	C-V2I-2024-07-30-ts1-tx-rsu-0.pdml C-V2I-2024-07-30-ts1-rx-rsu-0.pdml	C-V2I-2024-07-30-ts1-tx-rsu-1.pdml C-V2I-2024-07-30-ts1-rx-rsu-1.pdml	C-V2I-2024-07-30-ts1-tx-rsu-2.pdml C-V2I-2024-07-30-ts1-rx-rsu-2.pdml
	C-V2I-2024-07-30-ts2-tx-obu1-0.pdml C-V2I-2024-07-30-ts2-rx-obu1-0.pdml	C-V2I-2024-07-30-ts2-tx-obu1-1.pdml C-V2I-2024-07-30-ts2-rx-obu1-1.pdml	C-V2I-2024-07-30-ts2-tx-obu1-2.pdml C-V2I-2024-07-30-ts2-rx-obu1-2.pdml
	C-V2I-2024-07-30-ts2-tx-rsu-0.pdml C-V2I-2024-07-30-ts2-rx-rsu-0.pdml	C-V2I-2024-07-30-ts2-tx-rsu-1.pdml C-V2I-2024-07-30-ts2-rx-rsu-1.pdml	C-V2I-2024-07-30-ts2-tx-rsu-2.pdml C-V2I-2024-07-30-ts2-rx-rsu-2.pdml

Table 4 and Table 5 shows the resulting set of C-V2I testing datasets in the PCAP and PDML formats, respectively.

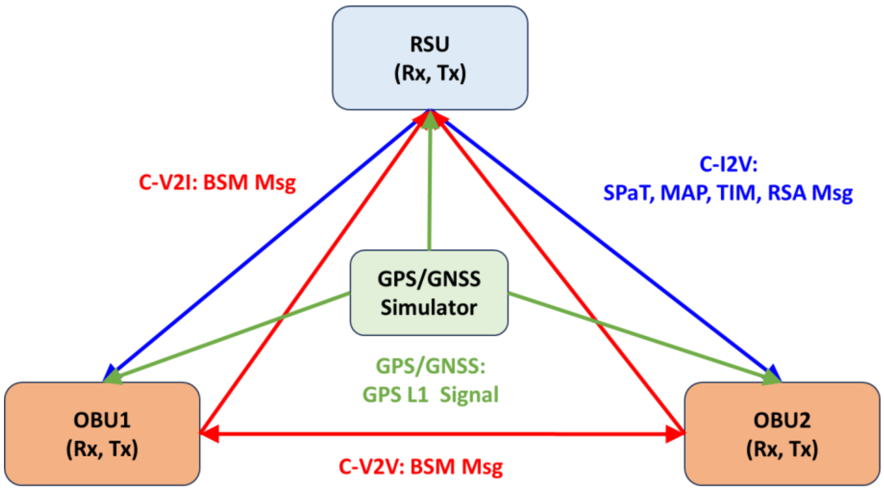

Figure 2.4. C-V2X (V2V and V2I) test case.

2.2.3. C-V2X Interoperability Testcase and Datasets

Figure 2.4 shows a C-V2X (V2V and V2I) interoperability testcase that consists of one SGS-5 GPS/GNSS simulator, one RSU, and two OBUs. The GSG-5 GPS simulator provides the GPS L1 signal to the two OBUs and RSU. Based on the GPS L1 Signal provided by the GSG-5 simulator, OBU1, OBU2, and RSU can communicate with each other via cellular network sidelink (LTE PC5) using IEEE 1609.3 WSM and SAE J2735 messages and leveraging the IEEE 1609.2 security services.

- OBU1 and OBU2 can transmit SAE J2735 BSM messages and can receive SAE J2735 BSM, SPaT, RSA, TIM, and MAP messages.
- The RSU transmits SAE J2735 SPaT, RSA, TIM, and MAP messages, while it can receive the SAE J2735 BSM messages from OBU1 and OBU2.

Table 6. C-V2X datasets in PCAP format.

Test case	C-V2X PCAP Datasets		
	0	1	2
C-V2X	C-V2X-2024-07-23-ts1-tx-obu1-0.pcap C-V2X-2024-07-23-ts1-rx-obu1-0.pcap	C-V2X-2024-07-23-ts1-tx-obu1-1.pcap C-V2X-2024-07-23-ts1-rx-obu1-1.pcap	C-V2X-2024-07-23-ts1-tx-obu1-2.pcap C-V2X-2024-07-23-ts1-rx-obu1-2.pcap
	C-V2X-2024-07-23-ts1-tx-obu2-0.pcap C-V2X-2024-07-23-ts1-rx-obu2-0.pcap	C-V2X-2024-07-23-ts1-tx-obu2-1.pcap C-V2X-2024-07-23-ts1-rx-obu2-1.pcap	C-V2X-2024-07-23-ts1-tx-obu2-2.pcap C-V2X-2024-07-23-ts1-rx-obu2-2.pcap
	C-V2X-2024-07-23-ts1-tx-rsu-0.pcap C-V2X-2024-07-23-ts1-rx-rsu-0.pcap	C-V2X-2024-07-23-ts1-tx-rsu-1.pcap C-V2X-2024-07-23-ts1-rx-rsu-1.pcap	C-V2X-2024-07-23-ts1-tx-rsu-2.pcap C-V2X-2024-07-23-ts1-rx-rsu-2.pcap
	C-V2X-2024-07-23-ts2-tx-obu1-0.pcap C-V2X-2024-07-23-ts2-rx-obu1-0.pcap	C-V2X-2024-07-23-ts2-tx-obu1-1.pcap C-V2X-2024-07-23-ts2-rx-obu1-1.pcap	C-V2X-2024-07-23-ts2-tx-obu1-2.pcap C-V2X-2024-07-23-ts2-rx-obu1-2.pcap
	C-V2X-2024-07-23-ts2-tx-obu2-0.pcap C-V2X-2024-07-23-ts2-rx-obu2-0.pcap	C-V2X-2024-07-23-ts2-tx-obu2-1.pcap C-V2X-2024-07-23-ts2-rx-obu2-1.pcap	C-V2X-2024-07-23-ts2-tx-obu2-2.pcap C-V2X-2024-07-23-ts2-rx-obu2-2.pcap
	C-V2X-2024-07-23-ts2-tx-rsu-0.pcap C-V2X-2024-07-23-ts2-rx-rsu-0.pcap	C-V2X-2024-07-23-ts2-tx-rsu-1.pcap C-V2X-2024-07-23-ts2-rx-rsu-1.pcap	C-V2X-2024-07-23-ts2-tx-rsu-2.pcap C-V2X-2024-07-23-ts2-rx-rsu-2.pcap

Table 6 shows the resulting set of C-V2X testing datasets in the PCAP format. Table 7 shows the resulting set of C-V2X testing datasets in the PDML format.

Table 7. C-V2X datasets in PDML format.

Test case	C-V2X PDML Datasets		
	0	1	2
C-V2X	C-V2X-2024-07-23-ts1-tx-obu1-0.pdml C-V2X-2024-07-23-ts1-rx-obu1-0.pdml	C-V2X-2024-07-23-ts1-tx-obu1-1.pdml C-V2X-2024-07-23-ts1-rx-obu1-1.pdml	C-V2X-2024-07-23-ts1-tx-obu1-2.pdml C-V2X-2024-07-23-ts1-rx-obu1-2.pdml
	C-V2X-2024-07-23-ts1-tx-obu2-0.pdml C-V2X-2024-07-23-ts1-rx-obu2-0.pdml	C-V2X-2024-07-23-ts1-tx-obu2-1.pdml C-V2X-2024-07-23-ts1-rx-obu2-1.pdml	C-V2X-2024-07-23-ts1-tx-obu2-2.pdml C-V2X-2024-07-23-ts1-rx-obu2-2.pdml
	C-V2X-2024-07-23-ts1-tx-rsu-0.pdml C-V2X-2024-07-23-ts1-rx-rsu-0.pdml	C-V2X-2024-07-23-ts1-tx-rsu-1.pdml C-V2X-2024-07-23-ts1-rx-rsu-1.pdml	C-V2X-2024-07-23-ts1-tx-rsu-2.pdml C-V2X-2024-07-23-ts1-rx-rsu-2.pdml
	C-V2X-2024-07-23-ts2-tx-obu1-0.pdml C-V2X-2024-07-23-ts2-rx-obu1-0.pdml	C-V2X-2024-07-23-ts2-tx-obu1-1.pdml C-V2X-2024-07-23-ts2-rx-obu1-1.pdml	C-V2X-2024-07-23-ts2-tx-obu1-2.pdml C-V2X-2024-07-23-ts2-rx-obu1-2.pdml
	C-V2X-2024-07-23-ts2-tx-obu2-0.pdml C-V2X-2024-07-23-ts2-rx-obu2-0.pdml	C-V2X-2024-07-23-ts2-tx-obu2-1.pdml C-V2X-2024-07-23-ts2-rx-obu2-1.pdml	C-V2X-2024-07-23-ts2-tx-obu2-2.pdml C-V2X-2024-07-23-ts2-rx-obu2-2.pdml
	C-V2X-2024-07-23-ts2-tx-rsu-0.pdml C-V2X-2024-07-23-ts2-rx-rsu-0.pdml	C-V2X-2024-07-23-ts2-tx-rsu-1.pdml C-V2X-2024-07-23-ts2-rx-rsu-1.pdml	C-V2X-2024-07-23-ts2-tx-rsu-2.pdml C-V2X-2024-07-23-ts2-rx-rsu-2.pdml

3. Testing Dataset Use

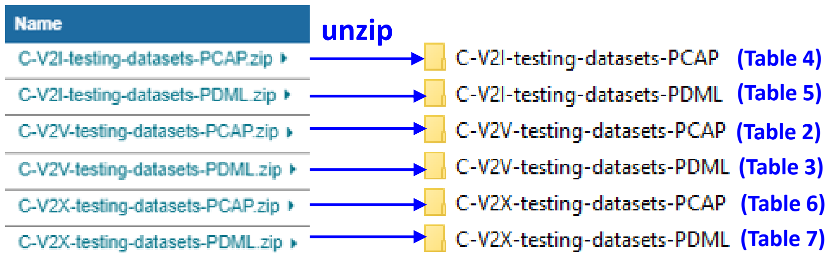

Figure 3.1. Organized structure of three testcase datasets.

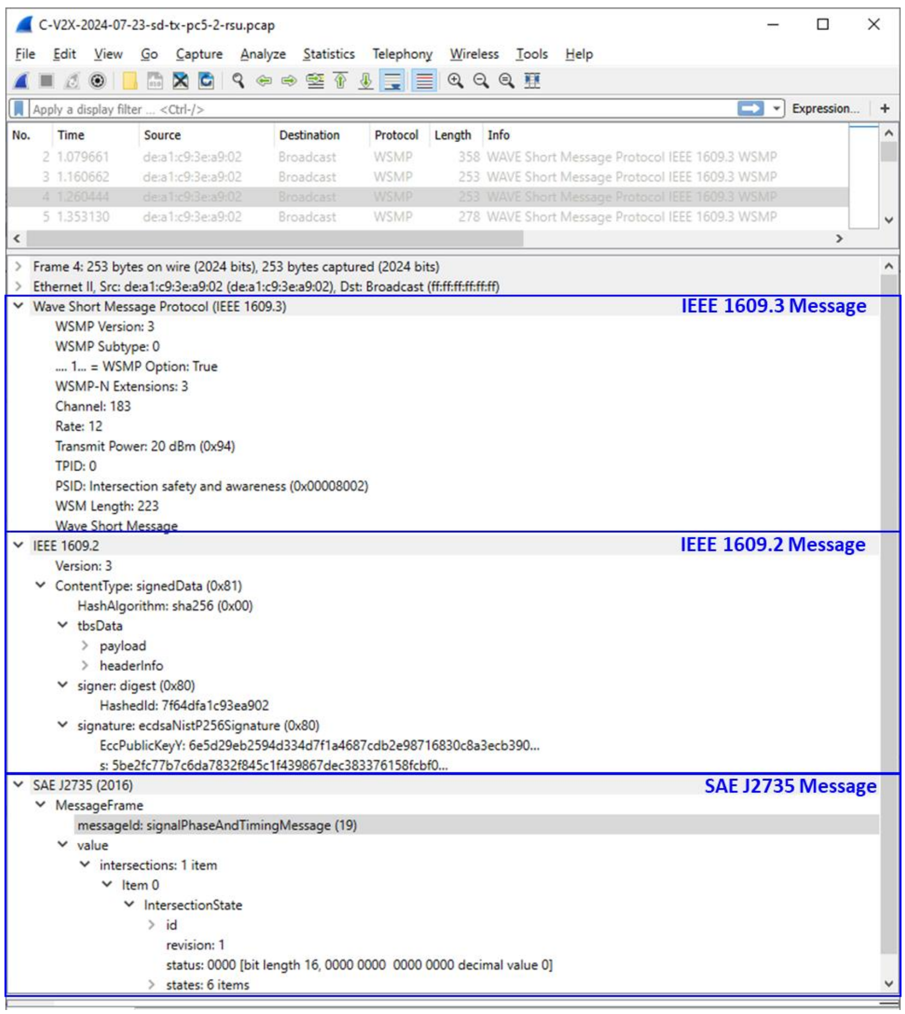

Figure 3.2. An example of IEEE 1609.3, 1609.2, and SAE J2735 message in a PCAP dataset.

Our three testcases are made up of C-V2I, C-V2V and C-V2X testcases. Figure 3.1 shows the organized structure of these testcase datasets. Each testcase includes both PCAP and PDML dataset files in zipped format (*.zip files). The corresponding total of six testing dataset zip files can be downloaded from NIST MIDAS [19] and unzipped into six separated folders as shown in Figure 3.1. The dataset files in the six folders are described in Table 2 through Table 7 in this document, as listed in Figure 3.1.

Figure 3.2 shows an example of IEEE 1609.3, 1609.2, and SAE J2735 messages in a PCAP dataset file for the standardized message analysis use. These PCAP datasets in Table 2, Table 4, and Table 6 can be used to display and analyze IEEE 1609.2 and 1609.3, and SAE J2735 messages using Wireshark [20] or a similar tool.


```
<proto name="16093" showname="Wave Short Message Protocol (IEEE 1609.3)" size="239" pos="14">
  <field name="16093.version" showname="WSMP Version: 3" size="1" pos="14" show="3" value="0b"/>
  <field name="16093.subtype" showname="WSMP Subtype: 0" size="1" pos="14" show="0" value="0b"/>
  <field name="16093.option" showname=".... 1... = WSMP Option: True" size="1" pos="14" show="1" value="1" unmaskedv
  <field name="16093.n_ext" showname="WSMP-N Extensions: 3" size="1" pos="15" show="3" value="03"/>
  <field name="16093.channel" showname="Channel: 183" size="1" pos="18" show="183" value="b7"/>
  <field name="16093.rate" showname="Rate: 12" size="1" pos="21" show="12" value="0c"/>
  <field name="16093.txpower" showname="Transmit Power: 20 dBm (0x94)" size="1" pos="24" show="20" value="94"/>
  <field name="16093.tpid" showname="TPID: 0" size="1" pos="25" show="0" value="00"/>
  <field name="16093.psid" showname="PSID: Intersection safety and awareness (0x00008002)" size="2" pos="26" show="0
  <field name="16093.length" showname="WSM Length: 223" size="2" pos="28" show="223" value="80df"/>
  <field name="" show="Wave Short Message" size="223" pos="30" value="03810040038078001375000002ab30100000500106302a9
</proto>
<proto name="16092" showname="IEEE 1609.2" size="223" pos="30">
  <field name="16092.version" showname="Version: 3" size="1" pos="30" show="3" value="03"/>
  <field name="16092.content" showname="ContentType: signedData (0x81)" size="1" pos="31" show="0x00000081" value="8
    <field name="16092.hashalg" showname="HashAlgorithm: sha256 (0x00)" size="1" pos="32" show="0x00000000" value="0
    <field name="16092.tabsData" showname="tbsData" size="0" pos="33" show="" value="">
      <field name="16092.payload" showname="payload" size="0" pos="33" show="" value="">
        <field name="16092.version" showname="Version: 3" size="1" pos="34" show="3" value="03"/>
        <field name="16092.content" showname="ContentType: unsecuredData (0x80)" size="1" pos="35" show="0x00000080"
          <field name="16092.varlen" showname="Length: 120" size="1" pos="36" show="120" value="78"/>
        </field>
      </field>
      <field name="16092.headerInfo" showname="headerInfo" size="0" pos="157" show="" value="">
        <field name="16092.psid" showname="Psid: 0x00000082" size="1" pos="159" show="0x00000082" value="82"/>
        <field name="16092.generationTime64" showname="generationTime64: 648858971210343" size="8" pos="160" show="6
        <field name="16092.generationLocation" showname="generationLocation: 00000000000000000000" size="10" pos="16
          <field name="16092.3d_lat" showname="Latitude: 0" size="4" pos="168" show="0" value="00000000"/>
          <field name="16092.3d_lon" showname="Longitude: 0" size="4" pos="172" show="0" value="00000000"/>
          <field name="16092.3d_elev" showname="Elevation: 0" size="2" pos="176" show="0" value="0000"/>
        </field>
      </field>
    </field>
    <field name="16092.signer" showname="signer: digest (0x80)" size="1" pos="178" show="0x00000080" value="80">
      <field name="16092.hashedid" showname="HashedId: 7f64dfa1c93ea902" size="8" pos="179" show="7f:64:df:a1:c9:3e:
    </field>
    <field name="16092.signature" showname="signature: ecdsaNistP256Signature (0x80)" size="1" pos="187" show="0x000
      <field name="16092.ecc_key_y" showname="EccPublicKeyY: 575b75d7fa449e6697b7c4b3aed33320612f6fdeaa7ea136\xe2\x8
      <field name="16092.s" showname="s: afaa841e89e980125c5222328774f21906bd22626b61b1e4\xe2\x80\xa6" size="32" pos
    </field>
  </field>
</proto>
<proto name="j2735_2016" showname="SAE J2735 (2016)" size="120" pos="37">
  <field name="j2735_2016.MessageFrame_element" showname="MessageFrame" size="120" pos="37" show="" value="">
    <field name="per.extension_bit" showname="0... .... Extension Bit: False" hide="yes" size="1" pos="37" show="0"
    <field name="j2735_2016.messageId" showname="messageId: signalPhaseAndTimingMessage (19)" size="2" pos="37" show
    <field name="per.open_type_length" showname="Open Type Length: 117" hide="yes" size="1" pos="39" show="117" valu
    <field name="j2735_2016.value_element" showname="value" size="116" pos="40" show="" value="">
      <field name="per.extension_bit" showname="0... .... Extension Bit: False" hide="yes" size="1" pos="40" show="0
      <field name="per.optional_field_bit" showname=".0.. .... Optional Field Bit: False (timeStamp is NOT present)"
      <field name="per.optional_field_bit" showname="..0. .... Optional Field Bit: False (name is NOT present)" hide
      <field name="per.optional_field_bit" showname="...0 .... Optional Field Bit: False (regional is NOT present)"
      <field name="per.sequence_of_length" showname="Sequence-Of Length: 1" hide="yes" size="1" pos="40" show="1" va
      <field name="j2735_2016.intersections" showname="intersections: 1 item" size="115" pos="41" show="1" value="00
        <field name="" show="Item 0" size="115" pos="41" value="002ab30100000500106302a9012880000f28870019288de03200
          <field name="j2735_2016.IntersectionState_element" showname="IntersectionState" size="115" pos="41" show="
```


Figure 3.3. An example of IEEE 1609.3, 1609.2, and SAE J2735 messages in a PDML dataset.

Figure 3.3 shows an example of IEEE 1609.3, 1609.2, and SAE J2735 messages in a PDML dataset file for the standardized message analysis use. These PDML datasets in Table 3, Table 5, and Table 7 are derived from the PCAP datasets using a proprietary Wireshark dissector plugin provided by Cohda Wireless. These PDML datasets can be parsed and used to analyze and assess compatibility and interoperability of IEEE 1609.2, 1609.3 and SAE J2735 messages using the interoperability analyzer software tool [20] developed based on IEEE 1609.2, 1609.3, and SAE J2735 standards.

4. Summary

This paper describes an IoT devices interoperability setup, three cellular vehicle-to-everything (C-V2X) interoperability testcases, and the resulting C-V2X testcase datasets, including testing dataset structure, dataset file naming method, and dataset file formats. It also describes how these datasets can be downloaded and used, including how to examine, analyze, and assess C-V2X compatibility and interoperability among commercial on-board units (OBUs) and road-side units (RSUs) based on IEEE 1609.2, 1609.3, and SAE J2735 standards.

References

[1] National Institute of Standards and Technology (2021) Enhanced Security Requirements for Protecting Controlled Unclassified Information. (Department of Commerce, Washington, D.C.), NIST.SP.800-172, https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-172.pdf.

[2] National Institute of Standards and Technology (2022) Profile of the IoT Core Baseline for Consumer IoT Products. (Department of Commerce, Washington, D.C.), NIST IR 8425, https://nvlpubs.nist.gov/nistpubs/ir/2022/NIST.IR.8425.pdf.

[3] IEEE (1990) IEEE 610.12 - Standard Glossary of Software Engineering Terminology. (IEEE, New York, NY) https://doi.org/10.1109/IEEESTD.1990.101064.

[4] Song EY (2018) Interoperability Testbed for Smart Sensors in Smart Grids, 2018 IEEE Power & Energy Society Innovative Smart Grid Technologies Conference (ISGT), (Washington, DC, USA), https://doi.org/10.1109/ISGT.2018.8403332.

[5] What is ITS? Available at https://www.dot.ny.gov/divisions/operating/oom/transportation-systems/systems-optimization-section/ny-moves/what-is-its.

[6] Eco-Approach and Departure at Signalized Intersections: Preliminary Modeling Results, Available at https://www.its.dot.gov/research_archives/aeris/pdf/UCR_eco-approach_final2.pdf.

[7] SAE (2022) SAE J2735-V2X Communications Message Set Dictionary, (SAE International, Warrendale, PA) https://www.sae.org/standards/content/j2735_202211/.

[8] IEEE (2022) IEEE 1609.2 - Standard for Wireless Access in Vehicular Environments—Security Services for Applications and Management Messages, (IEEE, New York, NY), https://doi.org/10.1109/IEEESTD.2023.10075082.

[9] IEEE (2020) IEEE 1609.3 - Standard for Wireless Access in Vehicular Environments (WAVE) -- Networking Services, (IEEE, New York, NY), https://doi.org/10.1109/IEEESTD.2021.9374154.

[10] GSG-5 GPS/GNSS Simulator, Available at https://safran-navigation-timing.com/wp-content/uploads/2021/07/GSG_UserManual_PN4031-600-54001Rev27-1.pdf.

[11] GPS410 - GPS Antenna Signal Splitter, Available at https://www.instockwireless.com/gps-splitter-4way-SMA-gps410.htm.

[12] Cohda MK6 RSU, Available at https://www.cohdawireless.com/wp-content/uploads/2024/07/CW_DL_Product-Brief-sheet-MK6-RSU-11-7-24.pdf.

[13] Cohda MK6 OBU, Available at https://www.cohdawireless.com/wp-content/uploads/2024/06/CW_DL_Product-Brief-sheet-MK6-OBU.pdf.

[14] Tektronix MDO4104B-6 Mixed Domain Oscilloscope, Available at https://download.tek.com/manual/MDO4000-Mixed-Domain-Oscilloscope-Service-Manual.pdf.

[15] Tektronix RSA306B Real-time spectrum analyzer, Available at https://www.tek.com/en/products/spectrum-analyzers/rsa306

[16] Cohda Mk6 software development kit (SDK), Available at https://www.cohdawireless.com/wp-content/uploads/2023/01/CW_Product-Brief-sheet-SDK-v2.pdf

[17] PCAP Capture File Format, Available at https://datatracker.ietf.org/doc/html/draft-ietf-opsawg-pcap.
[18] PDML Specification, Available at https://web.archive.org/web/20060103131443/http://analyzer.polito.it:80/30alpha/docs/dissectors/PDMLSpec.htm.
[19] C-V2X Interoperability Testing Datasets, Available at https://doi.org/10.18434/mds2-3541.
[20] Wireshark, Available at https://www.wireshark.org/
[21] C-V2X Interoperability Analyzer, Available at https://github.com/usnistgov/C-V2XInteroperabilityAnalyzer.