SmartCom

Good Practice Guides SmartCom Validation

(1) Test for communication interfaces used for the exchange of metrological data

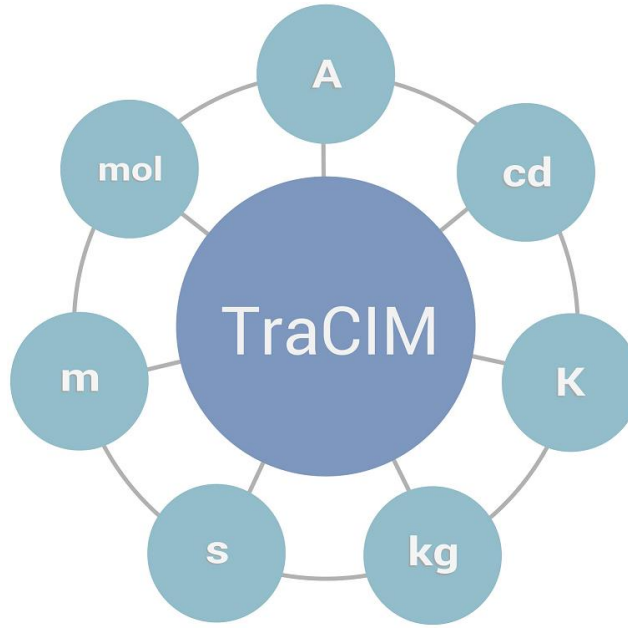
(2) Conformity test for unified DCCs

(3) TraCIM system

TraCIM D-SI

DOI: 10.5281/zenodo.3816696

EN



Good practice guide

Test for communication interfaces used for the exchange of metrological data

Version 1.0

DOI: 10.5281/zenodo.3816696

Editors

National Physical Laboratory, United Kingdom:
I. Smith, Y. Luo

Physikalisch Technische Bundesanstalt, Germany:
D. Hutzschenreuter, S. Schönhals

Comprising the results from our research and the fruitful and intensive discussions with all our other project partners and stakeholders worldwide.

Contact: smartcom@ptb.de

Teddington June 2020

DOI: 10.5281/zenodo.3816696

Table of Contents

DOI: 10.5281/zenodo.3816696

1 Introduction

The European Metrology Programme for Innovation and Research (EMPIR) Joint Research Project (JRP) “Communication and validation of smart data in IoT-networks” (short name “SmartCom”) [1] is concerned with establishing a means to exchange metrological data in communication networks.

A key output of the SmartCom JRP is the “Digital System of Units” (referred to subsequently as the “D-SI”) [2]. The D-SI provides a framework that allows metrological data, including associated uncertainty information, to be stored and transmitted in digital form. The D-SI forms the basis for the harmonised, clear, secure and economical exchange of measurement results in the case that those results are stored and transmitted as digital data. The D-SI allows real and complex quantities, and univariate and multivariate quantities to be specified. In addition to a general framework for metrological data, an implementation of the framework in Extensible Markup Language (XML) [3] has been developed within the SmartCom JRP.

For communication interfaces that transfer metrological data, it is imperative that the data conforms to all conditions deemed to be applicable. Examples include the requirements that only units identified within the BIPM SI Brochure [4] are used, that an expanded uncertainty must be a positive decimal number, and that a coverage probability must lie in the closed interval [0, 1]. It is therefore highly recommended that testing of metrological data is undertaken prior to transmission.

For the XML implementation of the D-SI, it is generally possible to undertake a subset of the necessary tests by checking that data provided in XML format is both well-formed and adheres to the XML schema for metrological data. However, since these checks are unable to cover all the required tests, it is necessary to develop a means to implement additional testing.

DOI: 10.5281/zenodo.3816696

This document describes the framework conditions for the online validation of communication interfaces that are used for the exchange of metrological data.

DOI: 10.5281/zenodo.3816696

2 General XML structure of metrological data in SmartCom

This guide considers version 1.3.1 of the D-SI XML structure which was developed within the SmartCom project. The XML Schema Definition (XSD) of the D-SI can be obtained from [5]. The XML structure allows metrological data to be stored in a machine-readable form.

For example, consider the following human-readable information relating to a measurement:

"The measured temperature is 20.10 °C with an expanded uncertainty of 0.50 °C corresponding to a coverage probability of $p = 0.95$ using a coverage factor of $k = 2$, where it is assumed that the probability distribution for the temperature is normal."

The same information is represented in machine-readable form as:

```
<si:real>
  <si:label>temperature<\si:label>
  <si:value>20.10<\si:value>
  <si:unit>\degreecelsius<\si:unit>
  <si:expandedUnc>
    <si:uncertainty>0.50<\si:uncertainty>
    <si:coverageFactor>2<\si:coverageFactor>
    <si:coverageProbability>0.95<\si:coverageProbability>
    <si:distribution>normal<\si:distribution>
  <\si:expandedUnc>
<\si:real>
```

The D-SI XML structure allows real quantities, complex quantities, multivariate (real and complex) quantities to be represented.

DOI: 10.5281/zenodo.3816696

3 Testing the syntax of metrological data

For data provided within an XML file, the tests that can be undertaken fall into three main categories: checking for well-formedness of the XML, validation against the XSD of the D-SI, and additional validation of the XML (that cannot be undertaken against the XSD of the D-SI). Each category is described in more detail below.

3.1 Test for well-formedness

Many editors or integrated development environments (IDEs) that can be used to draft XML can automatically test that an XML file is well-formed. Such a test considers the following aspects:

- Does the file have a root element?
- Do all XML elements have a closing tag?
- Is the case sensitivity of XML tags respected?
- Are all XML elements properly nested?
- Are all XML attribute values quoted?

Example 1: The XML is well-formed.

```
<si:real>
  <si:label>temperature<\si:label>
  <si:value>20.10<\si:value>
  <si:unit>\degreecelsius<\si:unit>
  <si:expandedUnc>
    <si:uncertainty>0.50<\si:uncertainty>
    <si:coverageFactor>2<\si:coverageFactor>
    <si:coverageProbability>0.95<\si:coverageProbability>
    <si:distribution>normal<\si:distribution>
  <\si:expandedUnc>
<\si:real>
```

DOI: 10.5281/zenodo.3816696

Example 2: There is a mismatch between the opening and closing tags for the coverage probability element, and therefore the XML is not well-formed.

```
<si:real>
  <si:label>temperature<\si:label>
  <si:value>20.10<\si:value>
  <si:unit>\degreecelsius<\si:unit>
  <si:expandedUnc>
    <si:uncertainty>0.50<\si:uncertainty>
    <si:coverageFactor>2<\si:coverageFactor>
    <si:coverageProbability>0.95<\si:coverageProb>
    <si:distribution>normal<\si:distribution>
  <\si:expandedUnc>
<\si:real>
```

3.2 Validation against D-SI XML Schema

Validation of the metrological data against the associated XML Schema Definition (XSD) file considers the following aspects:

- Is the file containing the metrological data a valid XML file?
- Are all mandatory elements defined?
- Are elements presented in the correct order?
- Are correct element tags used?
- Are correct data types used?

Many integrated development environments (IDEs) that can be used to draft XML also allow for the validation of XML against an XSD file. Numerous free web-based XML validation services are also available.

Example 3: The mandatory element for the coverage factor has been omitted, and therefore the XML is not validated against the D-SI XML schema.

DOI: 10.5281/zenodo.3816696

```
<si:real>
  <si:label>temperature<\si:label>
  <si:value>20.10<\si:value>
  <si:unit>\degreecelsius<\si:unit>
  <si:expandedUnc>
    <si:uncertainty>0.50<\si:uncertainty>
    <si:coverageProbability>0.95<\si:coverageProbability>
    <si:distribution>normal<\si:distribution>
  <\si:expandedUnc>
<\si:real>
```

It is recommended to ensure that XML is well formed and is validated against the D-SI XML schema before undertaking the further validation described in section 3.3.

3.3 Additional validation

The reference implementation of the D-SI data model for XML users [5] requires additional tests to be undertaken. These tests include, for example:

- The provision of SI identifiers for names of units.
- The provision of SI prefixes for units.
- The correct formatting of time stamps.
- Universal properties of uncertainty statements such as a symmetric covariance matrix.

For anyone wishing to store and exchange metrological data using the XML D-SI format, it is unreasonable to expect them to undertake this additional validation, for example, by developing bespoke software. Partners in the SmartCom project are therefore developing a system that will allow users to submit their data to an online server that undertakes, and informs them of the outcome of, the additional validation. This system will also be able to provide the validation of the well-formed XML and validation against the D-SI XML schema. The requirements for such a system are described in section 4.

DOI: 10.5281/zenodo.3816696

4 Requirements for, and implementation of, an online validation system

4.1 Requirements

The requirements for the online validation system can be summarised as follows:

- Each application of the validation system must provide one unambiguous and correct result.

- A set of rules must be developed that list all tests that the validation system must undertake. The rules will relate to a specific edition of the D-SI booklet [2].

- Prior to its being made available to users, the validation system must be tested, using a suitable number of test XML files, to ensure confidence in the results it returns. The test XML files should be reflective of actual cases that arise within various metrology domains.

- Users must be provided with a user manual for the validation system that gives a clear description of the test aim and the test procedure.

- The validation system must allow users to submit their XML data in a simplistic manner, e.g., using a GUI to select an XML file and pressing a button to submit it to the system or allowing automated testing through a suitable API.

DOI: 10.5281/zenodo.3816696

- The validation system must undertake validation and return to the user, in an appropriate format, information on the quality of the submitted XML file.

- There should be a plan for maintenance of the validation system. For example, if a new edition of the BIPM SI Brochure is released that allows for additional, or deprecates, units.

- The validation system must allow an unambiguous management of tests, e.g. by allowing registration of users on the system and subsequently log in to the system to request and trace instances of validation.

4.2 Implementation

The online validation system being developed by SmartCom partners leans heavily on technology developed within the European Metrology Research Programme (EMRP) JRP "Traceability for computationally-intensive metrology" (short name "TraCIM") [6]. Within the TraCIM JRP, an information and communications technology (ICT) infrastructure, referred to as the "TraCIM system" was developed that allows the verification of mathematical software to be undertaken online – see, for example, [7]. The TraCIM system requires users to submit and receive information in a similar way to that proposed for the online validation system. Therefore, it is appropriate to adopt the underlying software of the TraCIM system to satisfy the requirements of the online validation system.

The online validation system will classify submitted metrological data as belonging to one of the following quality classes:

- Platinum (or Next Generation).
- Gold.
- Silver.

DOI: 10.5281/zenodo.3816696

- Bronze.
- Improvable.

The criteria used to assess the quality are described in detail in [2]. A comprehensive set of example D-SI XML data to test the online validation system is available at [8].

DOI: 10.5281/zenodo.3816696

5 References

[1] EMPIR project 17IND02 SmartCom, webpage: https://www.ptb.de/empir2018/smartcom (accessed May 2020).

[2] Hutzschenreuter D., Härtig F., Heeren W., et al.: SmartCom Digital System of Units (D-SI) Guide for the use of the metadata-format used in metrology for the easy-to-use, safe, harmonised and unambiguous digital transfer of metrological data – Second Edition, doi: 10.5281/zenodo.3816686 (accessed May 2020).

[3] World Wide Web Consortium *Extensible Markup Language (XML)*; version 1.0; fifth edition: https://www.w3.org/TR/xml/ (accessed May 2020).

[4] BIPM Brochure, *The International System of Units (SI) 9th edition 2019*, https://www.bipm.org/en/publications/si-brochure (accessed May 2020).

[5] Hutzschenreuter D., Härtig F., Wiedenhöfer T., et al.: SmartCom Digital-SI (D-SI) XML exchange format for metrological data version 1.3.1: doi: 10.5281/zenodo.3826517 (accessed May 2020).

[6] EMRP project NEW06 TraCIM, project webpage: https://www.ptb.de/emrp/tcim.html (accessed May 2020).

[7] PTB TraCIM system 1.0 service, webpage: https://tracim.ptb.de/tracim/index.jsf (accessed May 2020).

DOI: 10.5281/zenodo.3816696

[8] GitLab repository of the D-SI XML reference implementation, webpage: https://gitlab1.ptb.de/d-ptb/d-si/xsd-d-si (accessed May 2020).

DOI: 10.5281/zenodo.3816696

DOI: 10.5281/zenodo.3816696

DOI: 10.5281/zenodo.3816696

DOI: 10.5281/zenodo.3816696

The content presented was developed within the framework of the EU-funded project SmartCom *"Communication and validation of smart data in IoT-networks"* with the support of international partners from science and industry.

https://www.ptb.de/empir2018/smartcom
(accessed June 2020)

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

DOI: 10.5281/zenodo.3816696