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Propose of Standards Based IT Architecture to Enrich the Value of Allergy Data by Telemonitoring Data

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Abstract. Interoperability is a key requirement for any IT-System to be future proof and cost efficient, due to the increasing interaction of IT-Systems in Healthcare. This feasibility study is part of a larger project focusing on the conceptualization and evaluation of interoperable and modular IT-Framework components for exchanging big data information sets. Hence, this project investigates the applicability of a standard based IT-Architecture for the integration of Personal Health Devices data and open data sources. As a proof of concept use case, pollen forecast data from the Medical University of Vienna were combined with Personal Health Device data and a data correlation was investigated. The standards were identified as well as selected in expert's reviewed and the Architecture was designed based on a literature research. Subsequently the prototype was implemented and successfully tested in interoperability tests. The study shows that the architecture meets the requirements. It can be flexibly extended according to further requirements due to its generic setup. However, further extensions of the Interoperability-Connector and a full test setup needs to be realized in future.

Keywords. Telemedicine, Interoperability, Standardization, Medical Devices, Hypersensitivity.

1. Introduction

The European eHealth Action Plan 2012-2020 [1], explicitly states the importance and benefits of eHealth services and the requirements on a wider adoption of interoperability standards. The EU funding project/framework Connecting Europe Facility (CEF) focuses within one sector on eHealth with a Digital Service Infrastructure (DSI) [2]. The increasing mobility of EU citizens is a challenge. The place of work and the main residence can be situated in different countries for a critical number of citizens. This fact raises challenges in the case of injuries or diseases to the distribution and access of medical information and services. Interoperable IT systems ideally foster the interconnectivity of Healthcare IT-Systems like Electronic Health Record (EHR) Systems, not only on a large scale, but also for example on a bilateral level between

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Hospital associations. This fact is once more reinforced by the necessity of the National Health Record projects in Europe, like the Austrian ELGA.

Nevertheless, apart from such prestigious projects, telemonitoring projects are emerging in diverse forms and shades. There are many different telemonitoring approaches in a dynamic and emerging field with fast evolving technologies that potentially lead to benefits for different stakeholders. As Maeng et al. [3] showed in a study from 2008-2012, readmissions were reduced from 38 to 44 percent, thus reducing overall costs. This numbers show the high potential of telemonitoring to improve efficiency and cost save. Further improvements can be expected from the integration of state-of-the-art IT-Standards for Interoperability like architectural building blocks of the Continua Health Alliance (CHA) [4].

The funded project "INNOVATE" aims to investigate interoperability standards, but also design and implement "development kits", for example interoperable and modular IT-Framework components for the integration and exchange of data from eHealth, mHealth as well as open data applications and data sources, based on interoperability standards. This project builds on past work on the investigation, design, implementation and testing of interoperability standards for telemonitoring [5,6]. These approaches were concerned with a Personal Health Device Setup in telemonitoring systems and EHR Systems measuring data and transmitting it via interoperability standards.

In this work the focus is extended to third party data sources, like open data and big data platforms for the use case of integration of pollen allergy related forecast data. Allergies are the 6th leading cause of chronic illness in the U.S. with an annual cost of 18 Billion Dollar and there is an important need to support patients affected according to [7]. Therefore, the proposed standards based IT-Architecture was applied in a prototypic setup for the integration of pollen forecast data provided by the Medical University of Vienna in this work. Personal Health Device (PHD) data from a telemonitoring setup was correlated with this forecast data. This may raise the quality of life for persons affected in future.

2. Methods

In a first step an internet based literature research, according to [8], was performed for a state-of-the-art research on the application of IT-Standards in the field of telemonitoring. The search was conducted using the databases ScienceDirect [9], IEEE Xplore [10], PubMed [11] as well as Google Scholar [12]. The following keywords and their combinations, where applied as parameters:

- Telemonitoring
- Continua Health Alliance
- IHE (Integrating the Healthcare Enterprises)
- HL7 (Health Level 7)
- FHIR (Fast Healthcare Interoperability Resources)
- IEEE 11073
- Bluetooth Low Energy
- Standardization

The selection process considered the actuality and the significance of the papers as well as the actuality and amount of practical application of the standards referenced. After this process, an expert's review was conducted to investigate the selected papers in detail. As a result the standards were selected and the standards based IT-Architecture was proposed. Subsequent the first prototypes started the work for the proof of concept after the implementation. The Hardware used in this setup was:

- Nonin Onyx Vantage 9590 Finger-Puls Oximeter (Continua Certified, IEEE 11073 standards family based)
- A&D Medical Blood Pressure Monitor UA-651ble (Continua Certified & Bluetooth Low Energy)
- Android 6.0 (Marshmallow) on a OnePlus 3 Smartphone
- Asus Zen Watch 2 (Smart Watch Bluetooth v4.1 BLE)
- Open Source HAPI FHIR for the Interfaces and the Server [13,14]

The requirements for the integration of the puls oximeter and the blood pressure device are derived from the CHA design guidelines [15] and CHA interface guidelines [16]. To meet the interoperability requirements derived from the use case the feasibility was tested by performing interoperability tests with the prototypes. Thus a possible correlation between changes in the patient's vital parameters (SpO2, pulse and blood pressure values) measured with the telemonitoring devices and the real time pollen allergy data recorded within the same timeframe should be reported (or not).

3. Results

The literature research focused to identify and study architectures and data exchange approaches from eHealth systems and approaches from other domains, like Smart City

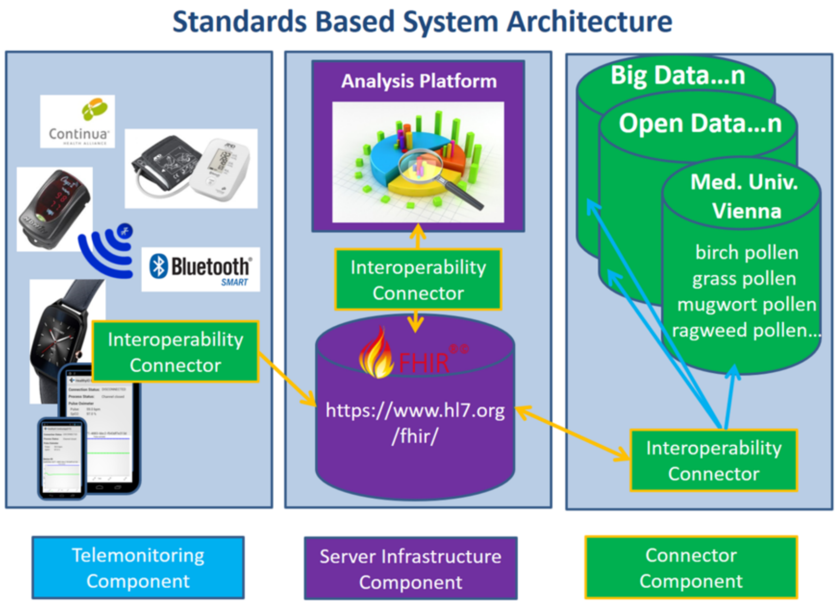

Figure 1. The proposed architectural approach for the overall system divided into three main components, based on interoperability standards. The telemonitoring component is concerned with the integration of personal health devices via an Android application. The Server Infrastructure component shows the core components for data storage and visualization. The connector component provides the necessary standard based interfaces and mapping algorithms to integrate different data sources (pollen forecast data in this proof of concept).

related systems or cloud approaches, independent of the health sector. This approach was selected to include a wider perspective of technologies used, since the integration of further 3rd party open data sources is a clear aim of the actual project. Out of the different identified architectures common approaches could be identified. One example is the registry/repository-model, similar to the definition of the "Integrating the Healthcare Enterprise" (IHE) XDS-Profile within the IT-Infrastructure Technical Framework [17]. Based on these methods, the author already proposed architectural approaches regarding integration of open-data platforms [18]. In the next step these approaches are extended with light-weight technologies, like RESTful web-services instead of SOAP based web-services. Such an approach was shown in the Smart City approach in [19]. Through this, the decision was made to use a RESTful web-services, i.e. FHIR based, approach as the integration and application of IT-standards is a clear requirement for this work.

The following specifications (Figure 1) were designed from the stated literature research i. a. [19-21], experts review and previous work [18], including the Continua Health Alliance, IEEE 11073 (X73) Standards Family, Bluetooth Low Energy and HL7 FHIR (Fast Healthcare Interoperability Resources). Figure 1, shows the resulting System providing data aggregation, data analysis and data exchange capabilities. The latter is completely based on the previously stated interoperability standards. Basically, the system was divided into three components, described in the following.

3.1. Telemonitoring Component

This component focuses on the telemonitoring part of the system. Two devices were used in the setup. The first was the Onyx Vantage 9590 Finger Puls Oximeter from the company Nonin. This device, which is a Continua Certified Device, is continuously measuring oxygen saturation as well as pulse and transmits the measured data via the IEEE 11073-20601 Optimized Exchange Protocol using the specified Medical Device Encoding Rules (MDER). In this case the transport channel of the protocol is Bluetooth by using the Health Device Profile (HDP) and Secure Simple Pairing (SSP). The device acts as an X73-Agent, which is the generic term for a Personal Health Device (PHD) in Continua's Terminology. The acquired data is then send to the Android Application running on the OnePlus 3 Smartphone, both acting as X73-Manager in Continua terms.

The second PHD used in the setup is A&D Medical Blood Pressure Monitor UA-651ble (CHA Certified) using Bluetooth Low Energy (BLE) technology, as described in the CHA Interface design guidelines [16]. It transmits systolic-, diastolic- and mean arterial pressure as well as pulse. The Smartphone and Smart Watch (Asus Zen Watch 2), acted as Continua Mangers. They include an X73 & BLE Interoperability Connector (not shown in the system architecture), which is capable of reading and extracting the measured data. This was performed using the X73 specifications via Bluetooth HDP for the pulse oximeter and BLE specifications for the blood pressure monitor. Therefore, the prototype system is able to support three different Manger devices: Smartphone, Tablet as well as Smartwatch.

3.2. Server Infrastructure Component

The focus lies on the server components of the system. Data from the PHD's is transformed and transmitted in the Android applications with the Interoperability Connector described in the connector component, to an instance of the open source FHIR server FHIRbase [13]. The server stores and provides the data via its FHIR API's to the visualization application. Therefore, the server is the core component for long time persistence and also stores additional data from other interconnected data sources, as described in the connector component. The visualization application finally requests the collected data (SpO2, Pulse, Systolic-, Diastolic- and MAP) for analysis.

3.3. Connector Component

This component is concerned with the development of a Java based “Interoperability Connector” used for the integration (data transformation) of further data sources and for the proper FHIR based exchange in the overall system. This connector, as well as further interoperability connectors such as the one used for X73 and BLE interfaces in the Android Apps, are part of a larger long time work focusing on the conceptualization and evaluation of interoperable and modular Framework components to allow exchange of data in a broader context. It uses the open source HAPI FHIR library [14] and extends the connectors capability for this work. The connector, on the one hand, transforms non-standardized data into the standardized format. Moreover, it provides the functionality to exchange the data with other FHIR capable components.

In this prototype setup, the data exchange interface system from the Medical University of Vienna (MUV) provides pollen allergy forecast data indicating the daily pollen loads. The values show levels of exposure for different particles like birch-, grass-, mugwort- and/or ragweed-pollen, where the dimensionless value is between 0-10. Data up to three days can be requested (today, tomorrow and the day after tomorrow). In this context, location information is needed to retrieve regionally correct information.

The interface is actively accessed using the connector as a client (pull-behavior). It transforms the data, from a proprietary format to a FHIR conform structure by using FHIR-Resources and Extension and push it to the FHIRbase server for storage. The connector is additionally used to transform the data received from the different PHD’s in a FHIR conform Resource and stores the data in the FHIRbase server. Finally, the connector is used to pull SpO2, Pulse, Systolic-, Diastolic- and MAP from the FHIRbase server to the visualization component for proper data pre-processing and illustration.

Figure 2 shows a XML-snippet of proposed FHIR-Resource setup with the Extension for the pollen allergy forecast data indicating the pollen load for birch pollen.

The main building block is an Observation-Resource referencing a Location-Resource to indicate the region of interest for pollen load. For each type of pollen one component is used to describe the load intensity. In this case the three values in the data-tag indicate the load forecast for the actual day, tomorrow and the day after tomorrow. Furthermore, the minima, maxima and period is specified for the dimensionless load value. The Location-Reference uses longitude & latitude to specify the area of interest. The Extension is used to differentiate between the use of historical or forecast data as well as to specify a date when the data was generated.

4. Discussion

In this work a prototype system, based on a proposed standard based IT-Architecture, was developed and successfully tested by interoperability tests. The proposed architecture provides the basis for the aggregation and exchange of data, collected on the one hand from devices belonging to a telemonitoring setup and on the other hand data stored in open data/big data platforms, in a standardized way.

```xml
<Observation xmlns="http://hl7.org/fhir">
  <contained>
    <Location xmlns="http://hl7.org/fhir" id="1">
      <position>
        <longitude value="48.239229"/>
        <latitude value="16.378234"/>
      </position>
    </Location>
  <contained/>
  <contained>
    <Organization xmlns="http://hl7.org/fhir" id="2">
      <name value="Data Provider"/>
    </Organization>
  <contained/>
  <extention url="http://fhtw.at/fhir/StructureDefinition/pollen-info">
    <extention url="obsType">
      <!-- alternative could be historicalData -->
      <valueCode value="forecastData">
    <extention/>
    <extention url="generationTime">
      <!-- date and time when the data was generated -->
      <valueDateTime value="2017-03-14T10:57:34+01:00">
    <extention/>
  <extention/>
  <status value="final"/>
  <code>
    <coding>
      <system value="1.2.40.0.29.99.1"/>
      <code value="Pollen_Forecast"/>
      <display value="Pollen_Forecast"/>
    </coding>
  </code>
  <subject>
    <reference value="#1"/>
    <display value="Region of Pollen Forecast"/>
  </subject>
  <effectivePeriode/>
    <start value="2017-03-14"/> <!-- 3 day forecast -->
    <end value="2017-03-16"/>
  <effectivePeriode>
  <performer>
    <reference value="#2"/>
  </performer>
  <component>
    <code>
      <coding>
        <system value="1.2.40.0.29.99.0.1"/>
        <code value="BETU"/>
        <display value="BETULA"/> <!-- birch pollen -->
      </coding>
    </code>
    <valueSampledData>
      <origin>
        <value value="0"/>
      </origin>
      <period value="86400000"/><!-- 24 hours in milliseconds -->
      <lowerLimit value="0"/><!-- minimal value -->
      <upperLimit value="10"/><!-- maximal value -->
      <dimensions value="1"/>
      <data value="1.03 1.36 1.37"/><!-- values of the pollen load -->
    </valueSampledData>
  </component>
  <compontent/><!-- n...components for types of pollen -->
</Observation>
```


Figure 2 shows an application XML-snippet of the proposed FHIR-Resource Setup based on the Observation-Resource with the Extension, to transport pollen allergy forecast data indicating the daily pollen loads to a server based on HL7 FHIR for proper storage. Therefore, the example shows the structure filled with test data.

The resulting prototype showed the possibility to possess a completely standardized communication chain for all components independent of the platforms (e.g. App- and Web-Based) and integrate non-standardized components with minimal effort. However, the workload to support all standardized interfaces should not be underestimated, as the necessary standards are generally complex. This was observed when the correct FHIR-Resources and possible needs for Extensions were identified for the mapping process from the proprietary interface of the allergy data repository to the FHIR conform structure. In this case the data was packed in an Observation-Resource and an Extension has been defined and was used which fulfills the requirements for this use case. The used approach can be applied to other data sources, as it focused on maximizing the use of standardized resources with minimal use of Extensions. Hence, as new resources are needed data with a different nature than the health-related information such as transportation information increased the workload. From a high-level perspective, an application could record the movement of citizens with public transports during the yearly flu epidemic. Based on this data predictions for the occupancy rates of hospitals could be made to optimize patient flows during influenza waves. A combination of non-health related data and health related data may lead to new insights and improved processes. However, the next step is to extend the proposed approach, especially the Connector-Component shall be further extended to transport environmental data, providing additional value. Furthermore, a complete data correlation analysis need to be made as due to time issues, only small spot-checks could be made yet.

Summarizing from a technical point of view, the used design, the modular and platform independent setup of the connectors are an important factor to provide an easy exchangeable and adaptable format for providing interoperability for non-standardized components. Apart of focusing on additional data sources to extend the capabilities of the connectors, an in-depth security analysis need to be done, to subsequently provide the necessary security measures as this system includes the exchange sensitive data from a security perspective.

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