



IEEE Standard for Design Criteria of Integrated Sensor-Based Test Applications for Household Appliances

STANDARDS

IEEE Consumer Technology Society

Developed by the
Emerging Technology Standards Committee

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IEEE Standard for Design Criteria of Integrated Sensor-Based Test Applications for Household Appliances

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Emerging Technology Standards Committee
of the
IEEE Consumer Technology Society

Approved 30 March 2023

IEEE SA Standards Board

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Abstract: A data integrated framework of the test software for household appliances is defined by this standard. The node information of complex virtual instruments (CVIs), the sensor parameter information, the test metadata information, and the sensor data information, as well as the means to acquire the information (either microservices or data-exchange files), are specified by this standard.

Keywords: complex virtual instruments, household appliances test, IEEE 1851™, microservice, sensor data, systems interoperability

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Introduction

This introduction is not part of IEEE Std 1851-2023, IEEE Standard for Design Criteria of Integrated Sensor-Based Test Applications for Household Appliances.

Quality control is an essential part of the household appliance manufacturing process. The appliance manufacturer performs various tests for household appliances. Most of the tests are completed by the test systems in multiple test laboratories distributed over a wide geographic area. The test systems include three parts: instruments equipped with sensors, computers, and sensor-based test applications. The test application part is responsible for automatically collecting, managing, analyzing, and presenting the data for the users, which is the backbone of the test systems.

Due to the lack of the development criterion of test applications for household appliances, there exist many problems, such as integration problems, reusability problems, interoperability problems, and exchange problems of test documents. Specifically, for some government supervision departments, it affects supervision efficiency due to diverse data formats, test types, and measurement systems. Limited human resources are also a vital problem. For the product manufacturing enterprises, it leads to low measurement and management efficiency. For the test software development corporations, it brings low development efficiency, huge development costs, long development cycles, and a waste of manpower resources. This document provides the standard format of testing data of household appliances, which makes it easier for users from different enterprises, including product supervisors of government, to read and exploit such kinds of data. This standard also provides the system framework and a set of microservices like testing data transforming and transferring, which are the basis for software engineers to develop integrated testing applications. This standard plays a very important role in improving the supervising efficiency of government departments, the quality management efficiency of the manufacturing enterprises, and the test software development efficiency of software development corporations.

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1. Overview

This standard was developed to serve as a design criteria for integrated sensor-based test applications for household appliances. It specifies the system integration framework, describes [the](#) test information format, and provides two means to acquire the information via [microservice](#) ~~Web service~~ interfaces and data-exchange files.

1.1 Scope

This standard defines the integrated framework ~~of the test software~~ for household appliances based on the complex virtual instrument (CVI) nodes and their interconnection service interfaces oriented to the data from intelligent sensors, including system framework, microservice interfaces ~~of Web services~~, and data exchange formats, which can be divided into: a) as: (1) the system framework to integrate the distributed test applications; b) the description of the appliance test ~~environment and test~~ information, including the metadata of the CVI node whole test application, the metadata of the sensor parameters appliance to be tested, the metadata of the test sensors, and the sensor data; c) the file format of test information data to be exchanged among distributed test applications; and d) the microservices ~~(4) The Web services~~ to transform and transfer monitored data.

1.2 Purpose

This standard defines the file format of test information data from household appliances and the microservices Web services that enable the exchange of such test information data. Implementation of this standard solves the ~~interoperability and~~ integration problems for CVI nodes of building test applications for household appliances testing as well as the problems with related to the exchange of related test information 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*).

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

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

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

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

1.4 Users

Anticipated users of the standard include the following:

- Household appliance test application developer
- Household appliance research and development staff
- Household appliance testing laboratory assistant
- Household appliance enterprise manager
- Government quality control staff

1.5 Conventions used within this document

~~This standard presents an integrated framework of the test application for household appliances, specifying test environment and test information.~~

This standard uses the vocabulary and definitions of relevant IEEE standards. In case of conflict of definitions, except for those portions quoted from standards, the following precedence shall be observed: a) Clause 3, b) the referenced document of Clause 2, and c) the *IEEE Standards Dictionary Online* [B2].⁸ The format and terminology standards follow the *IEEE Standards Style Manual* [B3]. ~~(1) Clause 2, (2) Annex C, and (3) the *IEEE Standards Dictionary Online*. The format and terminology standards follow *IEEE Standards Style Manual* [B1].¹~~

^{8,1} The numbers in brackets correspond to those of the bibliography in Annex C.

The CVI mentioned in this standard refers to a software element that meets the following conditions: a) connects different device interaction software using standardized input interfaces, b) receives unstructured data related to monitoring the objects through standardized input interfaces, and c) realizes unified management of sensing parameter data and monitoring objects. For the detailed definition of CVI and its related information, please refer to IEEE Std 2735TM.⁹

IEEE Std 2735 defines the CVI, the data converging node, the registered center, and the group user; explains relevant concepts; and describes a set of related interfaces for registering and obtaining data. The CVI related content mentioned in this standard is referenced from IEEE Std 2735.

Hypertext Transport Protocol (HTTP) defines the GET method and relevant concepts mentioned in this standard (RFC 9113 [B5]).

JavaScript Object Notation (JSON) is a subset of JavaScript Programming Language. Furthermore, it is a lightweight data interaction method based on the string. JSON is the primary method of data formatting to format the data in this standard (ECMA-262 [B1]).

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 2735-2022, IEEE Standard for Interoperability of Complex Virtual Instruments for Internet of Things.^{10,11}

⁹ Information on references can be found in Clause 2.

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3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause. ¹² ²

complex virtual instrument (CVI): Refers to a software element that meets the following conditions: a) connects different device interaction software using standardized input interfaces; b) receives unstructured data related to monitoring the objects through standardized input interfaces; and c) realizes unified management of sensing parameter data and monitoring objects. For the definition of CVI and its related information, please refer to IEEE Std 2735.

input item: A collection of input information in a single test describes the relevant information of the current household appliance test. The collection is composed of one or more single entry entries, and each entry includes two parts: entry name and entry content.

JavaScript Object Notation (JSON) dictionary: A key-value pair, consisting of a uniquely tagged value (key) of multiple JavaScript Object Notation (JSON) elements and a JSON element (value), is wrapped using curly brackets, which identify its start and end positions. In the dictionary, the corresponding unique JSON value can be queried by the key, and the key is separated from the value using a colon.

¹² IEEE Standards Dictionary Online is available at: <http://dictionary.ieee.org>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page. ~~subscription is available at~~ http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html

⁴ ~~W3C is a registered trademark of the World Wide Web Consortium (registered in numerous countries). Marks of W3C are registered and held by its host institutions: Massachusetts Institute of Technology (MIT), European Research Consortium for Information and Mathematics (ERCIM), and Keio University, Japan.~~

JavaScript Object Notation (JSON) element: A limited component of a JavaScript Object Notation (JSON) string logic structure, which can be dictionary, list, number, float number, logical value, string, null, or undefined.

NOTE—See ECMA-262 [B1].¹³

JavaScript Object Notation (JSON) list: An ordered list of multiple JavaScript Object Notation (JSON) elements can be queried by an index value starting with 0 to find the unique JSON element.

microservices: Refers to a software architecture that divides the whole complex background service interface into multiple modules with low coupling. These modules have no dependence and association with each other, or there is only a small amount of data or file association. Each of them can be replaced or updated individually without maintaining other modules. These services form a group that provides overall service support for front-end applications.

~~**element:** A bounded component of the logical structure of an eXtensible Markup Language (XML) document that has a type and that may have XML attributes and content.~~

NOTE—Adapted from W3C® Recommendation [B7]).^{3,4}

~~**eXtensible Markup Language (XML) attribute:** Name-value pair associated with an XML element.~~

~~**input item:** A set of items whose contents are the metadata that describe an appliance.~~

~~**key parameter:** A predefined set of keywords, each of which represents one type of information whose value is measured by physical sensors or calculated by specific algorithms or computations.~~

~~**laboratory:** A room or building where household appliances are tested.~~

~~**relative time:** The time (in units of seconds) in reference to the start of a test.~~

¹³ ³ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

Sensor: A concept that refers to physical sensors or logical sensors that reflect the performance of appliances. Physical sensors measure the physical properties of appliances, and logical sensors are defined based on physical sensors.

sensor parameter: The parameter obtained by the sensor. Normal sensing parameters are directly obtained by physical sensors, and virtual sensing parameters are obtained by logical sensors.

~~**sensor data:** A collection of structural data, each of which contains sensor identifier (ID) and measurement data of one sensor.~~

~~**sensor group:** A logical entity that contains a set of sensors with the same sensor type, in which maximum, minimum and average values of this group can be calculated.~~

~~**sensor identifier (ID):** The identifier of a sensor in a test unit.~~

~~**sensor metadata:** The information related to sensors and groups defined in a household appliance test.~~

~~**sensor type:** Category of sensors that share common characteristics.~~

~~**test capacity:** The number of test units in one laboratory.~~

test data: A collection of structural data, each of which contains time ~~stamp~~ and sensor data.

~~**test environment:** The overall information about one laboratory, which mainly consists of test unit navigation and test unit information.~~

test information: The information ~~data~~ produced in one test for one appliance over a period of time, including test metadata, sensor metadata, and test data.

test metadata: Defined to describe the attributes in a single test, including test standard, appliance type, tester, and so forth ~~The information that describes test data generated by one test, in which the product information is also contained.~~

test system: A measurement system consisting of instruments, the computer, and the complex virtual instrument (CVI) node software. ~~test applications.~~

~~test unit: A physical entity that is built to test one appliance. It contains a collection of sensors connected with instruments. One test unit corresponds to one appliance.~~

~~test unit navigation: A navigation tree that is used to access a test unit.~~

~~time stamp: The time when the sensor data are collected. It shall be in relative time form.~~

3.2 Acronyms and abbreviations

CVI complex virtual instrument

~~CDL~~ ~~Common Data Language~~

HTTP Hypertext Transport Protocol

JSON JavaScript Object Notation

~~netCDF~~ ~~Network Common Data Format~~

~~SOA~~ ~~Service Oriented Architecture~~

URL uniform resource locator

UTF-8 8-bit Unicode Transformation Format

~~XML~~ ~~eXtensible Markup Language~~

4. System framework

4.1 Architecture

A system framework is a conceptual model in which existing heterogeneous test systems shall be integrated seamlessly ([B1] Guo et al.). The implementation of [the](#) system framework [enables](#) ~~achieves the aim of~~ standardized data access [for each CVI node and across various types of laboratories, secure data integration of aggregation across household appliance testing systems.](#) The [main features](#) ~~enterprises, and uniform user operations. Some of characteristics~~ of the ~~system~~ framework [structure](#) are as follows. :

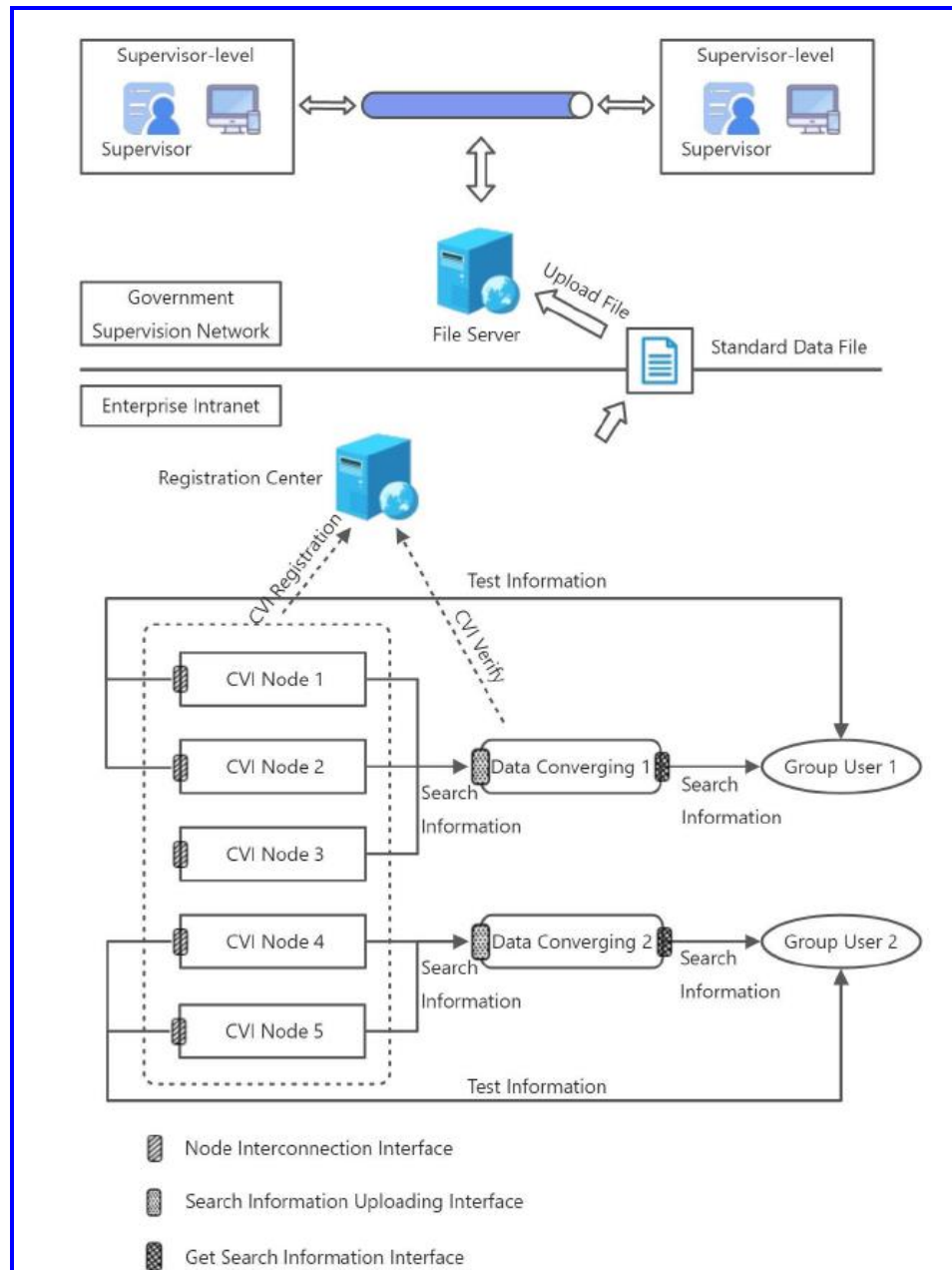
- ~~Interoperability and~~ Ease of integration. Various distributed and heterogeneous [CVI nodes](#) ~~test systems~~ can be ~~integrated~~ seamlessly [integrated through microservices.](#) In addition, ~~node based on Web services. Furthermore, test~~ data from different ~~household~~ appliance [companies shall](#) ~~enterprises can~~ be processed in a standard way.
- Scalability. The framework is scalable to integrate the increased number of test systems. A [CVI node](#) ~~test system~~ shall be added or removed by ~~either~~ registering or unregistering at the registration center.
- Uniformity. ~~A~~ Uniform software [interfaces are](#) ~~user interface shall be~~ achieved based on system integration. Users may pay more attention to product testing without worrying about the problems caused by diverse software operations and interfaces.

The system framework shall be divided into three application levels corresponding to [the CVI node,](#) [the laboratory,](#) enterprise, and [the supervisor of](#) government [supervisor.](#) Figure 1 shows the whole system architecture and specifies the parts that need to be standardized. The most basic one is the [CVI node](#) ~~laboratory~~-level application. High-level applications are based on low-level applications. Applications at each level meet different user requirements and have their ~~own~~ characteristics.

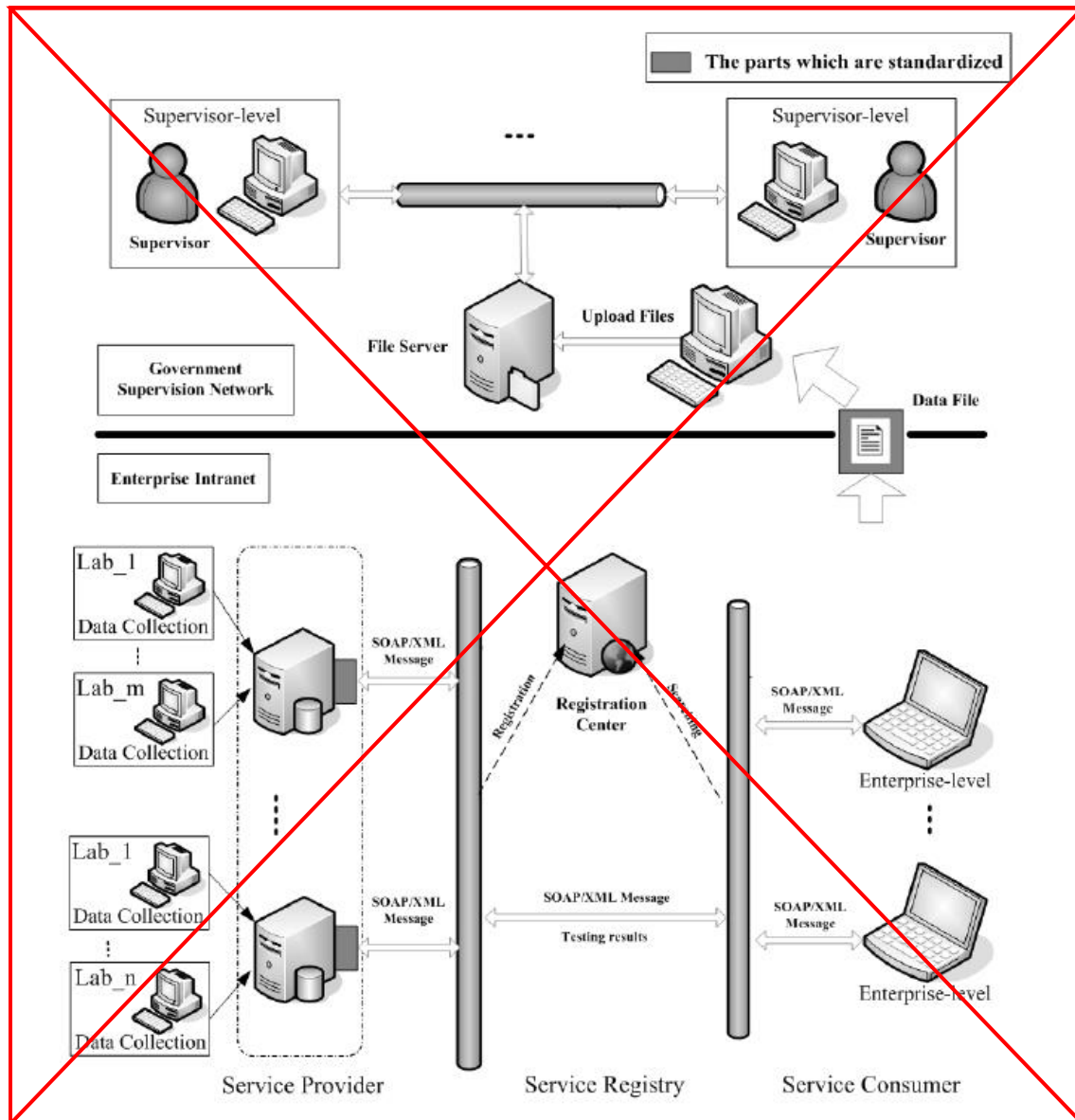
CVI node ~~Laboratory~~-level applications are responsible for collecting data from instruments and presenting it to users. These applications aim at specific ~~one-of-various~~ tests and are operated by laboratory assistants. Generally, they work in the local test laboratory. A typical test laboratory for household appliances follows the below topology: many ~~a-number-of~~ instruments are connected to a data collection personal computer (PC) using standard communication interfaces; each instrument is equipped with many sensors; several sensors [e.g., temperature (T), voltage (V), electrical energy (E), power (P)] constitute a test unit, as illustrated in Figure 2. One test unit corresponds to one appliance and is used to monitor the appliance's status. Enterprise managers take charge of checking the product testing of the whole enterprise and need to know the product testing status and results of each testing ~~test~~ laboratory. Traditionally, due to the heterogeneous local ~~laboratory-level~~ testing applications, enterprise managers have to travel across multiple test laboratories distributed over a wide range of areas, which degrades product test efficiency and increases test expense severely.

Enterprise-level applications, developed by adopting microservice, ~~Service-Oriented Architecture (SOA)~~, are built for solving the heterogeneity problem. Various CVI node ~~laboratory~~-level applications are integrated based on microservice. The typical ~~Web-services~~. ~~Typical~~ enterprise-level application comprises the service provider, service register, and service consumer. The service provider publishes the CVI node ~~test environment information (shown in 4.1)~~ and its ~~interconnection service interface~~ ~~test information (shown in 4.2)~~ according to the standard. ~~The service register provides the registration information of the test system.~~ The service provider provides the information of the CVI node and registers it with ~~its published Web service to~~ the service registration center. CVI node ~~registry, and the registry information required is shown in Table 1.~~ ~~Laboratory-level~~ applications often serve as service providers ~~provider~~, while enterprise-level applications are regarded as service consumers ~~consumer~~. Enterprise-level applications mainly focus on the primary ~~basic~~ test node information, test metadata, environment and test data (shown information (described in Clause 5 ~~4)~~ rather than the specified data format of each laboratory. Enterprise ~~level application. To protect commercial profits, enterprise~~ -level applications usually run in an internal network to protect commercial profits.

Supervisor-level applications facilitate supervisory inspections. It is not viable to provide open access ~~to of~~ test information based on [microservices](#) ~~Web services~~ since the government supervision network is isolated ~~from with~~ the enterprise intranet in most situations. In this case, data files are adopted to enable government inspections. The [inspection](#) ~~information-in-relation-to-inspections~~ is converted into a set of files and transferred to supervisory institutions. The format of data files is standardized so that they ~~can are able to~~ be decoded correctly.

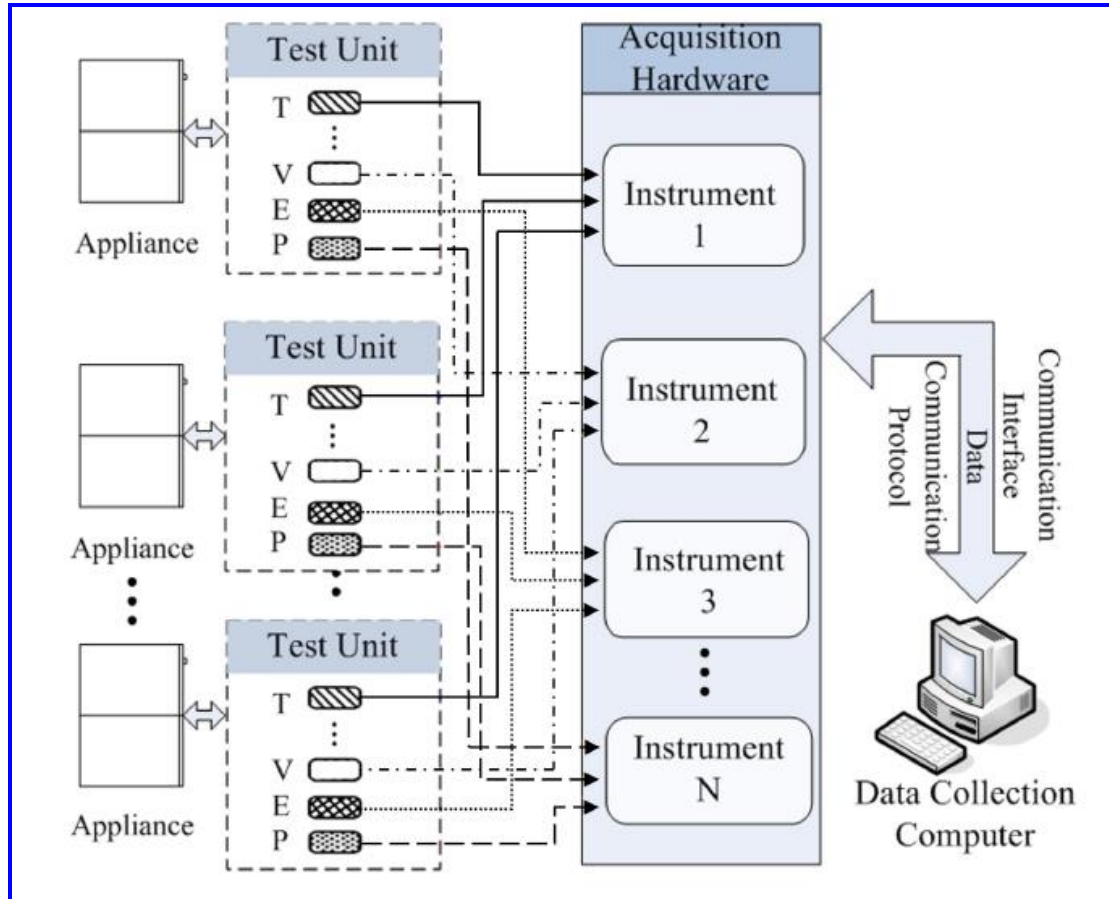


(New)



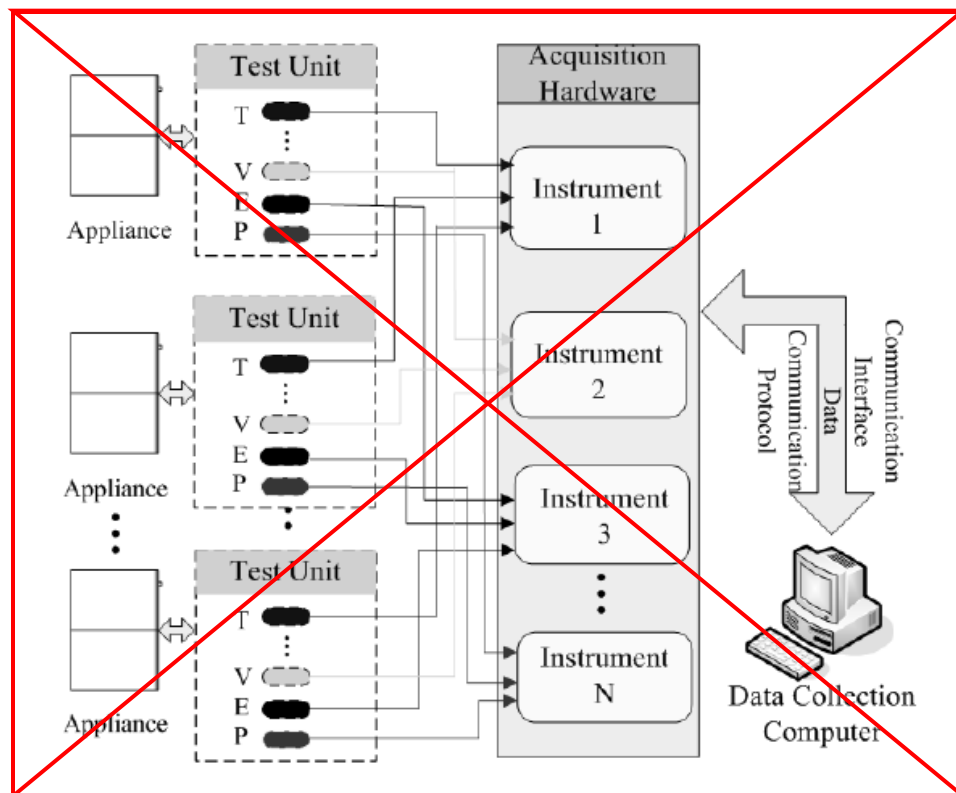
(Deleted)

Figure 1 — System framework



(New)

Figure 2 – A typical test laboratory for household appliances



(Deleted)

Figure 2—Typical hardware structure for one laboratory

Table 1—Registration Information

Registration information	Type	Comment	Use
Testing Service Name	String	The name of the Testing Service. The length of the string must be less than 256 characters.	Required
Testing Service URL	String	The URL that is published. The length of the string must be less than 256.	Required
Testing Service Description	String	Brief description of a Testing Service. The length of the string must be less than 1024 characters.	Optional

(Deleted)

4.2 Workflow

The workflow is as follows:

- a) The service provider publishes the relevant CVI nodes' interconnect service interfaces ~~Web services.~~
- b) The service provider registers the CVI node and publishes its registration information via the registration center ~~service register.~~
- c) The CVI node uploads the search information to the data converging node.
- d) A group user gets the search information of the CVI nodes from the data converging node.
- e) The group user gets the test information from the CVI node interconnection interface.
- ~~3) Remote users make use of Web services to build the enterprise level application.~~
- ~~4) Service consumer gets the registration information index from service register.~~
- ~~5) Service consumer gets data through Web service interfaces of the selected service provider.~~

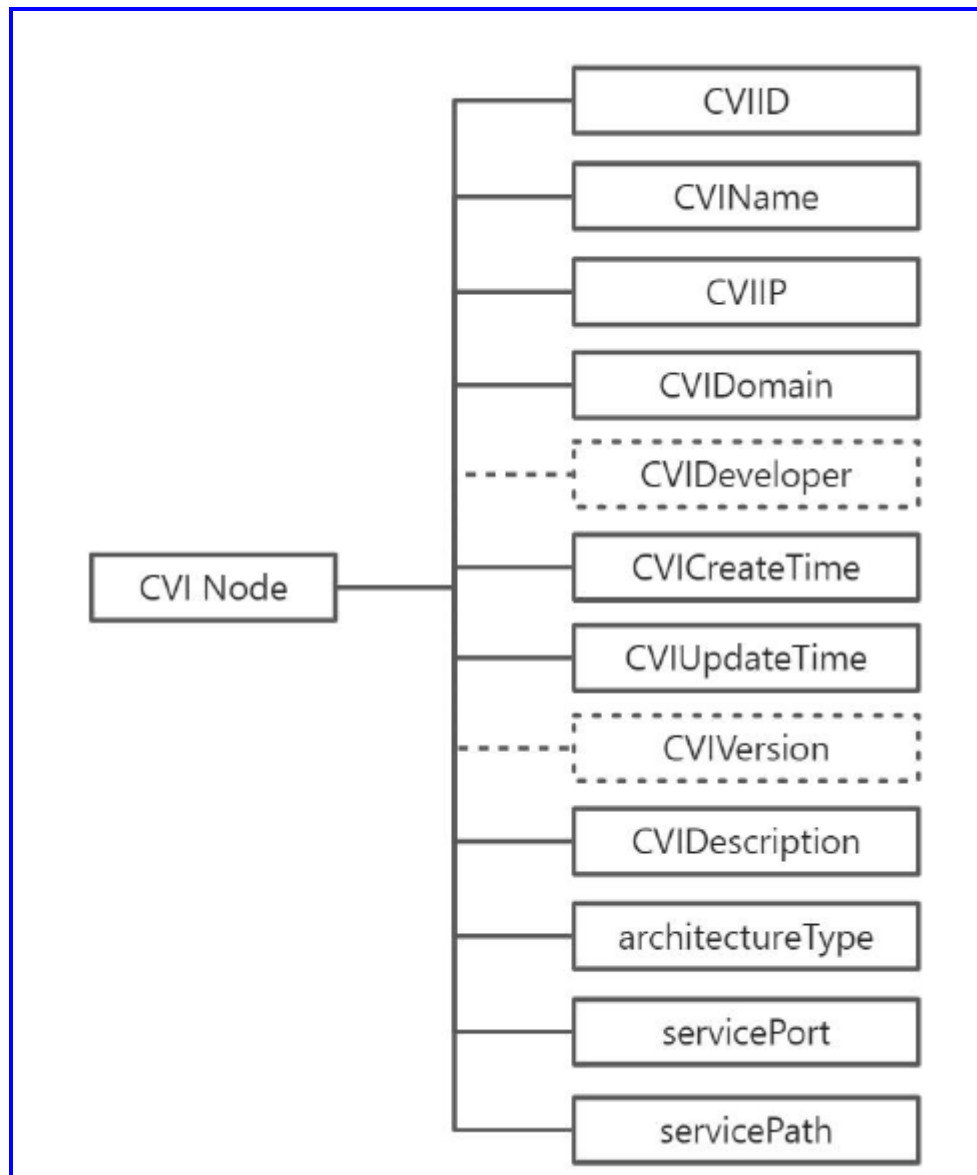
5. Test information structure

5.1 General

This section details the information related to the CVI node status and the tests under the node. The structure of this information may differ depending on the type of test and the test environment. The standard abstracts and proposes a common data model. The model covers the basic information in the CVI node for appliance testing in a more comprehensive way and can meet the requirements of various types of tests. In this data model, all pieces of information are covered by four elements (CVI Node, metaDataCollection, selectedSensor, and sensorDataCollection) and their subelements.

5.2 CVI node

Figure 3 illustrates the structure of the CVI element. Its child elements contain basic information about the CVI node, such as CVIID, CVI name, domain, developer, and so forth.



(New)

Figure 3 — Structure of CVI element

5.2.1 Child elements

The description of the CVI element is shown in Table 1.

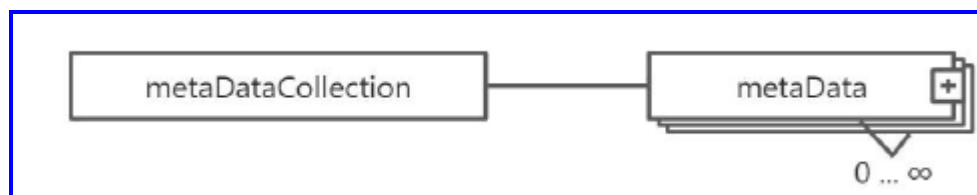
Table 1 — Description of CVI element

Name	Type	Description	Use
CVIID	String	Specify a unique CVI through CVIID	Required
CVIName	String	The name of the CVI node	Required
CVIIP	String	The Internet protocol (IP) address of the CVI node	Required
CVIDomain	String	The domain of the CVI node	Required
CVIDeveloper	String	The developer of the CVI node	Optional
CVICreateTime	String	A string indicating the creation time of the CVI node; the time format as follows: "yyyy-MM-dd HH:mm:ss"	Required
CVIUpdateTime	String	A string indicating the update time of the CVI node; the time format as follows: "yyyy-MM-dd HH:mm:ss"	Required
CVIVersion	String	The version of the CVI node	Optional
CVIDescription	String	The description information of the CVI node	Required
architectureType	String	The architecture type of the CVI node, where "B/S" stands for Browser/Server type and "C/S" stands for Client/Server type	Required
servicePort	Integer	The service port of the CVI interconnection service; should be an integer from 0 to 65 535	Required
servicePath	String	The main service path of the CVI interconnection service	Required

(New)

5.3 metaDataCollection

The metaDataCollection is a collection containing metadata information of multiple appliance tests, consisting of its child elements metaData, which contains metadata information of one test. The metaDataCollection structure is shown in Figure 4.



(New)

Figure 4 — Structure of metaDataCollection element

5.3.1 Child elements

The description of the metaDataCollection element is shown in Table 2.

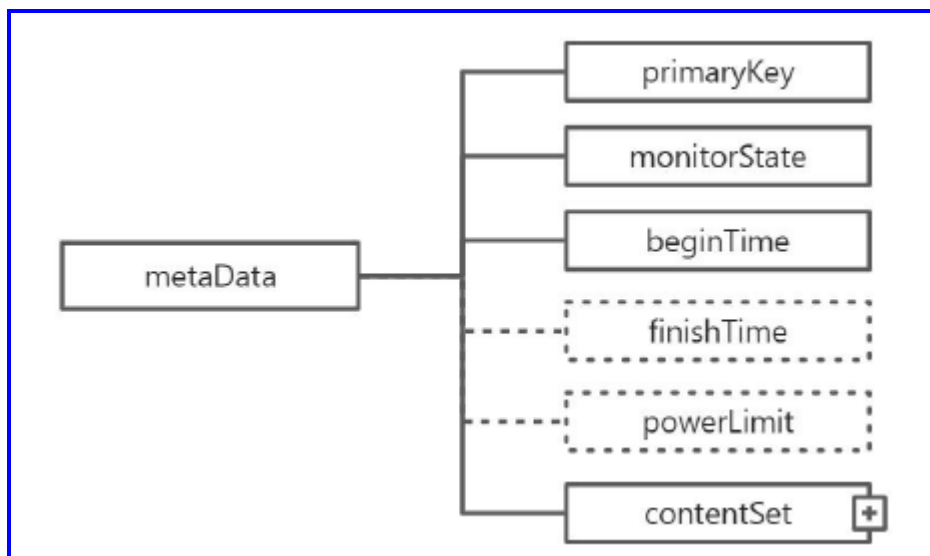
Table 2 — Description of metaDataCollection element

Name	Type	Description	Use
metaData	MetaData	Test metadata for a single test; see 5.3.2 for details	0 ... ∞

(New)

5.3.2 metaDataCollection/metaData

The metaData contains the metadata information of a test and consists of monitoring identifier, monitoring status, monitoring metadata generation time, monitoring end time, power limit, and monitoring metadata entry subelements. The metaData structure is shown in Figure 5.



(New)

Figure 5 — Structure of metaData element

5.3.2.1 Child elements

The description of the metaData element is shown in Table 3.

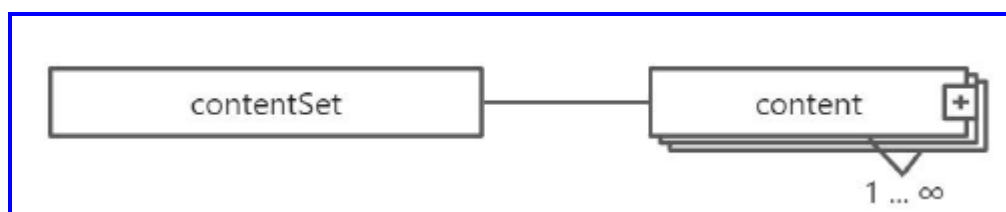
Table 3 – Description of metaData element

Name	Type	Description	Use
primaryKey	String	Unique identifier of one test.	Required
monitorState	Boolean	Monitoring status: “true” for monitoring. “false” for monitoring is over.	Required
beginTime	String	A string indicating when the monitoring metadata was generated, that is, when monitoring started, in the format “yyyy-MM-dd HH:mm:ss”.	Required
finishTime	String	A string indicating the end time of monitoring, in the format “yyyy-MM-dd HH:mm:ss”; this element is required if the current monitoring task has been ended.	Optional
powerLimit	Float	When the power is less than this value, the appliance is considered to be in a stopped state. The unit is “W.”	Optional
contentSet	String	Metadata of monitoring entry names and content collections; see 5.3.2.2 for details.	Required

(New)

5.3.2.2 metaDataCollection/metaData/contentSet

As shown in Figure 6, the contentSet contains the set of input entries in a single test, consisting of the child element content, which contains the name and content of a metadata entry in a single test. See 5.3.2.2.2 for its structure.



(New)

Figure 6 – Structure of contentSet element

5.3.2.2.1 Child elements

The description of the contentSet element is shown in Table 4.

Table 4 – Description of contentSet element

Name	Type	Description	Use
content	Content	One input entry message in a single test; see 5.3.2.2.2 for details	1 ... ∞

(New)

5.3.2.2.2 metaDataCollection/metaData/contentSet/content

The content element contains information about a monitoring metadata entry in a single test and consists of two parts: the input entry name and the input entry value. The specific format of the content element is shown in Figure 7.

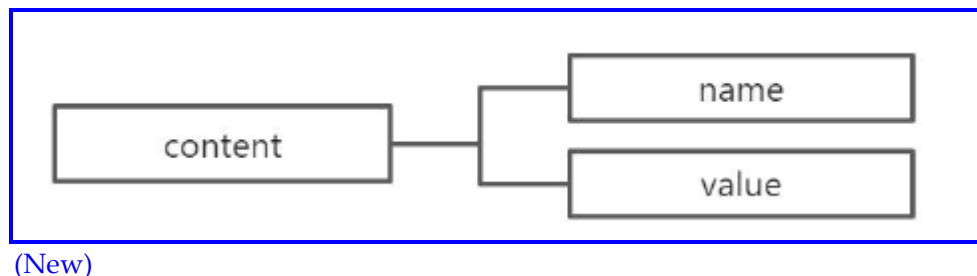


Figure 7 — Structure of content element

5.3.2.2.3 Child elements

The description of the content element is shown in Table 5.

Table 5 — Description of content element

Name	Type	Description	Use
name	String	Input entry name	Required
value	String	Input entry value	Required

(New)

5.4 selectedSensorCollection

Figure 8 shows the structure of the selectedSensorCollection element, which is a collection of selectedSensor child elements. Each selectedSensor element represents one sensing parameter used in one test. See 5.4.2 for its structure.