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SECoP AND SECoP@HMC – METADATA IN THE SAMPLE ENVIRONMENT COMMUNICATION PROTOCOL*

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Abstract

The integration of sample environment (SE) equipment in x-ray and neutron experiments is a complex challenge both in the physical world and in the digital world. Different experiment control software offer different interfaces for the connection of SE equipment. Therefore, it is time-consuming to integrate new SE or to share SE equipment between facilities. To tackle this problem, the International Society for Sample Environment (ISSE) developed the Sample Environment Communication Protocol (SECoP) to standardize the communication between instrument control software and SE equipment. SECoP offers, on the one hand, a generalized way to control SE equipment. On the other hand, SECoP holds the possibility to transport SE metadata in a well-defined way. In addition, SECoP provides machine readable self-description of the SE equipment which enables a fully automated integration into the instrument control software and into the processes for data storage. Using SECoP as a common standard for controlling SE equipment and generating SE metadata will save resources and intrinsically give the opportunity to supply standardized and FAIR data compliant SE metadata. It will also supply a well-defined interface for user-provided SE equipment, for equipment shared by different research facilities and for industry. In this article will show how SECoP can help to provide a meaningful and complete set of metadata for SE equipment and we will present SECoP and the SECoP@HMC project supported by the Helmholtz Metadata Collaboration.

INTRODUCTION

SECoP is a standardised and well documented communication protocol tailored to the needs of SE control. The main challenges for SE control and SE data/metadata collection are the diversity of available SE equipment and the flexibility of SE equipment: in some cases, the equipment is only assembled for a single experiment. In addition, SE equipment, such as magnets or cryostats, is often exchangeable between several beam lines or is provided by external users. All this complicates the collection of interoperable and reusable metadata. SECoP tackles these challenges with a hardware abstraction focussing on the relevant physical parameters (e.g. temperature, gas flow rate, or magnetic field) and basic functionalities (e.g. reading or driving a parameter). As SECoP is a communication protocol and not a control system, the individual hardware devices with their respective drivers have to be addressed in an underlying programming layer.

SECoP Abstraction

The abstraction in SECoP and its inherent structure is shown in Fig. 1. The Experiment Control System (ECS) is communicating via SECoP to the “Sample Environment Control Nodes” (SEC nodes). A SEC node provides access to one or several “modules”. A module represents in general a physical parameter, e.g. the hydrostatic pressure at the sample position. A module can have several “parameters” (e.g. the value and status) and “commands” (e.g. stop) associated with it. An individual parameter or command is addressed by the combination of the module name and the parameter or command name (e.g. “pressure1:value” with “pressure1” being here the module name and “value” being in this case the predefined parameter name for the main value of the module). The static information about parameters, modules and SEC nodes is stored in “properties” with predefined names and meanings (e.g. “description”).

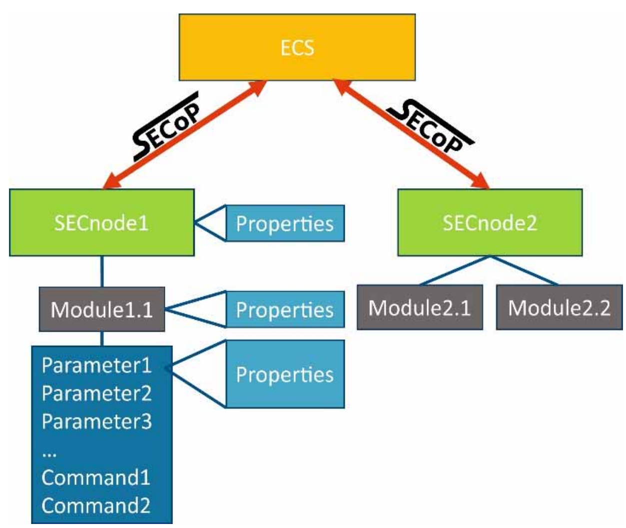

Figure 1: Abstraction and structure in SECoP. The actual SECoP protocol is used for communication between the Experiment Control Software (ECS) and the SEC nodes. For details and examples see text.

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For a deeper introduction to the SECoP syntax and the SECoP rules (e.g. handshake procedures) and for an overview of predefined parameters, commands and properties refer to [1] and [2].

SECoP Philosophy

SECoP is intended to simplify and standardise the control of SE equipment. For this purpose, the definition of SECoP is guided by the following basic principles:

- Simple (easy to implement and use)
- Inclusive (open to different control concepts)
- Self-describing (fully machine-readable content and structure)
- Provides metadata (offering a complete set of metadata)

In this paper we want to focus on the last principle, highlighting the way how SECoP can help to provide a meaningful and complete set of metadata for SE equipment.

METADATA IN SECoP

SECoP supports the provision of metadata in several ways. The metadata made available as part of SECoP ranges from static individual descriptions of the single elements to the changing process variables during an experiment. In this section we will give a complete overview on the available metadata in SECoP.

Live and Static Metadata

Metadata in SECoP can be divided in two classes: Live metadata and static metadata. Live metadata can change during an experiment, whereas static metadata must not change unless the SE equipment is reconfigured.
Examples for static metadata are:

- the properties of SEC nodes, modules, parameters and commands (e.g. “description”, “equipment_id”)
- the data properties “unit” “min” “max” in the SECoP data info structure for numerical data types
- parameters with the property “constant” containing the constant value of a parameter (e.g. a calibration curve of a sensor)

Static metadata can only be retrieved by the SECoP request message “describe” sent to a SEC node. The answer by the SEC node contains the complete structure report of the SEC node in the form of a structured JSON object describing the SEC node with all modules and their parameters and commands, together with the corresponding properties (for details see [1] and [2]). Whenever a SEC node is altered in a way that static metadata is changed, the ECS has to reconnect to the SEC node and retrieve the changed structure report by sending a “describe” request.

< describe

> describing . <structure report>

Live metadata can be transported by all parameters which don’t have the property “constant”. However, it depends on the specific experiment, if the data represented by a parameter is to be seen as metadata or as data. For example, the temperature measured by a sensor can be regarded as an essential experiment variable if it represents the sample temperature, or as metadata if the same temperature sensor only represents for example a precooling stage. SECoP provides a tool for detecting this difference: the module property “meaning” (see below).

Live metadata is received via SECoP for synchronous communication by “read” requests addressing the module and parameter, for example by

< read pressure1:value

> reply pressure1:value [1.013,{"t":1505396348.188}]

or by “update” messages for asynchronous communication.

> update pressure1:value [1.013,{"t":1505396348.232}]

Predefined Parameters and Properties

The machine-readable description of the SEC node is supported by predefined parameters and properties that assign a content-related meaning to the elements. While the predefined parameters (such as “value”, “target” or “status”) help to standardise the functionality of SEC nodes, the predefined properties directly add to the completeness of metadata information. Examples for predefined properties with direct relation to metadata are:

- The mandatory property “description” adds a human readable description to all SEC nodes and parameters.
- The mandatory SEC node property “equipment_id” contains a worldwide unique ID of an equipment as string. It should contain the name of the owner institute or provider company as prefix in order to guarantee worldwide uniqueness.
- The mandatory property “datainfo” of parameters contains a machine-readable description of the data type, the allowed value range and the optional data property “unit”.
- The optional property “group” for modules, parameters and commands introduces a grouping mechanism and a hierarchical structure to the elements of a SEC node (see section “structure” below).
- The optional module property “meaning” adds machine-readable significance (see section “meaning” below) to modules.

A full list of predefined properties and parameters can be found in [2].

Module Property “Meaning”

The module property "meaning" mentioned in the last section is represented by a tuple consisting of a string and an integer value. The value of the string (e.g. “temperature”, “magneticfield_regulation”) comes from an extensible vocabulary, the definition of which is one of the tasks of the SECoP@HMC project. The integer value of the tuple represents the importance of the module. If several modules of a SE equipment have the same “meaning” string, the higher “meaning” number indicates the higher importance. The "meaning" property can be mapped to other vocabularies, and SECoP data and metadata can thus be automatically sorted to the right places in data storage systems.

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Structure

When defining a SEC node, the creator of the SEC node must select and arrange the modules and parameters which will be published on the SECoP interface. In addition, the property "group" adds a second hierarchical level to the structure of the SEC node. This overall structure of the SEC node contains important information that can help in the search for the relevant data and metadata on the data storage systems.

SECoP@HMC

For the further development of the provision of metadata in SECoP and for the seamless integration of SECoP into existing control and data storage systems we started the project SECoP@HMC receiving funding within the 2021 project cohort of the Helmholtz Metadata Collaboration (HMC, [3]). Within SECoP@HMC, we

- develop metadata standards for typical SE equipment at large scale facilities (photons, neutrons, high magnetic fields),
- map these SECoP metadata standards to a unified SE vocabulary for a standardized metadata storage,
- integrate SECoP into several experiment control systems such as bluesky (HZB), NICOS (FRM II), Tango & Sardana (DESY),
- communicate the result to related communities and vendors, for more standardized SE metadata and to foster the use of SECoP.

Thus, a complete standardized system for controlling SE equipment and collecting and saving SE metadata will be available and usable in the experimental control systems of the participating facilities. This approach can be applied to other research areas as well.

CONCLUSION

SECoP is designed as a standard for communication to SE equipment at large scale facilities. It is tailored to the specific needs of SE equipment and offers particular advantages in the simple and automated integration of mobile or external SE equipment into experiment control at beamlines. Another major advantage is the extensive set of metadata that is an inherent part of SECoP. The self-describing qualities of SECoP simplify the automated provision of FAIR-compliant metadata for SE equipment.

With the SECoP@HMC project, we are adapting the metadata features of SECoP to the needs of the metadata community and facilitate seamless integration into existing control and data storage systems.

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