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C3-Cloud

"A Federated Collaborative Care Cure Cloud Architecture for Addressing the Needs of Multi-morbidity and Managing Poly-pharmacy"

PRIORITY Objective H2020-PHC-25-2015 - Advanced ICT systems and services for integrated care

D6.2 C3-Cloud Semantic Interoperability Platform

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EXECUTIVE SUMMARY

WP6 is responsible for the Interoperability Middleware design and development. The provided solution addresses technical, semantic and privacy/security interoperability challenges to seamlessly integrate with the existing health care, social care and home/community care information systems for enabling patient-centric interoperable care coordination in an informed manner with the involvement of all stakeholders.

Task 6.2 focuses on the development of the Semantic Interoperability Platform, to both handle structural mappings among different information models and resolve semantic mismatches due to use of different terminology systems and different compositional aggregations to represent the same clinical concept. Due to local implications of terminologies used, this task is in close relation with the pilot sites, according to the deliverables D8.1 Requirements and Use Cases of C3-Cloud Pilot Application, D3.2 Requirements Specification of the C3-Cloud Architecture, and the Description of Action. Task 6.2 started in month 9 (1st January 2017) and has ended in month 18 (31st October 2017).

Two different types of mappings are performed in the semantic interoperability suite: structural mappings and semantic mappings. Structural mappings are involved in the translation between local pilot sites data in local format and FHIR resources data format used in C3-Cloud. Semantic mappings perform the translation between coding systems used in local sites and within C3-Cloud components.

The deliverable D6.2 is a report that accompanies the demonstration that will be given at the project review on 8th December 2017. It defines the basic objectives of the task and tools by referencing to requirements. The document provides also a description of the implementation strategies as well as a manual for the demo. The main purpose of the demonstrator is to show the progress of the implementation of the C3-Cloud Semantic Interoperability Platform to implement the use cases in a concrete way.

Abbreviations and Acronyms

Abbreviation / Acronym	Full name
C3DP	Care and Cure Delivery Platform
CDSM	Clinical Decision Support Module
DoA	Description of Action
EHR	Electronic Health Record
FHIR	Fast Healthcare Interoperability Resources
HeTOP	Health Terminology/Ontology Portal
INSERM	Institut National de la Santé Et de la Recherche Médicale
JSON	JavaScript Object Notation
OSAKI	Servicio Vasco de Salud Osakidetza
RJH	Region Jämtland Härjedalen
SIS	Semantic Interoperability Suite
SWFT	South Warwickshire NHS Foundation Trust
TIS	Technical Interoperability Suite
TS	Terminology Service

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1. DOCUMENT OVERVIEW

1.1. Purpose

The purpose of Deliverable D6.2 is to demonstrate the semantic interoperability within the interoperability middleware of the C3-Cloud project. This present document covers the process of creation, development and deployment of the Semantic Interoperability Suite (SIS). It provides contextual information over the demonstration deliverable.

The report on the Semantic Interoperability demonstrator is organised as follows:

- Section 1 summarises the basic objectives of the task and tools that must be demonstrated by referencing to task requirements (DoA).
- Section 2 details the SIS objectives in terms of use cases and specifications as defined by the C3-Cloud project.
- Section 3 exposes the SIS architecture and the two sub-components, the structural mapper and the semantic mapper.
- Section 4 provides some information on how to use the demonstrator in the specific example designed with the pilot sites.
- Section 5 addresses some future plans to continue the integration work with the other components.

1.2. Scope

Following the Description of Action (DoA), Task 6.2 is developed to both handle structural mappings among different information models and resolve semantic mismatches due to use of different terminology systems and different compositional aggregations to represent the same clinical concept.

1.3. Context

In the C3-Cloud architecture (see Figure 1), patient's electronic health records are received from local EHR systems via the Technical Interoperability Suite (TIS), which requests structural mapping to Semantic Interoperability Suite (SIS) to retrieve these data in a FHIR format, used by all C3-Cloud components. Following Care and Cure Delivery Platform (C3DP) requests, TIS can also query SIS to obtain semantic mappings for given FHIR resources. These mappings ensure correct linking between different data values coding systems, used by pilot sites and C3-Cloud components.

Generally speaking, the Semantic Interoperability Platform has to handle both structural mappings and semantic mappings, ensuring that all data exchanged between pilot sites and all other C3-Cloud components stay understandable, consistent and coherent. SIS provides a **standard based data exchange protocol** to support these structural and semantic mapping queries.

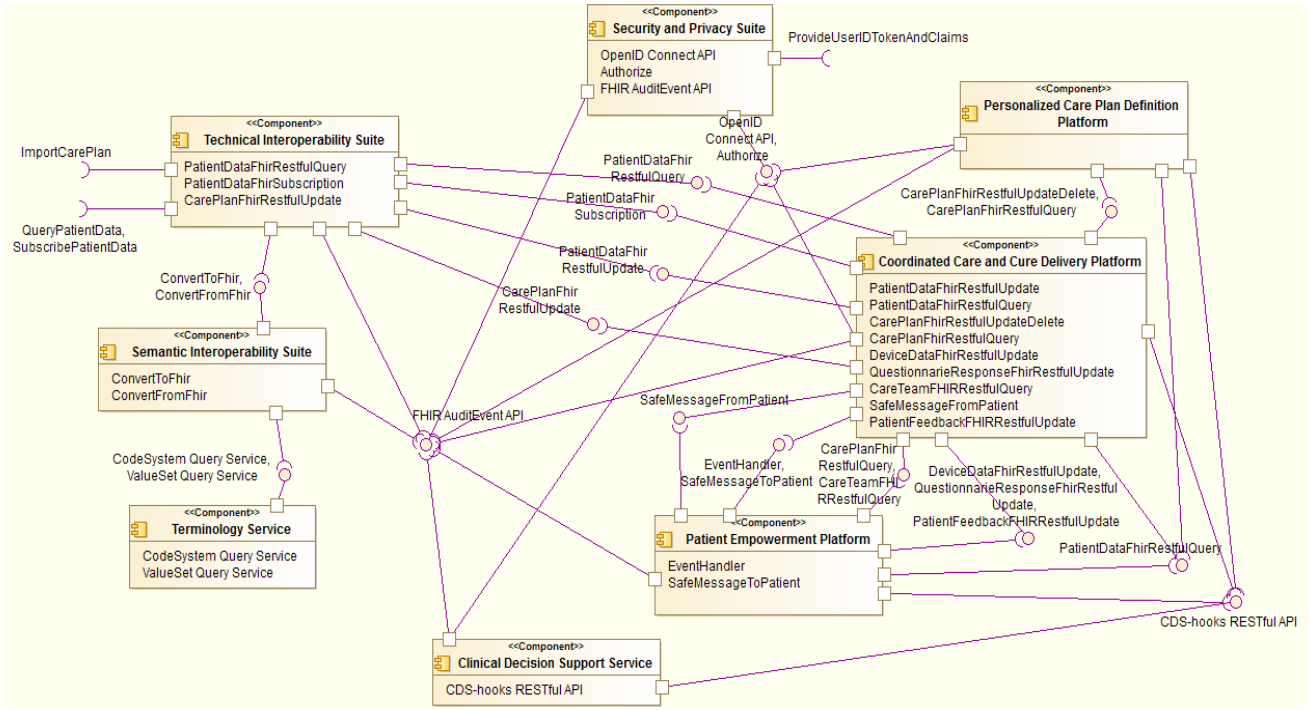


Figure 1: C3-Cloud Component Diagram from D3.3 - Conceptual Design of C3-Cloud Architecture

2. SIS OBJECTIVES

The Semantic Interoperability Suite addresses content level interoperability challenges between the information systems in local care information systems and C3-Cloud platform, by semantically mediating different clinical information representations. The design of SIS in based on FHIR. As part of the semantic mediation process, SIS uses a terminology service for terminology mappings and a semantic metadata registry to process interoperability.

SIS technical requirements and conceptual design were elicited and documented in D3.2 and D3.3. Following the progress of the project, changes to the original requirements and design have been made. This section defines basic objectives of the Task 6.2 and the delivered software tool, by referencing to the original requirements and design in D3.2 and D3.3 and describing their changes.

2.1. Use Cases for Semantic Interoperability Suite

D3.2 (section 3.3) identified six SIS use cases:

- SIS-1: Map specific input data to C3-Cloud format and codes
- SIS-2: Map C3-Cloud formatted data to specific output format and codes
- SIS-3: Map specific input data to other specific output format and codes
- SIS-4: Query terminology server for mapping
- SIS-5: Create mapping between specific data format and C3-Cloud format
- SIS-6: Register new data information model

It also identified 3 primary actors for 2 actor roles:

- SIS user: Abstract role that can be endorsed both by Clinical Decision Support (CDS) Modules or Technical Interoperability Suite (TIS)
- Administrator: The C3-Cloud administrator of the C3-Cloud implemented system.

Figure 2 shows the Use Case Diagram for SIS as available in D3.2.

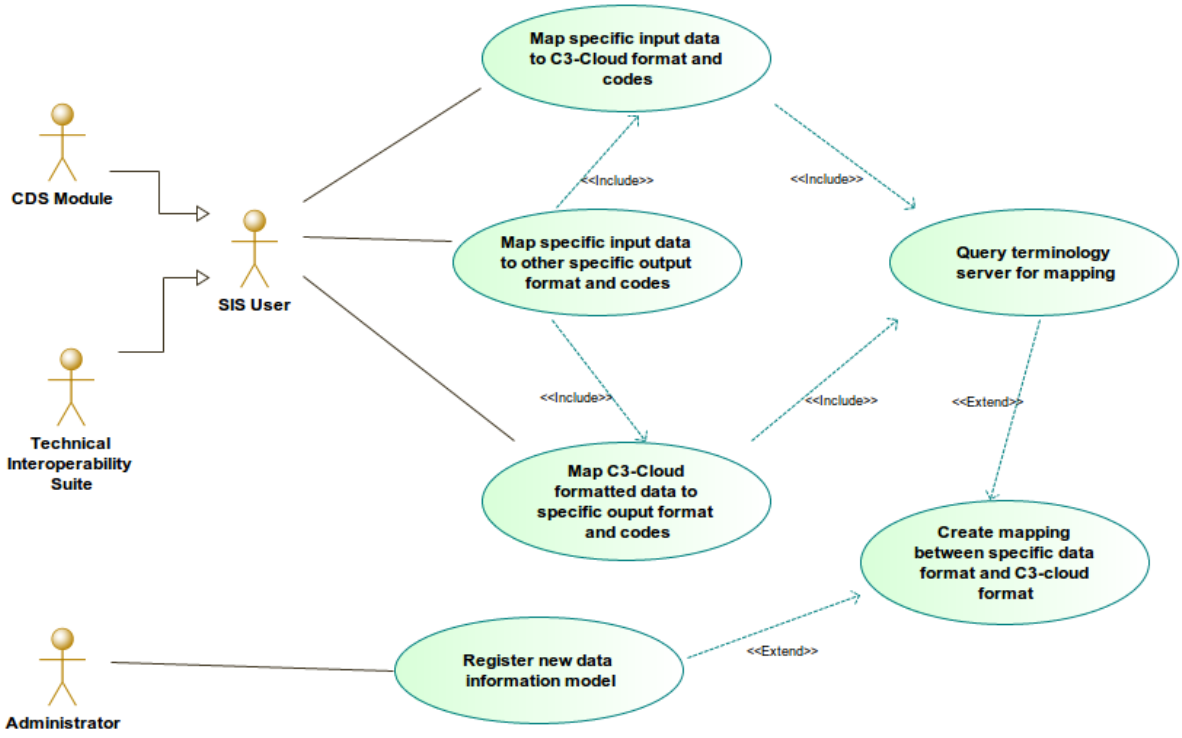


Figure 2: Use Case Diagram for SIS from D3.2

During the conceptual design phase and integration development in T6.2, two major changes were introduced to the original assumptions:

- Structural mappings and semantic mappings, initially part of same use cases, are split into separate use cases. This reflects the reality that these mappings are not intended to be queried at the same time and involve different mapping data sources. The related queries are now independent.
- TIS-SIS interaction: In the revised workflow, TIS is now the only interlocutor for SIS. Every top-level module gets its data through TIS, which queries SIS both for structural and semantic mappings.
- SIS-3: "*Map specific input data to other specific output format and codes*" reveals itself as a never occurring use case. As pilot site data is not intended to be shared with other pilot sites, mappings among different local data formats are not required.

Figure 3 presents the updated Use Case Diagram that includes these related changes.

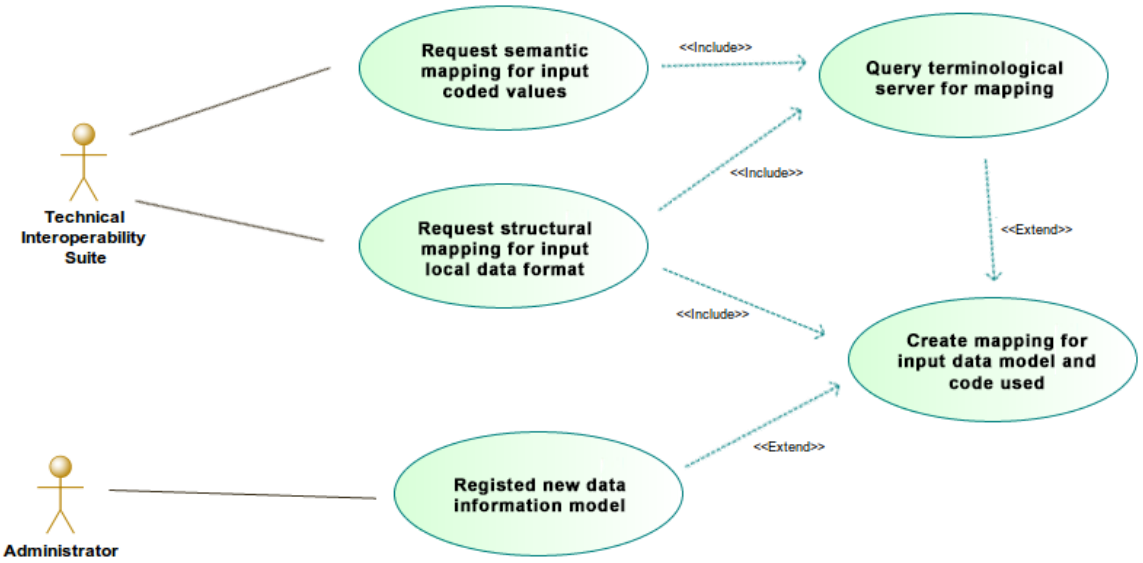


Figure 3: Updated Use Case Diagram for SIS

2.2. Specifications for Semantic Interoperability Suite

The functional requirement specifications for SIS can be summarised as follows:

- SIS maps input data from pilot sites, provided in their local format, to corresponding FHIR resources.
- SIS provides coding values and related coding system used from locally coded pilot site data.

The non-functional requirement specifications can be summarised as:

- The call to SIS from TIS should return results in reasonable time.
- The system shall be resilient to system failures of other components.
- All data communications with local care system EHR and C3-Cloud components should be protected and audited through TLS (transport layer security) and logged.

The detailed system requirement specifications for SIS, including functional, non-functional, interface and information requirements, are described in D3.2 (section 4.3). The requirements are maintained in WP3 using a requirement traceability matrix.

3. IMPLEMENTATION OF SEMANTIC INTEROPERABILITY SUITE

The Semantic Interoperability Suite enables data mappings, in terms of format and coding (information models), between the EHR system in local care settings and C3-Cloud components. The current section presents the current implementation of the C3-Cloud SIS, and the development of the prototype used in the present demonstrator.

3.1. Architecture Design of SIS

In D3.3, the initial architectural design of the Semantic Interoperability Suite is shown in Figure 4.

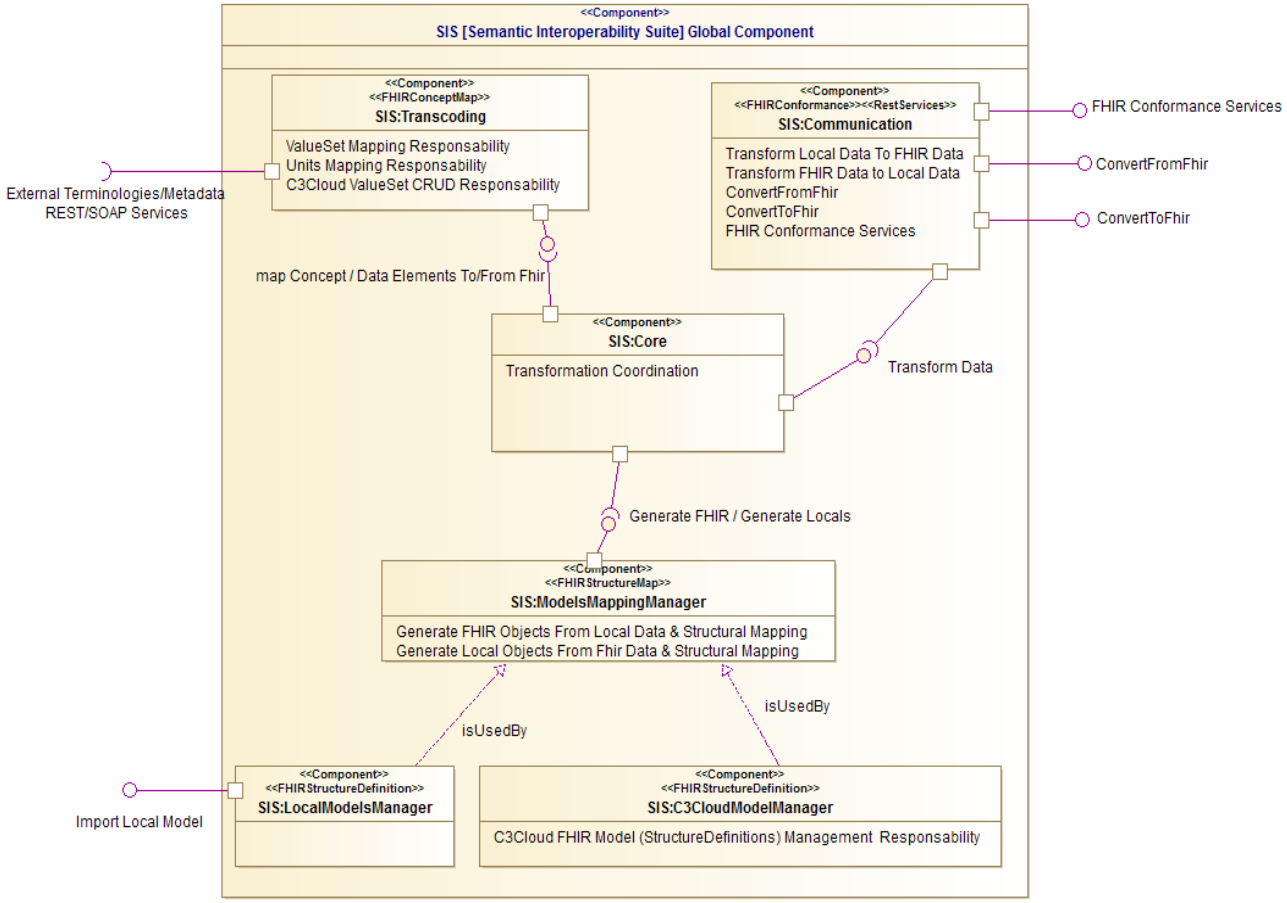


Figure 4: Semantic Interoperability Suite Component Diagram in D3.3

During the implementation phase, this architectural design has been slightly modified. Just like the use cases presented on the previous section, these architectural changes are related to the development and integration of SIS, as well as following exchanges with the pilot sites.

First of all, the terminological service has evolved. In the DoA, the C3-Cloud terminology service was intended to be built on previous development of integrated vocabulary service at Warwick (TRANSFoRm). The INSERM partner has access to the HeTOP tool that has the property to be multilingual and it was decided to use this tool instead (http://www.hetop.eu/hetop/). Generally speaking, the Health Terminology/Ontology Portal (HeTOP) is a tool that can be used by both human users and computer systems to access and browse biomedical terminologies or ontologies (T/O). Today, HeTOP contains more than 70 terminologies translated in 32 languages. Specific new mappings were however developed for the purpose of C3-Cloud, in particular to align local vocabularies to existing standards.

The terminology service supports FHIR *CodeSystem* and *ValueSet* resources and related operations, which SIS requires.

Figure 5 presents the current architecture of SIS as currently developed.

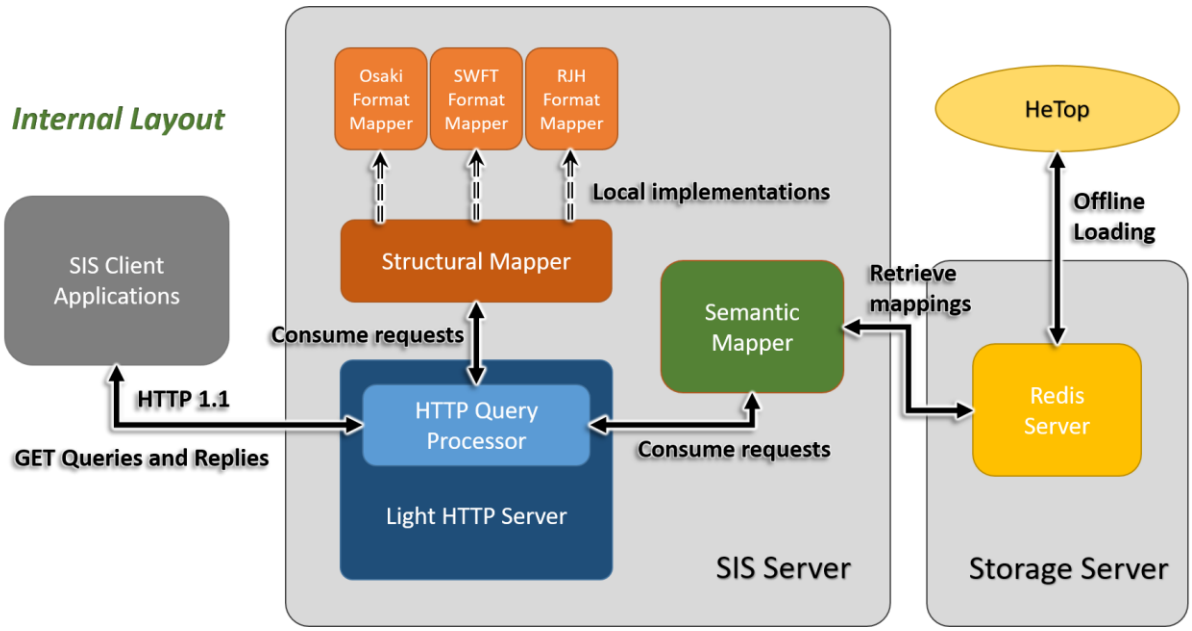


Figure 5: Semantic Interoperability Suite Architecture

Based on this architectural design, and following its main requirements, C3-Cloud SIS is articulated around two main sub-components:

- SIS Structural Mapper

The structural mapper of SIS is the internal SIS sub-component in charge of the generation of FHIR resources, which have to be filled with data provided in pilot site local format by TIS. To achieve its purpose, the structural mapper consists of pilot sites dedicated local format mappers. These mappers provide precise mappings to map every relevant data exported by the pilot site to its correct interpretation and place in FHIR resource.

FHIR resources mapped from pilot site data are defined in the C3-Cloud data dictionary, which is defined in D6.1 C3-Cloud Technical Interoperability Implementation Guidelines and Open Source Toolkits.

- SIS Semantic Mapper

The semantic mapper of SIS is in charge of transforming, using the HeTOP service, the vocabulary used to describe data exported by pilot site into standard codes that will be used in the high level components of C3-Cloud.

3.2. Prototype development

The main characteristics of the prototype development are the following:

- C3-Cloud SIS is implemented as a fully deployable exchange suite running on independent Docker containers.
- It is based on HTTP communication standards, with embedded JSON content.
- It supports FHIR inputs and outputs, and previously mapped local format pilot site inputs.
- SIS is developed using Java 8 Maven.
- Regarding the terminology server, we used Python 3 to develop an application that reads the mappings from use case files, and creates an HTTP service (Flask) that is able to achieve the tasks listed in the specifications.

The structural mapping generates JSON embedded FHIR resources.

The semantic mapping is based on a pre-filled registry containing, for each concept, the corresponding code(s) for each site's terminology, and the code used as reference by C3-Cloud. The registry will be continuously updated via a dedicated service method during the time of the project. This consists in manual mappings performed by physicians/terminologists using existing specialized portals such as HeTOP (http://www.hetop.eu). Since mappings cannot be exhaustive, the experts are currently focusing on the five use cases of the project (Figure 3) and more precisely on relevant concepts, which have to be identified in patients' data.

Multiple codes can be specified for a single concept if the used terminology has several codes corresponding to the concept (narrower-than relation).

Multiple terminologies are used as reference in order to match each concept exactly.

The semantic mapping logical program will be called in two different scenarios:

- Inside the 6.2 interoperability suite to perform the transcoding of local codes to standard codes.
- By the CDSM module to perform transcoding in the fly from local codes to standard codes or from standard codes to local codes to enrich the output care plans.

4. SIS DEMONSTRATOR

The current section describes the operations available on SIS, from its installation to its execution. This section can be seen as a user manual of the component, to describe how its final users can use the component.

4.1. Installation

The C3-Cloud Semantic Interoperability Suite can be easily deployed by running its related Docker image as containers.

This operation can be performed on any Linux server with docker.io capabilities. This is available on the GitLab of the project and will be published online for the demonstration that will be given at the project review.

```
docker run                  \
    --name c3c-sis          \
    -e     SIS_SITE=osaki   \
    --network=sis-network   \
    --ip = 172.25.1.1       \
    -p     8080:8080        \
    -t     c3c-sis-docker
```

Figure 6: Example of SIS docker run command

Once deployed, the SIS handles HTTP queries on the port defined with the `-p` option of the `docker run` command (example shown in Figure 6). This implies that other C3-Cloud components deployed on the same installation share all a common and coherent network-addressing plan.

The current SIS implementation comes with 3 Docker images: one for the SIS core server itself that handle TIS requests, one for the structural mapping storage and one for the terminological service. Only the first one is intended to directly interact with TIS and has to have dedicated IP according to this. Of course, all of the containers have to be accessible for SIS on the same virtual network.

4.2. Supported Features

According to the use cases, the C3-Cloud Semantic Interoperability Suite can handle two kinds of queries: structural mapping related queries and semantic mapping related queries. Both these queries have to be performed as standard HTTP 1.1 queries, according to the following API:

HTTP Query	Allowed fields	Input fields format	Return
AppendCodes	`resource` FHIR resource to populate with codes.	`resource` `JSON` format.	FHIR encoded resource with additional terminological codes, in `JSON` format.

AllergyIntolerance
Appointment
CarePlan
CareTeam
CommunicationRequest
Condition
Encounter
FamilyMemberHistory
Goal
Immunization
Location
MedicationRequest
MedicationStatement
Observation
Organization
Patient
Practitioner
Procedure
ProcedureRequest
ReferralRequest
RelatedPerson
	`data`
	input data to map.
	
	`format`
	requested output format; allowed values are: `json`, `xml`.
		`data`
		pilot site dependent format.
			FHIR encoded resource of the type of `data` input field, in the format requested by the `format` input field. Default is `JSON`.

Transcode	`fromSite`
	origin of the code to transcode.
	`codeSystem`
	local code system
	`code`
		`fromSite`
		String.
		`codeSystem`
		String.
		`code`
		String.
			FHIR encoded ConceptMap resource in `JSON` format.

HTTP Query	Allowed fields	Input fields format	Return
	local code to transcode. `toSite` destination requested.	`toSite` String.	

Table 1: Specifications of the API queries

This encoded document represents data provided by OSAKI clinical information system of a given patient. It is provided in the source format used by the pilot site.

```
<?xml version="1.0" encoding="utf-8"?>
<?xml-stylesheet type="text/xsl" href="CDA_Profesional.xsl"?>
<ClinicalDocument xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="urn:hl7-org:v3 CDASchema/CDA.xsd" xmlns
  <typeId root="2.16.840.1.113883.1.3" extension="POCD_HD000040" />
  <templateId root="2.16.724.4.50.1" />
  <id root="2.16.724.4.16.1.100.3.1" extension="1000000000037472" />
  <code code="11488-4" codeSystem="2.16.840.1.113883.6.1" codeSystemName="LOINC" displayName="Consultation note" />
  <title>Historia Clínica Resumida</title>
  <effectiveTime value="20170607121544" />
  <confidentialityCode code="N" codeSystem="2.16.840.1.113883.5.25" />
  <languageCode code="es-ES" />
  <setId root="2.16.724.4.16.1.100.3.1.1" extension="2000000000001671" />
  <versionNumber value="932" />
  <recordTarget>
    <patientRole>
      <id root="2.16.724.4.16.1.100.2.1" extension="10574682" />
      <id nullFlavor="UNK" />
      <id nullFlavor="UNK" />
      <id root="1.3.6.1.4.1.19126.4" extension="481004103386" />
      <id root="2.16.724.4.41" extension="802494" />
      <id nullFlavor="UNK" />
      <addr use="HP">
        <state>Bizkaia</state>
        <city>Getxo - Algorta</city>
        <postalCode>48992</postalCode>
        <streetNameType>Calle/Kalea</streetNameType>
        <streetName>Alango</streetName>
        <houseNumber>7</houseNumber>
        <additionalLocator>001</additionalLocator>
        <additionalLocator>A</additionalLocator>
      </addr>
      <telecom value="tel:000000000" />
      <patient>
        <name>
          <family>FICTICIO</family>
          <family>ACTIVO</family>
```

Figure 7: Extract showing an example of input coming from OSAKI pilot site

The semantic mapping is triggered via a HTTP GET request with four parameters: fromSite, code, codeSystem, toSite. The response is a FHIR formatted JSON document.

For example,

http://localhost:5000/c3-cloud/translate/?code=G63.2&code_system=ICD-10-SE&fromSite=RJH&toSite=CDSM

returns the following JSON-encoded FHIR resource:

```
{
  "group": [
    {
      "element": {
        "code": "G63.2",
        "display": "Diabetisk polyneuropati",
        "target": [
          {
            "code": "49455004",
            "comment": "The definitions of the concepts are exactly the
same (i.e. only grammatical differences) and structural implications of
meaning are identical or irrelevant (i.e. intentionally identical).",
            "display": "Diabetic polyneuropathy (disorder)",
            "equivalence": "Equivalent"
          }
        ]
      },
      "source": "2017",
      "sourceVersion": "http://www.internetmedicin.se/icd.aspx",
      "target": "July 2017 International Edition",
      "targetVersion": "http://www.snomed.org/snomed-ct"
    }
  ],
  "resourceType": "ConceptMap",
  "title": "mapping of 'diabetic polyneuropathy' from RJH to CDSM"
}
```


Figure 8: Example of a FHIR formatted JSON document response

4.3. Software demo

The demo was implemented using example of OSAKIDETZA site output as basis for raw mapping example deduction.

As this is implemented as a service, no installation is required.

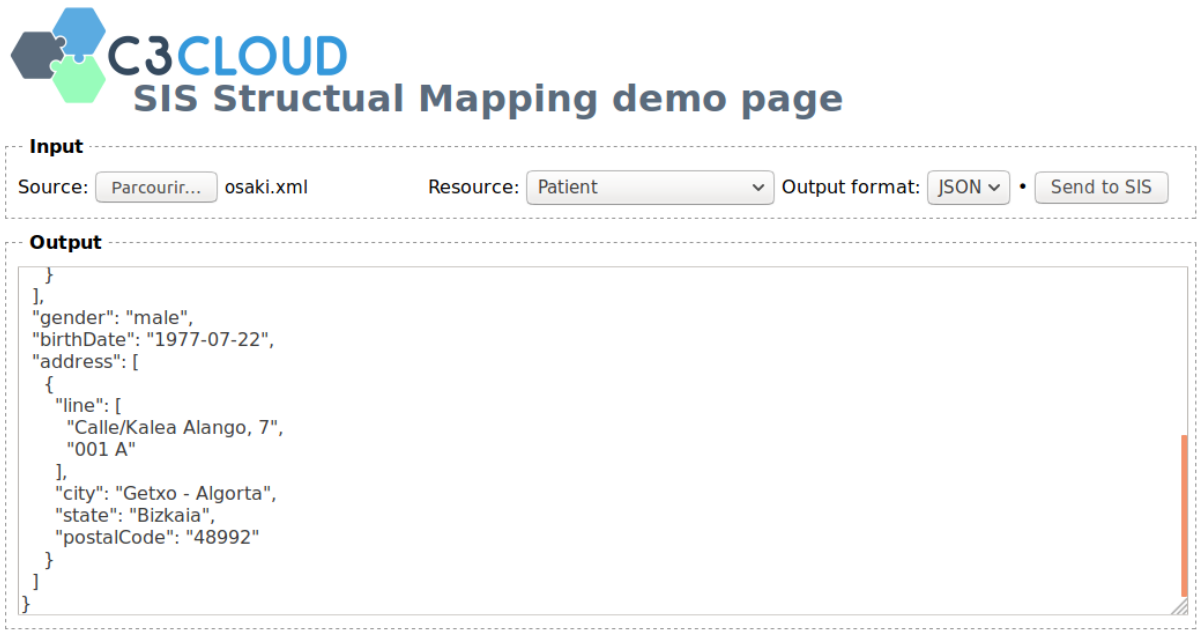


Figure 9: Screenshot of the SIS Structural mapping demo webpage

A demo webpage is available at http://cispro.chu-rouen.fr/c3-cloud/ , where it is possible to review the existing mappings, build HTTP GET mapping requests and see the server's response.

Here is an example of a request:

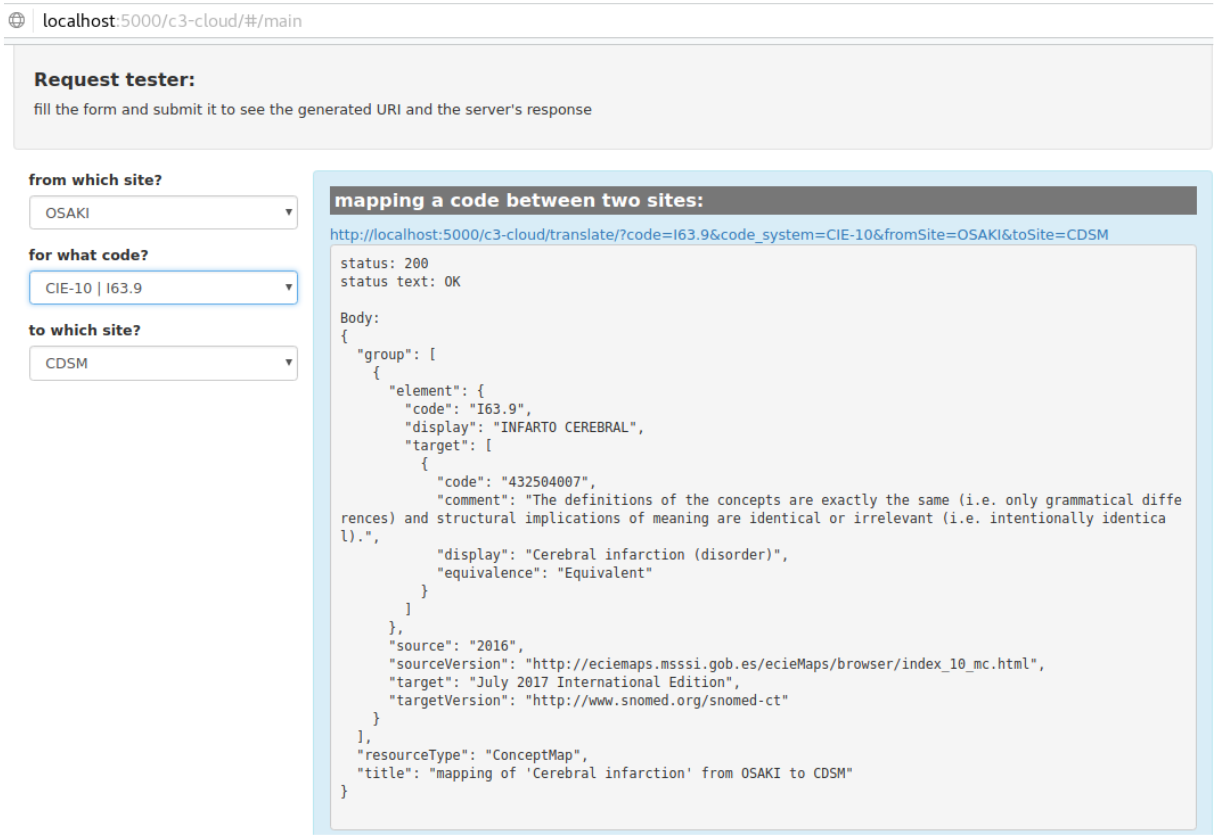


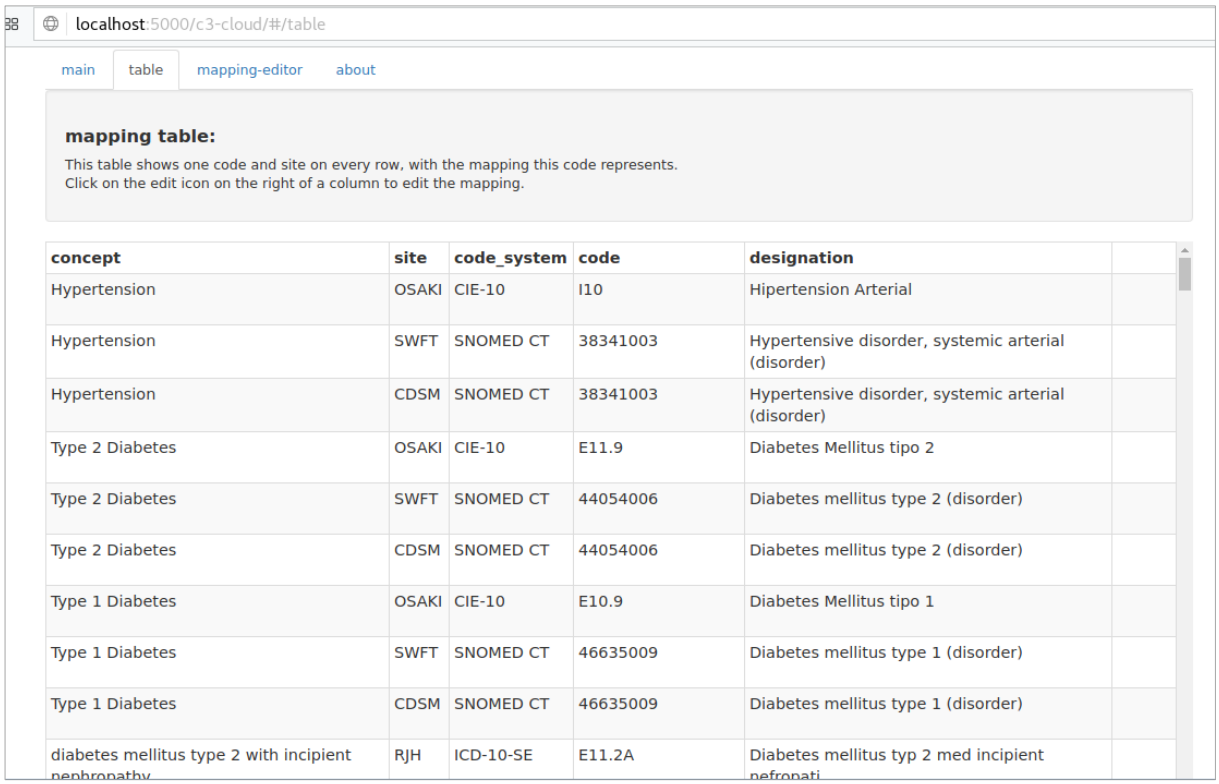
Figure 10: Screenshot of the Task 6.2 Demonstrator Request tester response

Here we want to map the code I63.9 in the code system CIE-10, which is used by the OSAKI pilot site, to the reference (CDSM) terminology.

We get as a response a JSON-encoded FHIR ConceptMap, describing the urls of the input and output code systems and their versions (CIE-10 and SNOMED CT respectively in this example), the input code and the corresponding code in the target system (the SNOMED CT code 432504007 here).

It also shows the type of relation (Equivalent here, the meaning of the two codes are the same).

Table 2 shows the listing of the different mappings. This allows to review the concepts and the corresponding code(s) for each site.



concept	site	code_system	code	designation
Hypertension	OSAKI	CIE-10	I10	Hipertension Arterial
Hypertension	SWFT	SNOMED CT	38341003	Hypertensive disorder, systemic arterial (disorder)
Hypertension	CDSM	SNOMED CT	38341003	Hypertensive disorder, systemic arterial (disorder)
Type 2 Diabetes	OSAKI	CIE-10	E11.9	Diabetes Mellitus tipo 2
Type 2 Diabetes	SWFT	SNOMED CT	44054006	Diabetes mellitus type 2 (disorder)
Type 2 Diabetes	CDSM	SNOMED CT	44054006	Diabetes mellitus type 2 (disorder)
Type 1 Diabetes	OSAKI	CIE-10	E10.9	Diabetes Mellitus tipo 1
Type 1 Diabetes	SWFT	SNOMED CT	46635009	Diabetes mellitus type 1 (disorder)
Type 1 Diabetes	CDSM	SNOMED CT	46635009	Diabetes mellitus type 1 (disorder)
diabetes mellitus type 2 with incipient nephropathy	RJH	ICD-10-SE	E11.2A	Diabetes mellitus typ 2 med incipient nefropati

Table 2: Screenshot of the mapping table to review the corresponding code(s) from each site

5. FUTURE PLANS

WP6 ends at the end of October 2017. Future plans are related to Task 7.4, which is the integration task. The current SIS has been tested with the OSAKI data, the semantic mapping work has to continue for the other two pilot sites, SWFT and RHJ.