



# POWER2DM

“Predictive model-based decision support for diabetes patient empowerment”

## Research and Innovation Project

**PHC 28 – 2015: Self-management of health and disease and decision support systems based on predictive computer modelling used by the patient him or herself**

POWER2DM D4.2 (or D4.1.2)

Personal Data Store Service Implementation

*Due Date:* 30<sup>th</sup> April 2017 (M15)  
*Actual Submission Date:* 25.04.2017  
*Project Dates:* Project Start Date: February 01, 2016  
Project End Date: July 31, 2019  
Project Duration: 42 months  
*Deliverable Leader:* SRDC

Project co-funded by the European Commission within H2020 Programme (20015-2016)

### Dissemination Level

<b>PU</b>	Public	X
<b>PP</b>	Restricted to other programme participants (including the Commission Services)	
<b>RE</b>	Restricted to a group specified by the consortium (including the Commission Services)	
<b>CO</b>	Confidential, only for members of the consortium (including the Commission Services)	

**Document History:**

<b>Version</b>	<b>Date</b>	<b>Changes</b>	<b>From</b>	<b>Review</b>
V0.1	14.03.2017	Implementation report template and content	SRDC	PD
V1.0	24.04.2017	Latest version	SRDC	

**Contributors (Benef.)** Tuncay Namlı (SRDC)  
Ozan Köse(SRDC)

**Responsible Author** Tuncay Namlı                      **Email** tuncay@srdc.com.tr

## POWER2DM Consortium Partners

Abbv	Participant Organization Name	Country
TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek	Netherlands
IDK	Institute of Diabetes "Gerhardt Katsch" Karlsburg	Germany
SRDC	SRDC Yazilim Arastirma ve Gelistirme ve Danismanlik Ticaret Limited Sirketi	Turkey
LUMC	Leiden University Medical Center	Netherlands
SAS	SAS Servicio Andaluz de Salud	Spain
SRFG	Salzburg Research Forschungs Gesellschaft	Austria
PD	PrimeData	Netherlands
iHealth	iHealth EU	France

## TABLE OF CONTENTS

Table of contents.....	4
<b>1 Introduction.....</b>	<b>5</b>
1.1 Purpose and Scope.....	5
1.2 References.....	5
<b>2 Summary of Implementation.....</b>	<b>5</b>
2.1 onFHIR.io.....	5
2.2 Configuration of onFHIR.io for POWER2DM.....	6
2.2.1 Specializing the Data Model.....	7
2.2.2 Extending Search Mechanism.....	8
2.2.3 Defining ValueSets.....	9
2.2.4 Writing Conformance Statement.....	10
2.2.5 Configuring Database Indexing for optimizing search.....	11
2.2.6 POWER2DM PDS Source Code.....	11
2.3 PDS Client as Java Library.....	12
<b>3 Demonstration of Functionalities.....</b>	<b>13</b>
3.1 Send Get Requests from Browser.....	13
3.2 Use Postman to access the REST services.....	14
3.3 Integration with Smart on FHIR applications.....	17
3.4 FHIR Compliance tests.....	18
3.5 Performance benchmarking.....	19
3.6 Publication of Resource Definitions to Simplifier.net.....	22
<b>4 Appendices.....</b>	<b>23</b>
4.1 Appendix A – Sample FHIR Definitions.....	23

# 1 Introduction

## 1.1 Purpose and Scope

The purpose of deliverable D4.2 is to provide the software implementation and demonstrator for POWER2DM Personal Data Store Service. This document provides a report illustrating its functionalities and how it is used, configured and deployed.

## 1.2 References

- D1.3 Conceptual Design of POWER2DM
- D4.1 Personal Data Model and Service API

# 2 Summary of Implementation

As SRDC, we have been working on a HL7 FHIR compliant personal health data repository, called onFHIR.io which we are planning to commercialize as a cloud service (monthly/yearly subscription model) and with a licensing model for on-premise deployments. POWER2DM project give us to chance to test our repository and business model as well as improve it. We use the onFHIR.io as the Personal Data Store Service for POWER2DM by configuring it for the specific requirements of POWER2DM; building the data model, defining the FHIR conformance statement, defining search parameters, defining the other FHIR mechanisms (compartment search, and value sets). The following sections summarize these details.

## 2.1 onFHIR.io

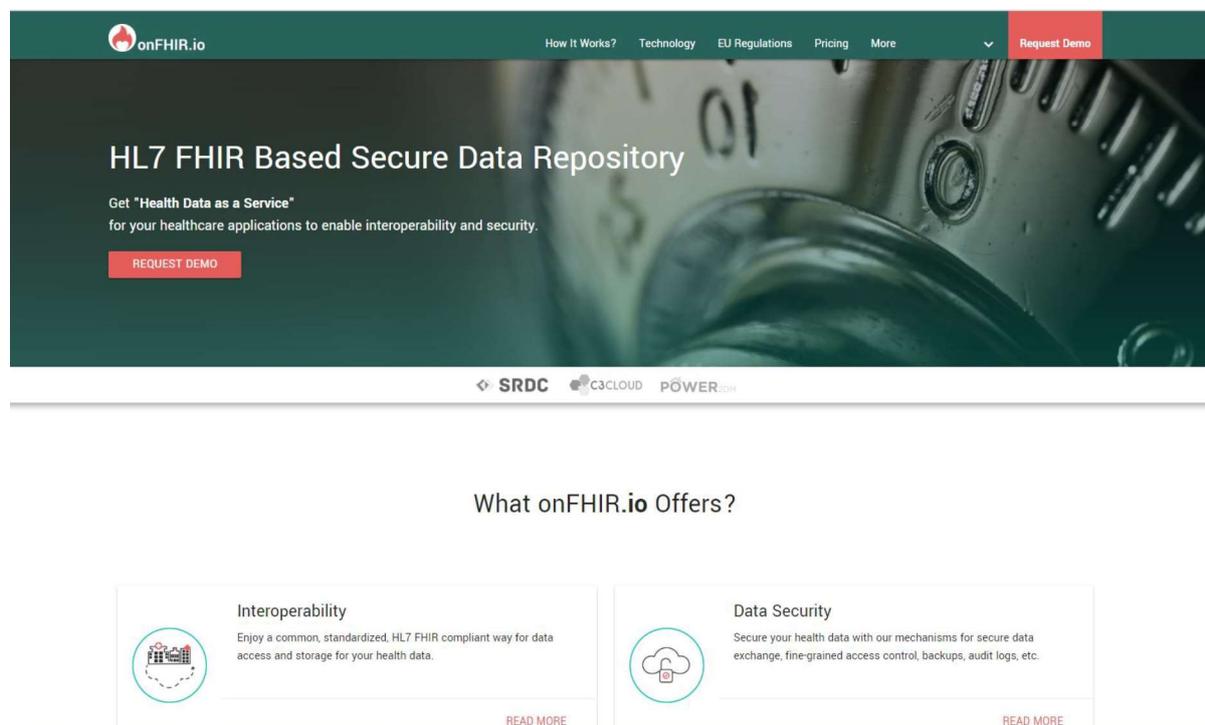


Figure 1 onFHIR.io Product Web Page (under development)

onFHIR.io<sup>1</sup> is a secure clinical data repository where anyone can use it as backend for any mobile health applications or healthcare applications in general by using its FHIR REST API for storing or querying health data. In addition, onFHIR.io can be integrated with EHR, HIS, LIS, etc. and ingest the data in different formats and open the data via FHIR compliant secure services. onFHIR.io provides the following basic functionalities;

- **Interoperability:** A common, standardized, HL7 FHIR compliant way for data access and storage for your health data.
- **Data Security:** Secured health data with mechanisms for secure data exchange, fine-grained access control, backups, audit logs, etc.
- **Scalability and Performance:** Flexibility of the system to handle records of millions of patients without compromising for write or query performance.

It provides a very flexible, FHIR compliant repository with the following properties;

- **FHIR Compliant Data Model:** onFHIR enables to store FHIR compliant resources either complying to any version of the base specification or further FHIR profiles (extensions and restrictions) on base spec.
- **FHIR Compliant REST API:** onFHIR implements the RESTfull FHIR API with all of its services; CRUD services, 'search', 'vread', 'history', 'conformance', 'batch' and 'transaction'.
- **Content Validation:** onFHIR validates the content of the resources for conformance to FHIR base resource definitions and further FHIR resource profiles automatically for each create or update operation.
- **Configurable Search Mechanism:** onFHIR provides a FHIR compliant search service supporting both resource or compartment based searching. Moreover, you can configure the search mechanism by FHIR conformance resources (Conformance, SearchParameter, CompartmentDefinition) and select which type of mechanism you will allow and which search parameters you will support for each resource.
- **Horizontal Scalability:** onFHIR uses MongoDB as persistency mechanism and use its sharding mechanism for horizontal scalability of the system. So you can support thousands of records in a single machine or millions/billions of records scattered to several machines.
- **Performance Tuning:** onFHIR enables to tune the write and search performance for each resource type (optimum sharding and database index creation) according to your use case.
- **Redundancy and Availability:** onFHIR uses MongoDB replication capabilities to enable replications of data in multiple replica set and provides data redundancy and data availability.
- **Authorization:** onFHIR.io complies with the authorization standards specifically OAuth 2.0 and Heart WG UMA and OAuth profiles.
- **Encryption:** Each Rest API call uses HTTPS/TLS to protect the data transfers.
- **Audit Logging:** onFHIR.io creates and stores audit records compliant with FHIR AuditEvent Resource definition for all data accesses and operations. You can configure it to store all audit events locally.

We are planning to announce onFHIR.io as a complete product within this year in the upcoming months.

## 2.2 Configuration of onFHIR.io for POWER2DM

onFHIR.io is a very flexible system and all the REST API and supported data model is configured by the configuration files which are in fact the specific FHIR infrastructure resources;

- **FHIR Conformance<sup>2</sup> resource:** The conformance statement is a key part of the overall conformance framework in FHIR. It is used as a statement of the features of actual software, or of a set of rules for an application to conform to. The application developers which claims

---

<sup>1</sup> <http://onfhir.io/>

<sup>2</sup> <https://www.hl7.org/fhir/conformance.html>

to conform to FHIR use this resource to define the features they implemented and conform to in FHIR specification. In onFHIR.io, we use this file as the base configuration file in the other direction to bring up the system with the specified functionalities accordingly.

- **FHIR StructureDefinition<sup>3</sup> resource:** A StructureDefinition resource describes a structure - a set of data element definitions, and their associated rules of usage. These structure definitions are used to describe both the content defined in the FHIR specification itself - Resources, data types, the underlying infrastructural types, and also are used to describe how these structures are used in implementations. In other words, you can define your data model by restricting and specializing base FHIR resources by using these definitions.
- **FHIR CompartmentDefinition<sup>4</sup> resource:** In FHIR, a compartment is a logical grouping of resources which share a common property e.g. Patient → resources that belongs to a patient. FHIR allows compartment based search for these groups e.g. /Patient/[pid]/Observation searches all observations belong to the patient with given patient id. onFHIR.io uses these compartment definitions to configure compartment search capabilities.
- **FHIR SearchParameter<sup>5</sup> resource:** A SearchParameter resource defines a search parameter for a resource type. FHIR base specification already defines several search parameters for each resource type. However, they allow new definitions and by this mechanism you can extend the search mechanism. onFHIR.io use these definitions to automatically configure the search mechanism.
- **FHIR ValueSet<sup>6</sup> resource:** These resources define value sets used in the data models as target value sets for specific data elements. onFHIR.io stores these value sets in the repository to serve them to the applications.

## 2.2.1 Specializing the Data Model

We used this configuration mechanism of onFHIR.io to setup a POWER2DM specific Personal Health Data Repository and Service. We have started from the data model and by using the Forge tool<sup>7</sup>, we define the StructureDefinition for each POWER2DM resource type that we define in “D4.1 Personal Data Model and Service API. Forge is a graphical editor for defining resource profiles in FHIR and it produces StructureDefinitions in the end.

Figure 2 illustrates the profiling of FHIR Observation resource (on the left) to POWER2DM\_DietaryIntakeLog resource (on the right). As it is shown, some data elements are removed from the definition (overlines) and component element is extended with several components to represent the nutritional intake values. Table 1 illustrates the resulting StructureDefinition resource in XML representation.

This profiling procedure is done for all POWER2DM Resources and Data Type profiles listed in the D4.1.

<sup>3</sup> <https://www.hl7.org/fhir/structuredefinition.html>

<sup>4</sup> <http://hl7.org/fhir/2017Jan/compartmentdefinition.html>

<sup>5</sup> <http://hl7.org/fhir/searchparameter.html>

<sup>6</sup> <http://hl7.org/fhir/valueset.html>

<sup>7</sup> <https://fhir.furore.com/forge/>

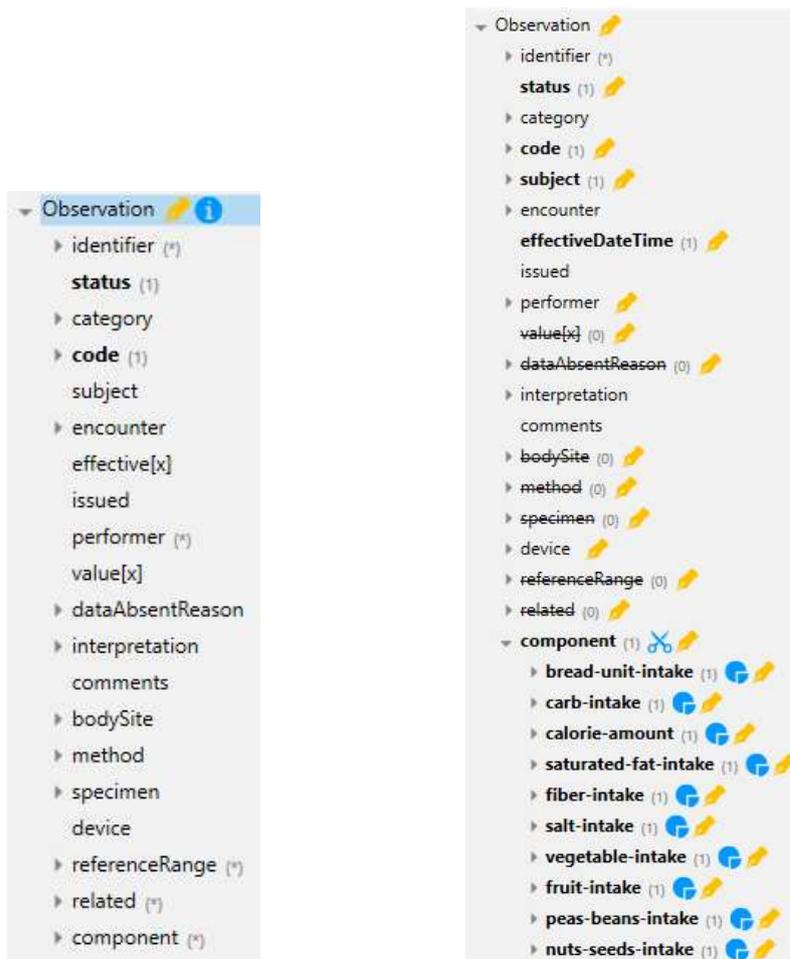


Figure 2 Profiling POWER2DM DietaryIntakeLog Resource from base FHIR Observation

## 2.2.2 Extending Search Mechanism

D4.1 defines the search parameters for each POWER2DM resource type. Most of the parameters are already defined by FHIR but some of them are not as they depend on extended models. For example “related” parameter defined for POWER2DM\_Barrier resource is used to search patient barriers that are related with specific problem. The following is an example for this type of search;

e.g. Get active Barriers of patient related with patient’s “Low dose insuling problem” (Assuming this Problem record has id 584354)

**GET [https://www.power2dm.eu/pds/Patient/-/Condition?\\_profile=http://www.power2dm.eu/pds/StructureDefinition/POWER2DM\\_Barrier&clinicalStatus=active&related=Condition/584354](https://www.power2dm.eu/pds/Patient/-/Condition?_profile=http://www.power2dm.eu/pds/StructureDefinition/POWER2DM_Barrier&clinicalStatus=active&related=Condition/584354)**

```

{
  "resourceType": "SearchParameter",
  "id": "Condition-related",
  "url": "http://www.power2dm.eu/pds/SearchParameter/Barrier-related",
  "name": "related",
  "status": "active",
  "publisher": "SRDC Corp.",
  "code": "related",
  "base": "Condition",
  "type": "reference",
  "description": "The problem that is related with the Barrier",
  "xpath": "f:Condition/f:extension[@url='http://www.power2dm.eu/pds/StructureDefinition/POWER2DM-relatedProblem']/f:valueReference",
  "xpathUsage": "normal",
  "target": [
    "Condition"
  ]
}

```

Figure 3 SearchParameter definition for Barrier-related parameter

As onFHIR.io depends on the SearchParameter definitions for configuring the search mechanism, we define the SearchParameter definitions for each parameter that is not defined in FHIR base specification.

Figure 3 shows the SearchParameter definition for the “related” parameter. As shown, the “code” gives the name of the parameter to be used in the search query, “type” indicates that this is a FHIR reference type parameter and “xpath” gives the path to the data element that this parameter is about.

For compartment search we use the FHIR base Patient compartment definition directly.

### 2.2.3 Defining ValueSets

We define each value set as FHIR ValueSet definition as shown in Figure 4; patient ethnicities value set. Here the code system is proprietary with the given power2dm URL; <http://power2dm.eu/pdm-patient-ethnicity> in which 4 codes are defined each correspond to an ethnicity defined in D4.1.

```

{
  "resourceType": "ValueSet",
  "id": "pdm-patient-ethnicity",
  "status": "draft",
  "publisher": "POWER2DM",
  "description": "Possible ethnicity of patients from the perspective of POWER2DM risk score calculations",
  "codeSystem": {
    "system": "http://power2dm.eu/pdm-patient-ethnicity",
    "concept": [
      {
        "code": "white",
        "display": "White"
      },
      {
        "code": "afro-caribbean",
        "display": "Afro-caribbean"
      },
      {
        "code": "asian indian",
        "display": "Asian-indian"
      },
      {
        "code": "other",
        "display": "Other"
      }
    ]
  }
}

```

Figure 4 ValueSet definition for Patient ethnicities

## 2.2.4 Writing Conformance Statement

The other configuration resources are all supplementary and we need a Conformance statement to initialize on FHIR repository. In conformance statement you can configure the REST operations for each resource type. Figure 5 illustrates a fragment from POWER2DM Conformance statement that configures REST services for Condition based resources (POWER2DM Diagnosis, Problem, Barrier, Complaint).

The “interactions” element list all the allowed operations for these resources. For example, you can remove the “delete” and the repository then will not allow deletion of these resources. The “searchParam” element list all the search parameters supported for these resources. As shown, the first 4 parameters are already defined by FHIR but the last one is defined by ourselves so we need to give the “definition” path where the SearchParameter definition exists.

```
{
  "type": "Condition",
  "interaction": [
    {
      "code": "read"
    },
    {
      "code": "create"
    },
    {
      "code": "update"
    },
    {
      "code": "delete"
    },
    {
      "code": "search-type"
    },
    {
      "code": "history-instance"
    }
  ],
  "searchParam": [
    {
      "name": "patient",
      "type": "reference",
      "target": [
        "Patient"
      ]
    },
    {
      "name": "code",
      "type": "token"
    },
    {
      "name": "category",
      "type": "token"
    },
    {
      "name": "clinicalstatus",
      "type": "token"
    },
    {
      "name": "related",
      "definition": "http://www.power2dm.eu/pds/SearchParameter/Barrier-related",
      "type": "reference",
      "target": [
        "Condition"
      ]
    }
  ]
}
```

Figure 5 Fragment of POWER2DM Conformance statement - Configuring REST services for Condition resources

## 2.2.5 Configuring Database Indexing for optimizing search

onFHIR.io has another configuration file for defining database indexes for each resource type so that search is optimized accordingly. Figure 6 illustrates a fragment of database index configuration file that optimizes indexing for Goal, Condition and Observation resources. For all resources, data is sharded (multi-server deployments how data will be distributed among servers) according to id of the patient they belong to. For Observation, the index will be defined for the “code” and “date” search parameters which specifies the type of Observation (e.g. Blood Glucose measurement) and date of observation. In other words, searching Observations with these search parameters will take less time.

```

{
  "resource": "Observation",
  "shardKey": ["subject"],
  "indexes": [
    "code",
    "date"
  ]
},
{
  "resource": "Condition",
  "shardKey": ["patient"],
  "indexes": [
    "clinicalstatus",
    "code"
  ]
},
{
  "resource": "Goal",
  "shardKey": ["subject"],
  "indexes": [
    "status",
    "targetMeasure"
  ]
},
}

```

Figure 6 Fragment of DB-Index-configuration to define indexes for Goal, Condition, Observation resources

## 2.2.6 POWER2DM PDS Source Code

All these configurations and the standalone application of onFHIR.io is packaged as a project and it is served from our Gitlab repository (<http://gitlab.srdc.com.tr/power2dm/pds> ). It is also cloned to POWER2DM repository. Developers from other POWER2DM partners use the project to run the pds repository in their local settings for testing.

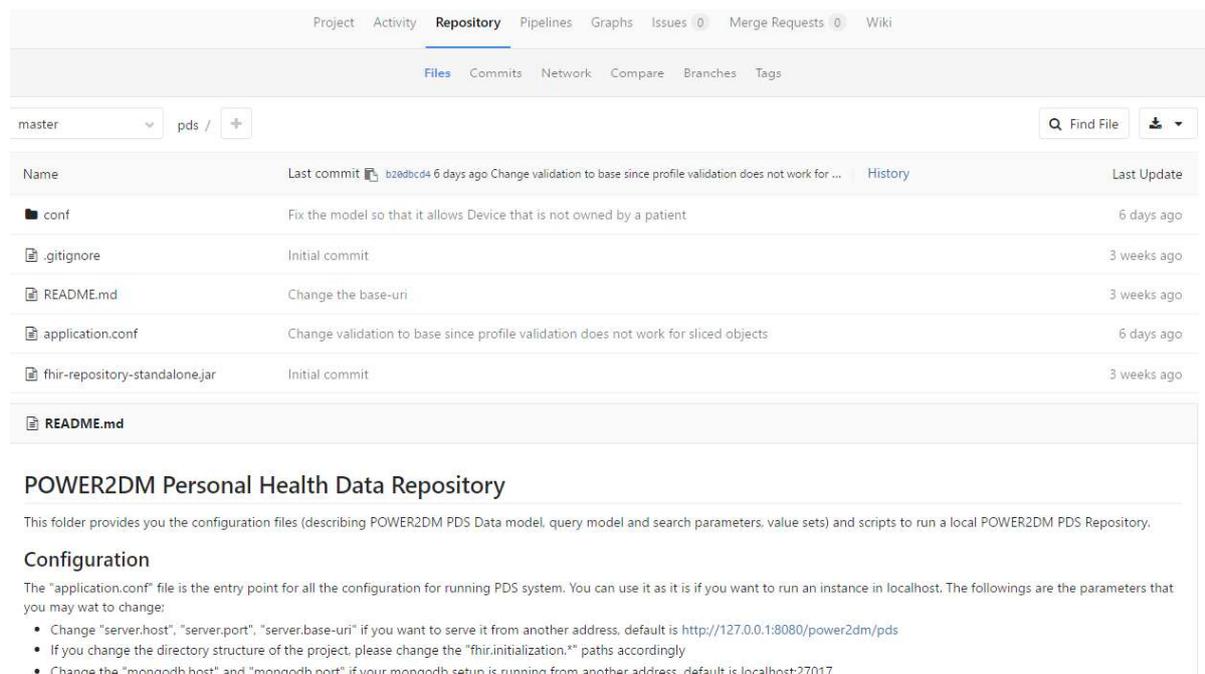


Figure 7 Snapshot from the gitlab for power2dm/pds

The README file describes how to configure and run the pds repository service.

## 2.3 PDS Client as Java Library

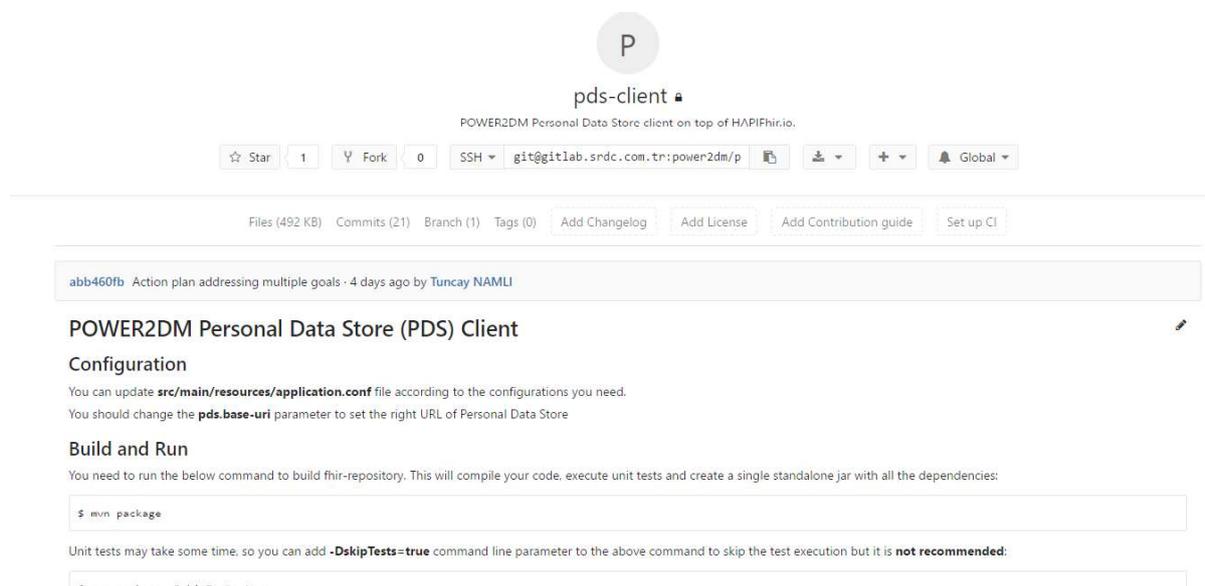


Figure 8 Snapshot from pds-client project on gitlab

As described in the D1.3 Conceptual Design, we have provided a Java client library for PDS to access the REST API easily from JVM based projects. The source code is packaged in a project called **pds-client** and the source code is provided from the <http://gitlab.srdc.com.tr/power2dm/pds-client>.

The software is based on HAPI Client library<sup>8</sup> with the extensions of object model and search mechanisms with POWER2DM data model and new search parameters as well as enumerations for value sets.

### 3 Demonstration of Functionalities

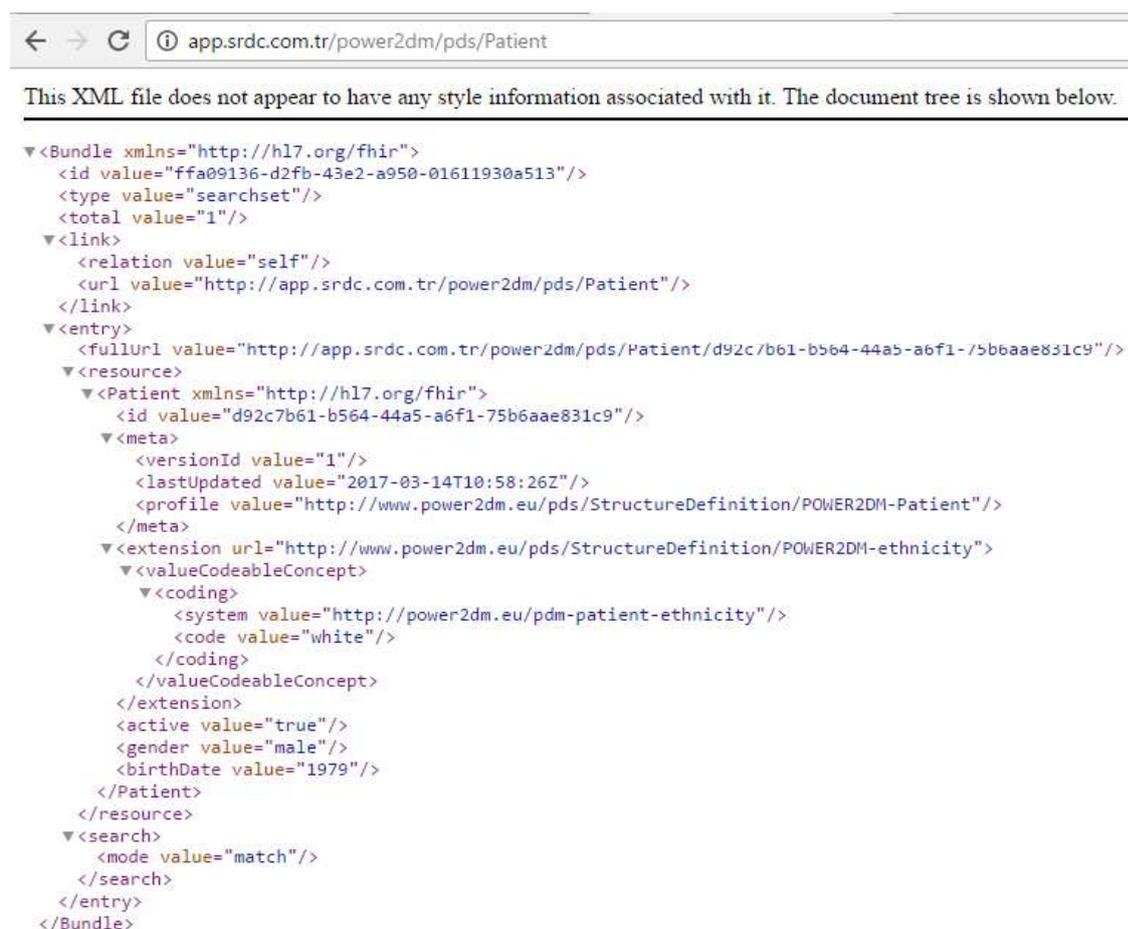
The POWER2DM PDS is deployed on our cloud for demonstration and as testing environment for other partners. The main URL for the repository is <http://app.srdc.com.tr/power2dm/pds>.

#### 3.1 Send Get Requests from Browser

You can use your browser to retrieve data from the PDS repository. The followings are some examples and results as snapshots.

Running <http://app.srdc.com.tr/power2dm/pds/Patient> will retrieve all Patients in the repository as shown in Figure 9.

Running [http://app.srdc.com.tr/power2dm/pds/Patient/d92c7b61-b564-44a5-a6f1-75b6aae831c9/Observation?code=http://loinc.org/41653-7&\\_count=2](http://app.srdc.com.tr/power2dm/pds/Patient/d92c7b61-b564-44a5-a6f1-75b6aae831c9/Observation?code=http://loinc.org/41653-7&_count=2) will return all the blood glucose measurements in a FHIR bundle with paging count 2 .



```

<?xml version="1.0" encoding="UTF-8" standalone="yes" ?>
<Bundle xmlns="http://hl7.org/fhir"
  id="ffa09136-d2fb-43e2-a950-01611930a513"
  type="searchset"
  total="1">
  <link
    relation="self"
    url="http://app.srdc.com.tr/power2dm/pds/Patient"/>
  <entry>
    <fullurl value="http://app.srdc.com.tr/power2dm/pds/Patient/d92c7b61-b564-44a5-a6f1-75b6aae831c9"/>
    <resource>
      <Patient xmlns="http://hl7.org/fhir"
        id="d92c7b61-b564-44a5-a6f1-75b6aae831c9">
        <meta
          versionId="1"
          lastUpdated="2017-03-14T10:58:26Z"
          profile="http://www.power2dm.eu/pds/StructureDefinition/POWER2DM-Patient"/>
        <extension url="http://www.power2dm.eu/pds/StructureDefinition/POWER2DM-ethnicity">
          <valueCodeableConcept>
            <coding
              system="http://power2dm.eu/pdm-patient-ethnicity">
              <code value="white"/>
            </coding>
          </valueCodeableConcept>
        </extension>
        <active value="true"/>
        <gender value="male"/>
        <birthDate value="1979"/>
      </Patient>
    </resource>
  </entry>
  <search
    mode="match">
  </search>
</entry>
</Bundle>

```

Figure 9 Example search on Patients (XML representation)

<sup>8</sup> [http://hapifhir.io/doc\\_rest\\_client.html](http://hapifhir.io/doc_rest_client.html)

```

← → ↻ Ⓞ app.srdc.com.tr/power2dm/pds/Patient/d92c7b61-b564-44a5-a6f1-75b6aae831c9/Observation?code=http://loinc.org|41653-7&_count=2
This XML file does not appear to have any style information associated with it. The document tree is shown below.
▼<Bundle xmlns="http://hl7.org/fhir">
  <id value="c16ba8b3-9a4e-474d-b603-c1bcd72f57df"/>
  <type value="searchset"/>
  <total value="24"/>
  ▼<link>
    <relation value="self"/>
    <url value="http://app.srdc.com.tr/power2dm/pds/Patient/d92c7b61-b564-44a5-a6f1-75b6aae831c9/Observation?code=http://loinc.org|41653-7&_count=2"/>
  </link>
  ▼<link>
    <relation value="first"/>
    <url value="http://app.srdc.com.tr/power2dm/pds/Patient/d92c7b61-b564-44a5-a6f1-75b6aae831c9/Observation?code=http://loinc.org|41653-7&_count=2&_page=1"/>
  </link>
  ▼<link>
    <relation value="next"/>
    <url value="http://app.srdc.com.tr/power2dm/pds/Patient/d92c7b61-b564-44a5-a6f1-75b6aae831c9/Observation?code=http://loinc.org|41653-7&_count=2&_page=2"/>
  </link>
  ▼<link>
    <relation value="last"/>
    <url value="http://app.srdc.com.tr/power2dm/pds/Patient/d92c7b61-b564-44a5-a6f1-75b6aae831c9/Observation?code=http://loinc.org|41653-7&_count=2&_page=12"/>
  </link>
  ▼<entry>
    <fullUrl value="http://app.srdc.com.tr/power2dm/pds/Observation/88b7283f-6b7a-4bf1-8c29-df5512702791"/>
    ▼<resource>
      ▼<Observation xmlns="http://hl7.org/fhir">
        <id value="88b7283f-6b7a-4bf1-8c29-df5512702791"/>
        ▼<meta>
          <versionId value="1"/>
          <lastUpdated value="2017-03-14T10:59:45Z"/>
          <profile value="http://www.power2dm.eu/pds/StructureDefinition/POWER2DM-SimpleQuantityObservation"/>
        </meta>
        <status value="final"/>
        ▼<code>
          ▼<coding>
            <system value="http://loinc.org"/>
            <code value="41653-7"/>
          </coding>
        </code>
        ▼<subject>
          <reference value="Patient/d92c7b61-b564-44a5-a6f1-75b6aae831c9"/>
        </subject>
        <effectiveDateTime value="2017-01-02T09:00:00Z"/>
        ▼<valueQuantity>
          <value value="3.0"/>
          <unit value="mg/dL"/>
          <system value="http://unitsofmeasure.org"/>
          <code value="mg/dL"/>
        </valueQuantity>
        ▼<device>
          <reference value="Device/4c979580-0c95-479b-b3cc-25e165038f8b"/>
        </device>
      </Observation>
    </resource>
    ▼<search>
      <mode value="match"/>
    </search>
  </entry>
  ▼<entry>
    <fullUrl value="http://app.srdc.com.tr/power2dm/pds/Observation/1cd32e9c-84d9-4576-98a2-9844d6a8efdd"/>
    ▼<resource>
      ▼<Observation xmlns="http://hl7.org/fhir">
        <id value="1cd32e9c-84d9-4576-98a2-9844d6a8efdd"/>
        ▼<meta>

```

### 3.2 Use Postman to access the REST services

You can also use a REST client like Postman<sup>9</sup> to test the REST services of PDS.

Figure 10 illustrates an example resource creation request submitted from Postman. It creates a Dietary Intake Log for the patient, and the repository creates it responds with HTTP 201 created.

As shown in Figure 12, the same request when sent by an invalid Observation resource (missing “code” element this time) returns with error HTTP 422 Unprocessable Entity as defined in FHIR specification with information about errors.

Figure 13 shows the same query used in Section 3.1, this time requesting JSON representation. Figure 11 illustrates the deletion of an Observation with the given id where sever deletes and successfully return HTTP 204 No Content.

<sup>9</sup> <https://chrome.google.com/webstore/detail/postman/fhbjgblifljbdggehcdcbncdddomop>

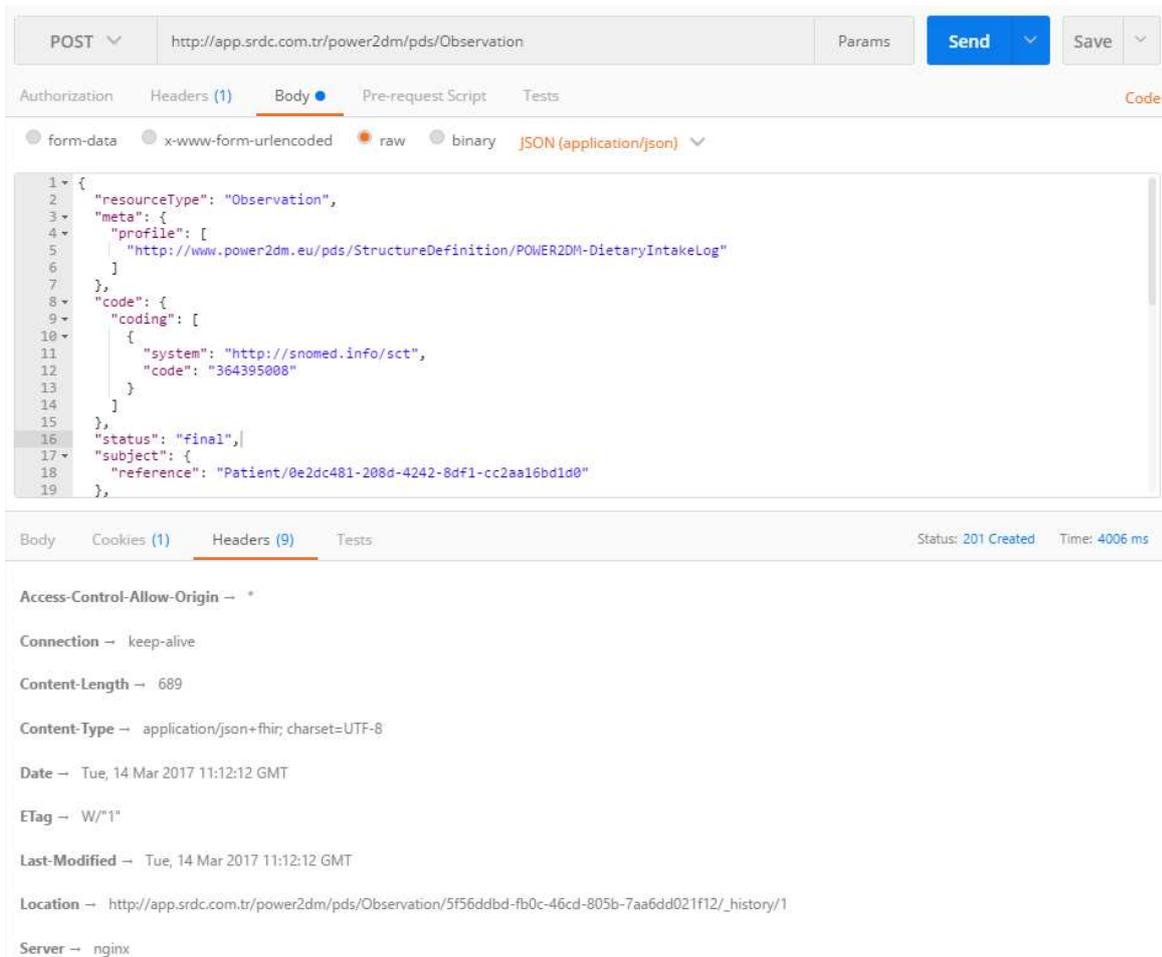


Figure 10 Creating a resource - Snapshot from Postman



Figure 11 Deleting a resource -- Snapshot from Postman

## H2020 POWER2DM

The screenshot shows a REST client interface with a POST request to `http://app.srdc.com.tr/power2dm/pds/Observation`. The request body is a JSON object representing an observation. The response is a 422 Unprocessable Entity error with the following JSON body:

```
1 {
2   "resourceType": "OperationOutcome",
3   "issue": [
4     {
5       "severity": "error",
6       "code": "invalid",
7       "diagnostics": "Element '.code': minimum required = 1, but only found 0"
8     },
9     {
10      "severity": "warning",
11      "code": "invalid",
12      "diagnostics": "Unable to validate code \"162535007\" in code system \"http://snomed.info/sct\"",
13      "location": [
14        "/component/code"
15      ]
16    },
17    {
18      "severity": "information",
19      "code": "invalid",
20      "diagnostics": "Binding for path /component/code/coding has no source, so can't be checked",
21      "location": [
22        "/component/code/coding"
23      ]
24    }
25  ]
26 }
```

Figure 12 Creating an invalid resource returning error

The screenshot shows a REST client interface with a GET request to `http://app.srdc.com.tr/power2dm/pds/Observation?code=http://loinc.org|41653-7`. The response is a 200 OK status with the following JSON body:

```
1 {
2   "resourceType": "Bundle",
3   "id": "52e970de-22d2-423c-bed3-3c1304b3070e",
4   "type": "searchset",
5   "total": 24,
6   "link": [
7     {
8       "relation": "self",
9       "url": "http://app.srdc.com.tr/power2dm/pds/Observation?code=http://loinc.org|41653-7"
10    }
11  ],
12  "entry": [
13    {
14      "fullUrl": "http://app.srdc.com.tr/power2dm/pds/Observation/88b7283f-6b7a-4bf1-8c29-df5512702791",
15      "resource": {
16        "resourceType": "Observation",
17        "id": "88b7283f-6b7a-4bf1-8c29-df5512702791",
18        "meta": {
19          "profile": [
20            "http://www.power2dm.eu/pds/StructureDefinition/POWER2DM-SimpleQuantityObservation"
21          ],
22          "versionId": "1",
23          "lastUpdated": "2017-03-14T10:59:45Z"
24        },
25        "status": "final",
26        "code": {
27          "coding": [
28            {
29              "system": "http://loinc.org",
30              "code": "41653-7"
31            }
32          ]
33        },
34        "subject": {
35          "reference": "Patient/d92c7b61-b564-44a5-a6f1-75b6aae831c9"
36        }
37      }
38    }
39  ]
40 }
```

Figure 13 Querying a resource (JSON representation)

### 3.3 Integration with Smart on FHIR applications

SMART on FHIR is a set of open specifications to integrate apps with Electronic Health Records, portals, Health Information Exchanges, and other Health IT systems by using FHIR specification. We also check if we can integrate our POWER2DM PDS repository with their demo application. They build a sandbox for demonstrations and their applications can work on any FHIR server by redirection.

Running the following from the browser will run their sample “fhir-demo” web application on top of our PDS repository deployed in our Cloud service for patient with the given id.

<https://fhir-dstu2.smarthealthit.org/apps/fhir-demo/app/launch.html?fhirServiceUrl=http://app.srdc.com.tr/power2dm/pds&patientId=d92c7b61-b564-44a5-a6f1-75b6aae831c9>

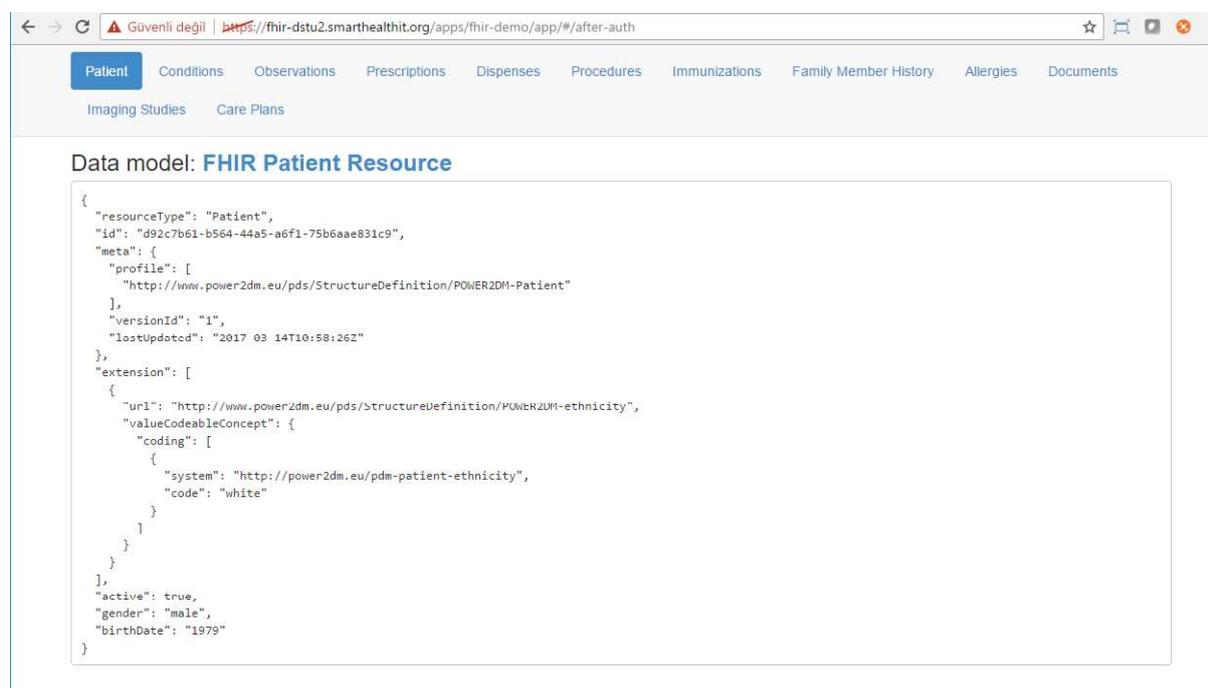


Figure 14 Snapshot for running Smart on FHIR fhir-demo application on PDS

As shown in Figure 14, the application retrieve the patient record and show it. Clicking on Conditions tab retrieves the Conditions and show the result as shown in Figure 15.

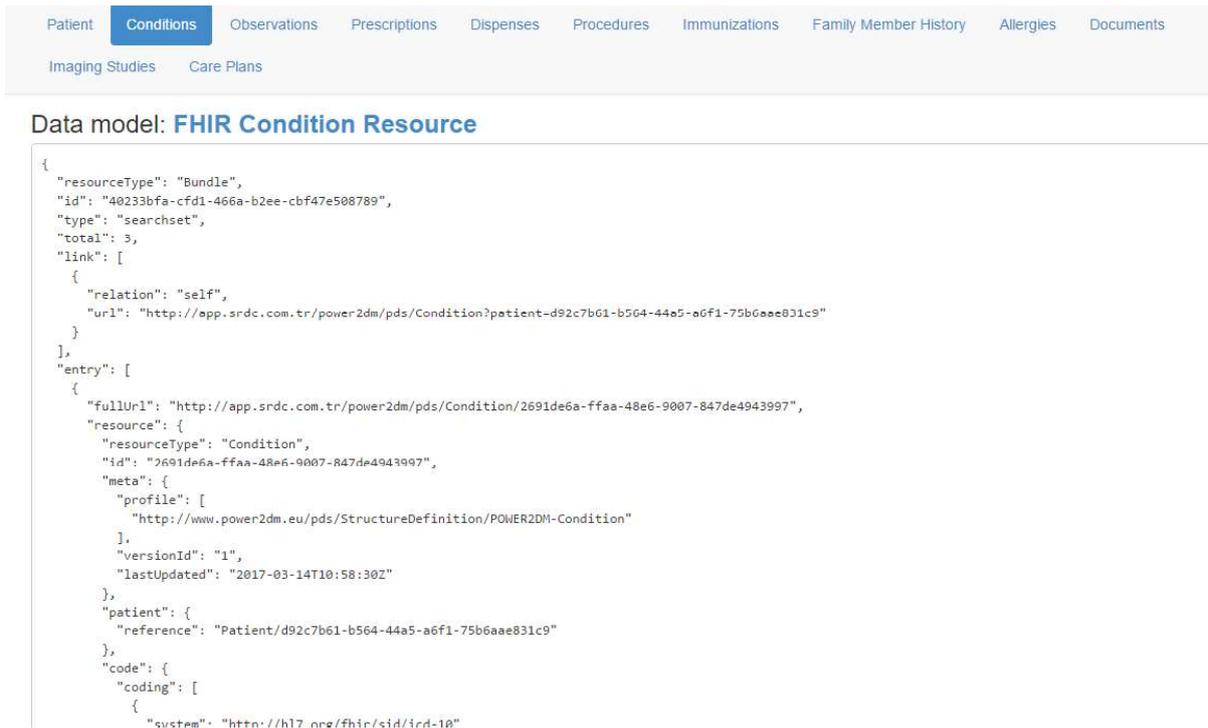


Figure 15 Snapshot for running Smart on FHIR fhir-demo application on PDS - Conditions

### 3.4 FHIR Compliance tests

We have tested the PDS repository for FHIR compliance with two different online testing environment designed to test FHIR conformance.

Figure 16 illustrates the test results in one of the environments Crucible (<https://projectcrucible.org/#homepageCarousel>). The first one in the list “SRDC onFHIR” tops the list for FHIR compliance.

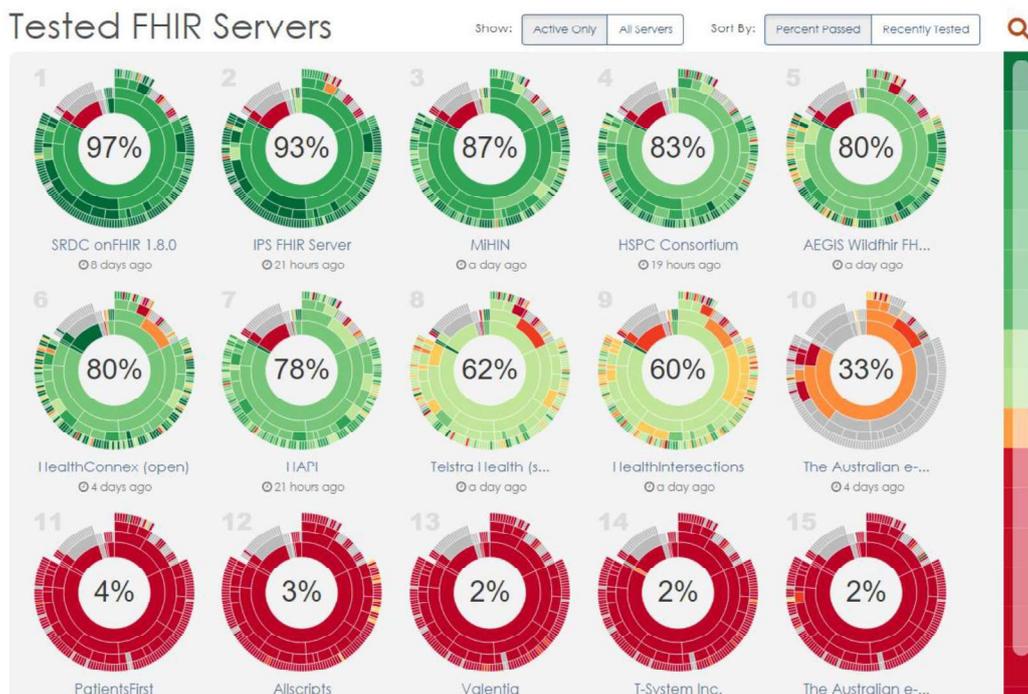


Figure 16 FHIR Compliance test results on Crucible testing environment

Figure 17 illustrates onFHIR.io’s compliance performance on the other testing environment called Touchstone (<https://touchstone.aegis.net/touchstone/>).



Figure 17 FHIR compliance test results on Touchstone testing environment

As seen from the snapshots, we are nearly fully compliant with the specification; only missing some operation implementations that are not mandatory for a FHIR repository.

### 3.5 Performance benchmarking

We have done some performance testing for the POWER2DM PDS deployment on a single server. The server characteristics are as follows;

- 16GB RAM
- Intel Core i7 4GHZ CPU
- Windows 10 64 bit

Figure 18 shows the resource creation (write) performance for creation of 20 patient resources and 5 resource (Observation, DiagnosticReport, Condition) for each patient. Average resource creation time is less than 10 ms per resource.

Similarly Figure 19 shows the query performance for all resource types and as shown in average it is less than 8 ms per resource.

# H2020 POWER2DM

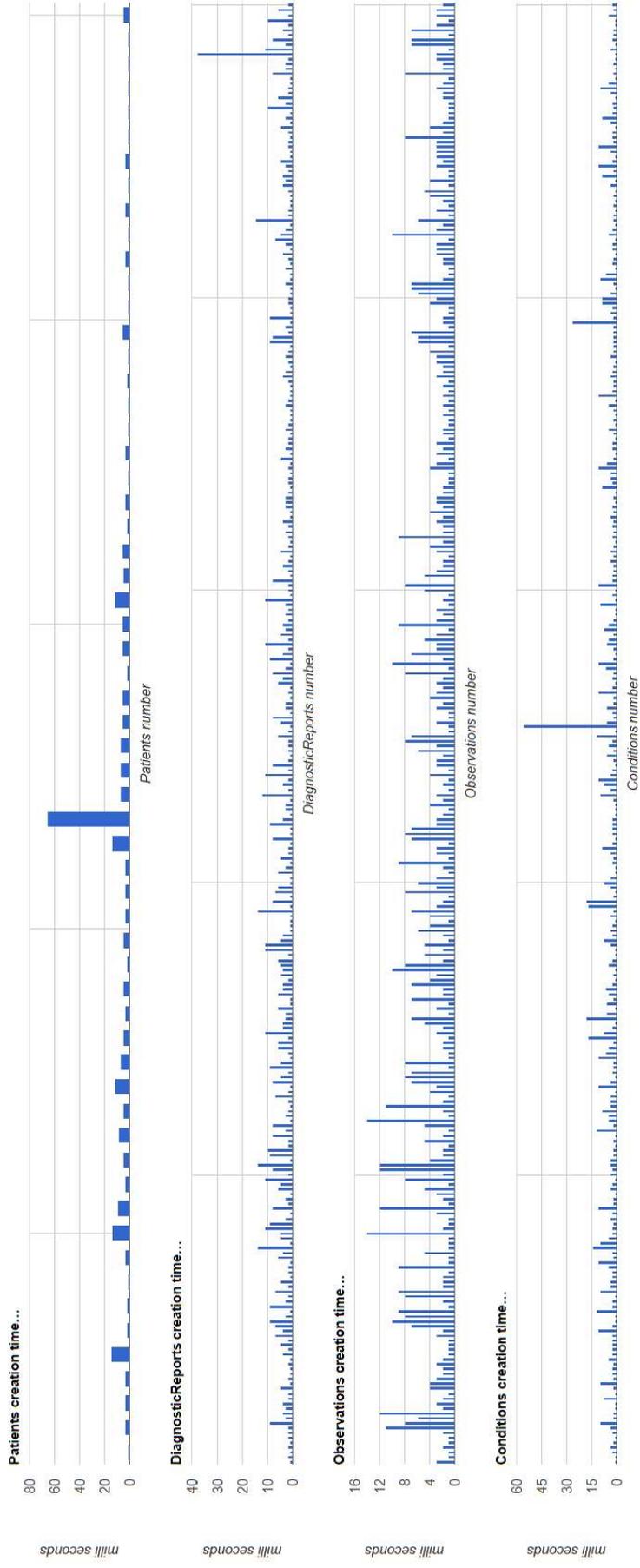


Figure 18 Resource create (write) performance for POWER2DM PDS



Figure 19 Resource query (read) performance for POWER2DM PDS

### 3.6 Publication of Resource Definitions to Simplifier.net

All POWER2DM resource and data type profile definitions and search parameter definitions are published to Simplifier.net<sup>10</sup> which is a public repository for FHIR resource definitions and related projects. We have opened an account for POWER2DM project and publish all the resources within the scope of account. You can access the profile definitions from <https://simplifier.net/POWER2DM?category=StructureDefinition>. Similarly you can access the search parameter definitions from <https://simplifier.net/POWER2DM?category=SearchParameter>. Figure 20 shows the snapshot of the simplifier.net, clicking on one of the resource definition will show the definition in detail as shown in Figure 21.

The screenshot shows the Simplifier.net interface for the POWER2DM project. The header includes the Simplifier.net logo, a search bar, and a 'FEEDBACK' button. Below the header, the project name 'POWER2DM' is displayed, along with a description: 'Predictive model-based decision support for diabetes patient empowerment (Ongoing H2020 Project)'. The page is categorized as a 'PUBLIC PROJECT' with a 'Scope' of 'International'. There are 0 bookmarks and a 'Subscribe' button. The main content area shows a list of resource definitions, each with a 'Draft' status and a date of 11/14/2016. The resources listed are:

- POWER2DM\_Acknowledgement**: Profile on Procedure. Profile to represent an acknowledgement of planned action by patient to indicate it is done.
- POWER2DM\_ActionPlan**: Profile on ProcedureRequest. Profiling to represent Treatment or Self-management action plan in POWER2DM Care Program.
- POWER2DM\_ActivityTrackerDailySummary**: Profile on Observation. Profiling to represent a daily summary of physical activity based on activity tracker device data.
- POWER2DM\_AppliedIntervention**: Profile on Procedure. Profile to represent information about an applied self-management intervention to patient (type of intervention, time, etc).
- POWER2DM\_Appointment**: Profile on Appointment.

Figure 20 Snapshot from Simplifier.net - POWER2DM project FHIR definitions

<sup>10</sup> <https://simplifier.net>

PROJECT POWER2DM  
**POWER2DM\_RiskAssessment**  
 Profile to represent risk assessments in POWER2DM (e.g. risk of CVD due to diabetes)

type Profile on RiskAssessment status Draft version 0.1 FHIR 1.0.2 Canonical http://www.power2dm.eu/pds/StructureDefinition/POWER2

Overview Details Table XML JSON Example History

Name	Flags	Card.	Type	Description & Constraints
RiskAssessment			RiskAssessment	
subject		1..	Reference(Patient)	
date		1..		
performer		1..	Reference(Practitioner   Device)	
method		1..		Binding: http://power2dm.eu/pds/ValueSet/pdm-risk-assessment-methods (required)
basis		1..	Reference(Resource   SimulationParameters)	
prediction		1..		
outcome				Possible outcome for the subject (e.g. risk of CHD)
probability[x]		1..	decimal, Range	Binding: (unbound) (required)
whenRange			Range	

Documentation for this format

Figure 21 POWER2DM\_RiskAssesment resource definition view in Simplifier.net

## 4 Appendices

### 4.1 Appendix A – Sample FHIR Definitions

Table 1 StructureDefinition of POWER2DM\_DietaryIntakeLog resource

```
<?xml version="1.0" encoding="utf-8"?>
<StructureDefinition xmlns="http://hl7.org/fhir">
  <id value="POWER2DM-DietaryIntakeLog" />
  <meta>
    <lastUpdated value="2016-12-07T11:23:46.489+03:00" />
  </meta>
  <url value="http://www.power2dm.eu/pds/StructureDefinition/POWER2DM-DietaryIntakeLog" />
  <version value="0.1" />
  <name value="POWER2DM-DietaryIntakeLog" />
  <display value="POWER2DM-DietaryIntakeLog" />
  <status value="draft" />
  <publisher value="SRDC Corp." />
  <date value="2016-11-30T00:00:00+03:00" />
  <description value="StructureDefinition for POWER2DM Dietary Intake Log Resource " />
  <kind value="resource" />
  <constrainedType value="Observation" />
  <abstract value="true" />
  <base value="http://hl7.org/fhir/StructureDefinition/Observation" />
  <differential>
    <element>
      <path value="Observation" />
    </element>
  </differential>
</StructureDefinition>
```

```

    <code value="Observation" />
  </type>
</element>
<element>
  <path value="Observation.extension" />
  <slicing>
    <discriminator value="url" />
    <rules value="open" />
  </slicing>
</element>
<element>
  <path value="Observation.extension" />
  <name value="acknowledgedPlannedAction" />
  <short value="Extension for Observations to record acknowledged action plan" />
  <definition value="Optional Extensions Element - found in all resources." />
  <max value="1" />
  <type>
    <code value="Extension" />
    <profile value="http://www.power2dm.eu/pds/StructureDefinition/POWER2DM-
acknowledgedPlannedAction" />
  </type>
</element>
<element>
  <extension url="http://hl7.org/fhir/StructureDefinition/structuredefinition-display-hint">
    <valueString value="default: final" />
  </extension>
  <path value="Observation.status" />
  <fixedCode value="final" />
</element>
<element>
  <path value="Observation.code" />
  <binding>
    <strength value="extensible" />
    <description value="Codes identifying names of Observations used in POWER2DM Care program ..." />
    <valueSetReference>
      <reference value="http://www.power2dm.eu/pds/ValueSet/pdm-observations" />
    </valueSetReference>
  </binding>
</element>
<element>
  <path value="Observation.code.coding.system" />
  <fixedUri value="http://snomed.info/sct" />
</element>
<element>
  <path value="Observation.code.coding.code" />
  <fixedCode value="364395008" />
</element>
<element>
  <path value="Observation.subject" />
  <min value="1" />
  <type>
    <code value="Reference" />
    <profile value="http://www.power2dm.eu/pds/StructureDefinition/POWER2DM-Patient" />
  </type>
</element>
<element>
  <path value="Observation.effectiveDateTime" />
  <min value="1" />
  <type>
    <code value="dateTime" />

```

```

</type>
</element>
<element>
  <path value="Observation.performer" />
  <max value="1" />
  <type>
    <code value="Reference" />
    <profile value="http://www.power2dm.eu/pds/StructureDefinition/POWER2DM-Patient" />
  </type>
</element>
<element>
  <path value="Observation.value[x]" />
  <max value="0" />
</element>
<element>
  <path value="Observation.dataAbsentReason" />
  <max value="0" />
</element>
<element>
  <path value="Observation.bodySite" />
  <max value="0" />
</element>
<element>
  <path value="Observation.method" />
  <max value="0" />
</element>
<element>
  <path value="Observation.specimen" />
  <max value="0" />
</element>
<element>
  <path value="Observation.device" />
  <type>
    <code value="Reference" />
    <profile value="http://www.power2dm.eu/pds/StructureDefinition/POWER2DM-Device" />
  </type>
</element>
<element>
  <path value="Observation.referenceRange" />
  <max value="0" />
</element>
<element>
  <path value="Observation.related" />
  <max value="0" />
</element>
<element>
  <path value="Observation.component" />
  <slicing>
    <discriminator value="code.coding" />
    <rules value="openAtEnd" />
  </slicing>
  <min value="1" />
  <max value="1" />
</element>
<element>
  <path value="Observation.component" />
  <name value="bread-unit-intake" />
  <min value="1" />
  <max value="1" />
</element>

```

```

<element>
  <path value="Observation.component.code.coding.system" />
  <fixedUri value="http://snomed.info/sct" />
</element>
<element>
  <path value="Observation.component.code.coding.code" />
  <fixedCode value="226394005" />
</element>
<element>
  <path value="Observation.component.valueQuantity" />
  <min value="1" />
  <type>
    <code value="Quantity" />
  </type>
</element>
<element>
  <path value="Observation.component" />
  <name value="carb-intake" />
  <min value="1" />
  <max value="1" />
</element>
<element>
  <path value="Observation.component.code.coding.system" />
  <fixedUri value="http://snomed.info/sct" />
</element>
<element>
  <path value="Observation.component.code.coding.code" />
  <fixedCode value="162535007" />
</element>
<element>
  <path value="Observation.component.valueQuantity" />
  <min value="1" />
  <type>
    <code value="Quantity" />
  </type>
</element>
<element>
  <path value="Observation.component" />
  <name value="calorie-amount" />
  <min value="1" />
  <max value="1" />
</element>
<element>
  <path value="Observation.component.code.coding.system" />
  <fixedUri value="http://snomed.info/sct" />
</element>
<element>
  <path value="Observation.component.code.coding.code" />
  <fixedCode value="162533000" />
</element>
<element>
  <path value="Observation.component.valueQuantity" />
  <min value="1" />
  <type>
    <code value="Quantity" />
  </type>
</element>
<element>
  <path value="Observation.component" />
  <name value="saturated-fat-intake" />

```

```

    <short value="Saturated Fatty Acid" />
    <min value="1" />
    <max value="1" />
  </element>
</element>
  <path value="Observation.component.code.coding.system" />
  <fixedUri value="http://snomed.info/sct" />
</element>
</element>
  <path value="Observation.component.code.coding.code" />
  <fixedCode value="226328000" />
</element>
</element>
  <path value="Observation.component.valueQuantity" />
  <min value="1" />
  <type>
    <code value="Quantity" />
  </type>
</element>
</element>
  <path value="Observation.component.referenceRange" />
  <max value="1" />
</element>
</element>
  <path value="Observation.component" />
  <name value="fiber-intake" />
  <min value="1" />
  <max value="1" />
</element>
</element>
  <path value="Observation.component.code.coding.system" />
  <fixedUri value="http://snomed.info/sct" />
</element>
</element>
  <path value="Observation.component.code.coding.code" />
  <fixedCode value="162520006" />
</element>
</element>
  <path value="Observation.component.valueQuantity" />
  <min value="1" />
  <type>
    <code value="Quantity" />
  </type>
</element>
</element>
  <path value="Observation.component.referenceRange" />
  <max value="1" />
</element>
</element>
  <path value="Observation.component" />
  <name value="salt-intake" />
  <short value="Salt intake" />
  <min value="1" />
  <max value="1" />
</element>
</element>
  <path value="Observation.component.code.coding.system" />
  <fixedUri value="http://snomed.info/sct" />
</element>
</element>

```

```

    <path value="Observation.component.code.coding.code" />
    <fixedCode value="309544001" />
  </element>
</element>
<element>
  <path value="Observation.component.valueQuantity" />
  <min value="1" />
  <type>
    <code value="Quantity" />
  </type>
</element>
</element>
<element>
  <path value="Observation.component.referenceRange" />
  <max value="1" />
</element>
</element>
<element>
  <path value="Observation.component" />
  <name value="vegetable-intake" />
  <min value="1" />
  <max value="1" />
</element>
</element>
<element>
  <path value="Observation.component.code.coding.system" />
  <fixedUri value="http://snomed.info/sct" />
</element>
</element>
<element>
  <path value="Observation.component.code.coding.code" />
  <fixedCode value="226448008" />
</element>
</element>
<element>
  <path value="Observation.component.valueQuantity" />
  <min value="1" />
  <type>
    <code value="Quantity" />
  </type>
</element>
</element>
<element>
  <path value="Observation.component" />
  <name value="fruit-intake" />
  <min value="1" />
  <max value="1" />
</element>
</element>
<element>
  <path value="Observation.component.code.coding.system" />
  <fixedUri value="http://snomed.info/sct" />
</element>
</element>
<element>
  <path value="Observation.component.code.coding.code" />
  <fixedCode value="226452008" />
</element>
</element>
<element>
  <path value="Observation.component.valueQuantity" />
  <min value="1" />
  <type>
    <code value="Quantity" />
  </type>
</element>
</element>
<element>
  <path value="Observation.component" />
  <name value="peas-beans-intake" />
  <min value="1" />

```

```
<max value="1" />
</element>
<element>
  <path value="Observation.component.code.coding.system" />
  <fixedUri value="http://snomed.info/sct" />
</element>
<element>
  <path value="Observation.component.code.coding.code" />
  <fixedCode value="226450000" />
</element>
<element>
  <path value="Observation.component.valueQuantity" />
  <min value="1" />
  <type>
    <code value="Quantity" />
  </type>
</element>
<element>
  <path value="Observation.component" />
  <name value="nuts-seeds-intake" />
  <min value="1" />
  <max value="1" />
</element>
<element>
  <path value="Observation.component.code.coding.system" />
  <fixedUri value="http://snomed.info/sct" />
</element>
<element>
  <path value="Observation.component.code.coding.code" />
  <fixedCode value="226456006" />
</element>
<element>
  <path value="Observation.component.valueQuantity" />
  <min value="1" />
  <type>
    <code value="Quantity" />
  </type>
</element>
</differential>
</StructureDefinition>
```