

IEEE Standard for Interoperability of Complex Virtual Instruments for Internet of Things

IEEE Instrumentation and Measurement Society

Developed by the
Sensor Technology Committee

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STANDARDS

IEEE Standard for Interoperability of Complex Virtual Instruments for Internet of Things

Developed by the

Sensor Technology Committee
of the
IEEE Instrumentation and Measurement Society

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Abstract: A framework for IoT application systems, a definition of a complex virtual instrumentation model, and agreement on a framework and interfaces to achieve interoperability of IoT applications, while specifying the communication methods, invocation parameters and return value formats of the interfaces, is given in this standard.

Keywords: complex virtual instrumentation, IEEE 2735™, Internet of Things, interoperability

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Introduction

This introduction is not part of IEEE Std 2735-2022, IEEE Standard for Interoperability of Complex Virtual Instruments for Internet of Things.

Internet of Things (IoT) application systems play an important role in smart industry, smart city, smart ocean, environmental monitoring, smart building, smart transportation, etc., enhancing the awareness and management of these fields. The main problems of current IoT application systems are the lack of integration mechanism between application systems, and the difficulty of data sharing and interconnection between systems, leading to high development, management and operation and maintenance costs.

This standard achieves interoperability of IoT applications by defining Complex Virtual Instrument (CVI) and the interaction methods between them. Complex Virtual Instrument is a software element with the following characteristics: (1) it can connect different instrument interaction software to realize the control and data acquisition of multiple sensing instruments; (2) it realizes the unified management of sensing parameter data and monitoring objects; (3) it provides a standardized data sharing interface; (4) interoperability between CVIs is realized through the data sharing interface.

This standard describes the CVI architecture, the CVI software properties, the CVI software interconnection methods, and the interface information of the CVI software interconnection parties. In addition, this standard describes the IoT Registration Center and data converging node. The Registration Center is used to manage CVIs and assign unique identities to them. Group users retrieve index information through the data converging node and then connect to the corresponding CVIs to obtain data. Following this standard, seamless integration can be achieved between CVIs in the same or similar domains of IoT, and interoperability between applications can be realized. This standard plays an important role in enhancing the standardization of IoT application development process, improving the efficiency of IoT application development and operation and maintenance, and strengthening IoT data integration.

The content of this standard is organized as follows: [Clause 1](#) introduces the scope and purpose of the standard; [Clause 2](#) lists the normative references used in this standard; [Clause 3](#) lists the terms and abbreviations used in this standard; [Clause 4](#) details the CVI architecture and the CVI software and association structure to which the CVI software design should refer; [Clause 5](#) describes the CVI software interconnection framework and the CVI software interoperability process; [Clause 6](#) describes the attributes of the CVI software that are stored in the CVI description file; [Clause 7](#) specifies the CVI software data access methods; [Clauses 8 through Clause 10](#) describes the interfaces of the CVI node, Registration Center, and data converging node, respectively, specifying the functions, parameters, and return values of the interfaces; and [Clause 11](#) describes the security measures that should be considered when implementing the CVI software and the interconnection system.

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IEEE Standard for Interoperability of Complex Virtual Instruments for Internet of Things

1. Overview

1.1 Scope

This standard provides the definitions and terminologies, reference model, and data structure of Complex Virtual Instruments (CVIs) for Internet of Things (IoT). CVIs framework, including architectural model, protocols, and data interface requirements are also defined to allow for flexible and scalable solutions to CVIs Interoperability and easy-to-implement cloud services that are able to be maintained in a sustainable manner.

1.2 Purpose

This standard addresses interoperability issues of Complex Virtual Instruments (CVIs) for Internet of Things (IoT) and provides CVIs framework and requirements that outline the technologies and processes to help ensure flexible, reliable, and sustainable solutions to interoperability issues of IoT system. This standard assists developers in adopting CVIs-based development methods in building IoT software system, improves development efficiency by leveraging reusable and configurable CVIs, aids IoT enterprises to accelerate integration of IoT heterogeneous data, lays data foundation for big data analysis and applications, and promotes management level and usage of IoT data.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{6,7}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

⁶The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁷The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE Std 1451.0™-2007, Standard for a Smart Transducer Interface for Sensors and Actuators-Common Functions, Communication Protocols, and Transducer Electronic Data Sheet (TEDS) Formats.^{8,9}

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this standard, the following terms and definitions apply. Terms not defined in this entry should be referred to the authoritative dictionary of IEEE Standard Terms.¹⁰

Complex Virtual Instruments (CVI): A software element, which connects to the instrument interaction software through a normalized input interface, receives structured and unstructured data related to the monitoring objects, and enables the unified management of sensing parameter data and monitoring objects.

CVI description file: Files that store CVI properties.

CVI node: A system consisting of one or more computers and the database software, CVI software, and node interconnection interface running on them.

data converging node: A node in an interoperability group, which can create interoperability groups and pool index information of nodes in the group. An interoperability group only has one data converging node.

group users: The node that invokes the interface provided by the data converging node or CVI node to obtain the data.

instrument interaction software: A stand-alone program module that is able to communicate with sensing instruments or smart sensors to collect data and interface with the data input modules of complex virtual instruments.

monitoring metadata: Data describing information about the attributes of the monitored objects.

monitored object: The object to be monitored by the CVI-connected sensing instruments, which can be a specific object or a certain area or range.

Registration Center: The service node used to provide identifications for the CVI nodes or data converging nodes in the entire interconnection systems and is responsible for managing all CVI nodes.

sensing instrument: A hardware module connected to many sensors, which has a signal conversion functions and communication interfaces.

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¹⁰The numbers in brackets correspond to those of the bibliography in Annex A.

sensing parameters: Sensing parameters contain physical sensing parameters and logical sensing parameters. The former is the sensing value provided by the sensing instrument, and the latter is parameters calculated from multiple physical sensing parameters collected at the same moment.

sensors: A physical device that reflects information about the objects being measured and reflects the physical, chemical, or biological properties of the objects.

Smart Sensors: Sensors with information processing functions that generally have the ability to collect, process, and exchange information. In this standard, “smart sensor” refers to sensors that comply with IEEE Std 1451 or other relevant standards. See Clause 5 of IEEE Std 1451.0™–2007.¹¹

socket: An inter-process communication mechanism provided by the operating system. The socket address consists of an IP address and a port number. The endpoints identified by the two socket addresses can communicate with each other after the communication protocol is specified.

3.2 Acronyms and abbreviations

CVI	Complex Virtual Instrument
IoT	Internet of Things
JSON	JavaScript Object Notation
URL	Uniform Resource Locator

4. CVI Architecture Reference Model

4.1 General

CVI Architecture Reference Model [B1] is the general architecture of IoT systems in this standard. It includes the CVI Hierarchy Model, CVI Node Structure Model, CVI Software Model, and CVI Interconnection model.

4.2 CVI Hierarchy Model

In the CVI Hierarchy Model [B1], the overall structure of IoT is reasonably divided. The CVI Hierarchy Model is shown in Figure 1. From the bottom-up is the smart instrument layer, data transmission layer, instrument interaction layer, node application layer, system service layer, and group application layer. The meaning of each layer is listed as follows:

- a) The smart instrument layer is the sum of smart instruments at the front end of the IoT.
- b) The data transmission layer includes the connection hardware and communication protocol software between the computer and the sensing instruments. It is the basis for information transmission between the sensing instruments and the computer.
- c) The instrument interaction layer refers to the instrument interaction software running on the computer, which converts the control commands from the node application layer into control commands for specific sensing instruments and sends them to the corresponding sensing instruments to realize the control of the sensing instruments. It also receives and parses the sensing parameter data returned by the sensing instruments and encapsulates it, then passes it to the node application layer software.
- d) The node application layer refers to the collection of node application software running on the computer, mainly including CVI software, database, and node interconnection interface. The node application software obtains sensing parameter data from the instrument interaction software. It also

¹¹Information on references can be found in Clause 2.