Using XDS and FHIR to Support Mobile Access to EHR Information Through Personal Health Apps

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***Abstract*—The widespread usage of electronic health record (EHR) systems and the prevalence of personal health apps has led to the digitization of huge quantities of health and medical data. However, the lack of plug and play interoperability between them is a major bottleneck, significantly restricting their exploitation potential. This paper presents a novel infrastructure developed for enabling the seamless integration between such systems, focusing on the use of state-of-the-art, widely accepted, interfaces. The infrastructure effectively supports end-user needs for integrated care, bringing linked EHR information from multiple providers at the point of care by means of personal health apps. Integration is provided through cross-enterprise document sharing (XDS) and fast healthcare interoperability resources (FHIR) services. The described infrastructure facilitates interoperability by enabling citizens to use a personal health app of their choosing for accessing own medical record information stored at multiple sites, by combining the benefits and potential of both XDS and FHIR.**

Keywords—FHIR, Interoperability, Personal Health Apps, Hospital Information Systems, Electronic Health Record, XDS

I. Introduction

As more and more health data are being collected and processed in both healthcare organizations' information systems and personal health apps, there is now, more than ever apparent the need for their integration. The secondary usage of these data has the potential to boost research collaboration and healthcare delivery, significantly, eventually improving the quality of life.

To this direction, several data models have been developed in order to provide standardized interfaces for the exchange of EHR data. XDS is an interoperability profile that facilitates the registration, distribution and access across health enterprises of patient EHRs [1]. It focuses on providing a standards-based specification for managing the sharing of documents between any healthcare enterprise, ranging from a private physician office to a clinic to an acute care in-patient facility and personal health record systems. Systems involved in this profile are enterprise-wide information systems that manage a patient's EHR, such as a Hospital Information System (HIS).

FHIR [2] on the other hand, is one of the latest, cutting-edge interoperability standards for electronic exchange of healthcare information. It combines the best features of Health Level Seven (HL7) v2, HL7 v3 and clinical document architecture (CDA) product lines, leveraging the latest web standards and focusing on implementability. However, although prominent, FHIR has not yet transitioned to the implementations available worldwide and to legacy standardized interfaces that dominate existing implementations. As such, the need for integrating EHRs originating from primary care or any HIS, e.g. by means of XDS, and personal health applications is evident.

To this direction, this paper presents an infrastructure developed exactly for enabling the integration of both legacy, XDS and FHIR compatible EHR systems with personal health applications enabling citizens to have a holistic view over their health data. More specifically, it presents a whole infrastructure consisting of the following components:

A. **PHR-C:** A personal health app [3], enabling citizens to manage their own health record in an innovative way;

B. **ICS-M**: A set of nursing and medical applications that any HIS can have incorporated. ICS-M is already established in more than 20 hospitals in Greece [4] supporting a multitude of medical specialties, such as those for pathology, cardiology, pediatrics, orthopedics, etc.; and

C. **Integration Server**: The integration server responds to XDS and FHIR compatible service calls and is able to communicate with either FHIR compatible or legacy EHR systems, enabling data exchange, facilitating this way interoperability.

Although there are already available FHIR approaches, and attempts to bridge the gap between CDA and FHIR [5], to the best of the authors' knowledge the developed infrastructure is currently the only one being able to enable interoperability between XDS compatible legacy EHRs and FHIR effectively enabling access to the medical health record for the individuals.

2372-9198/19/$31.00 ©2019 IEEE
DOI 10.1109/CBMS.2019.00058

II. Related Work

The need for open and interoperable personal health apps [6][7] and EHRs has been evident during the last years. However, most recent EHR and personal health record (PHR) systems are institution-specific (limited to a certain organization) and the issues of interoperability and data protection have not been examined in detail [8]. Traditionally, XDS based solutions are used for enabling data exchange between EHRs [9][10]. Besides XDS solutions, several FHIR-approaches have been proposed already for exposing patient records to the individuals such as Apple [11], where a HIS and the user's application is connected using FHIR, whereas users can access their available medical data from multiple providers. Another recent attempt to use FHIR on EHR data [12] uses natural language processing (NLP) tools in order to recognize clinical elements combining them with structured elements to build a complete FHIR resource. Another interesting approach is mHealth [13], a mobile health app that allows exchanging directly clinical and medical data with health care services through FHIR. Finally, the authors of [14] propose the development of an integrated patient generated data collection platform and an application, embedded in the EHR, using the FHIR and SMART technologies. The purpose of this implementation is to improve the data collection of heart failure patients (data collected from patients) and the distribution of these data to therapists. Although the aforementioned FHIR approaches pave the way for enabling access to patient records through user devices, still most of the medical information in hospitals is only accessible through Integrating the Healthcare Enterprise (IHE) compliant, legacy interfaces. As such, a solution being able to bridge FHIR and IHE interfaces is a key requirement for enabling the effective secondary usage of personal health data. The proposed approach tries to fill that gap by implementing an integration server, responding to both XDS and FHIR compatible service calls, enabling direct exchange of information among EHR systems and personal health apps.

III. Architectural Solution

In the presented solution, communication and data exchange between the different components of the architecture is achieved by using RESTful services. In addition, the different types of clinical data, available by the hospitals, are transformed into the resources provided by the specification, including those clinical data that are of interest to users of personal health apps. In this work the focus is on patient clinical documents stored in EHRs located in hospitals (i.e. laboratory results, discharge summaries, etc.). The goal of the proposed architecture is to provide to the citizen the possibility to access his updated medical data online through a personal health app (PHR-C). Since citizen's medical data can be found in many hospitals there should be a repository where all these data will be collected and become available for the PHR-C. Also, since HIS and PHR-C can be from different vendors, the infrastructure components and the transactions should adhere to IHE specifications that in nowadays are supported by the majority of the hospital systems available in the market. The actors involved in the procedure of exchanging clinical data between the HIS and the PHR-C are the Health Professional that updates the patient's medical data in the HIS and the citizen/ user of PHR-C (Patient). Figure 1 presents the high-level architecture of the designed solution showing the

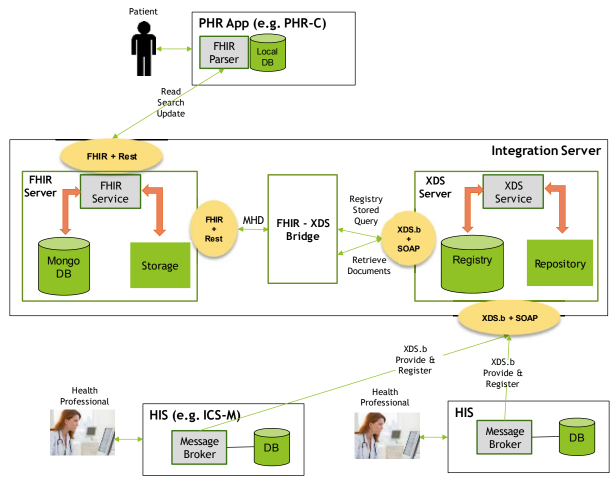

Figure 1. High-level architecture.

interactions between the PHR app (PHR-C), the Integration Server, and two hospital information systems.

A. PHR-C

1) Presentation of the system

PHR-C [3] is a state of the art personal health app enabling individuals to store and manage their health data. PHR-C includes many apps focusing on problems/ diagnoses, treatments, procedures, laboratory results, allergies, immunizations, demographics, vital signs and measurements. Those data elements are able to capture individual health information, similar to the structure available in any HIS. In addition, there are apps for enhancing the communication between patients and doctors (appointments, reminders, offline messaging), whereas additional tools for monitoring the quality of life and the psycho-emotional status of the individual are also available. Some screenshots of the aforementioned system are shown in Figure 2. In addition, the PHR-C enables access to the clinical data the hospitals have shared with a FHIR Server. As such, a user can retrieve his/ her data stored into the FHIR Server by submitting a read/ search request using the corresponding FHIR REST API calls. A FHIR parser module gets the response in FHIR format, parses it and stores into the local PHR database for future access.

2) Extending PHR-C with FHIR/ SMART

FHIR is an open standard, published by HL7 in 2014, with the goal of defining an agreed-upon specification of data format and an RESTful API that will allow service providers to develop applications and systems that operate in the modern healthcare ecosystem. FHIR defines a set of "Resources" that represent granular clinical concepts. The resources can be managed in isolation, or aggregated into complex documents.

In this work, the FHIR specification is integrated to allow for the interoperable operation and communication of PHR-C with other healthcare systems build upon FHIR. Initially, remapping was performed to the underlying modules and healthcare data that PHR-C handles to FHIR resources. For example, the

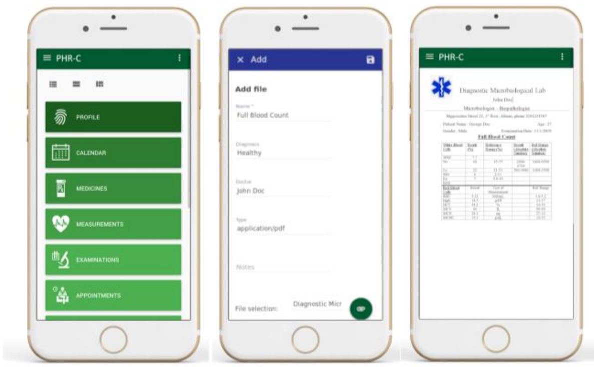

Figure 2. Some screenshots of the PHR-C health app.

allergies module, which handles the health information of patients' allergy intolerances, is associated to the *AllergyIntolerance* resource defined in FHIR. This allows a patient using PHR-C to view allergy reports aggregated from external healthcare systems implementing the FHIR specification, thus offering a global view of his/her health operation over possibly multiple health apps. Another example is the *procedure module* whose data have been mapped to the *Procedure* FHIR resource.

SMART on FHIR [15] on the other hand, aims to provide healthcare providers with a specification that allows for the development of portable and reusable applications that run on the healthcare ecosystem that use the well-defined and known web-based technologies present in the FHIR specification. The SMART on FHIR platform was integrated with PHR-C. This integration allows the utilization of the extensive library of applications released in the App Gallery of the SMART platform and as such it further increases usability of the presented platform. This is due to the fact that through SMART enabled apps, patients are given multiple new ways, already developed by the community, to view, access and transfer their health data. Besides patients, clinicians are able as well to access, edit and monitor their patients' data.

B. *ICS-M*

This is the provider of the patient clinical data shared with the patient through PHR-C. When there is an update on the patient clinical data that are relevant to the patient, the HIS registers the clinical document to the XDS Server. Each software module can operate in one or more hospital departments in collaboration with one or more other software modules and be fully operational. All applications can exchange information, so that all records are stored uniformly and reviewed by all users with permission rights.

C. *Integration Server*

Integration server is the interoperability infrastructure that enables the sharing of clinical data between healthcare applications (any HIS and personal health record systems) that may use different representation for their clinical documents (CDA or FHIR). Integration server handles the communication between the clinical systems, the storage of the clinical data and all the transformations needed between the different standards used for the clinical documents structure.

1) *XDS-Server.*

XDS [16] focuses on providing a standards based specification for managing the sharing of documents between any healthcare enterprise, ranging from a private physician office to a clinic to an acute care inpatient facility and personal health record systems. This is managed through federated document repositories and a document registry to create a longitudinal record of information about a patient within a given clinical affinity domain. As depicted in Figure 3, these are distinct entities with separate responsibilities:

- A Document Repository is responsible for storing documents in a transparent, secure, reliable and persistent manner and responding to document retrieval requests.
- A Document Registry is responsible for storing information about those documents so that the documents of interest for the care of a patient may be easily found, selected and retrieved irrespective of the repository where they are actually stored.
- Documents are provided by one or more Document Sources.
- They are then accessed by one or more Document Consumers.

In the proposed architecture any HIS can act as the document source that register and store their clinical documents in the XDS Registry/ Repository. FHIR Server has the role of document consumer that requests document from XDS Repository (upon request that comes from PHR application), makes the required mappings in order to transform clinical documents retrieved from XDS into FHIR documents and sends them to PHR.

2) *FHIR-Server.*

This component is responsible for storing all medical data and documents of the patient. Any HIS can be the provider of these clinical data. The FHIR server provides a RESTful API who define a set of common interactions (read, update, search, etc.) performed on a repository of typed resources. More specifically, the FHIR server supports searching and reading operations on the following resources:

- Patient resource in order to provide demographics to the client;
- Document Reference resource to provide access to general patient documents in the form of PDFs etc.;
- Clinical resources that represent lab results, discharge summaries and clinical guidelines.

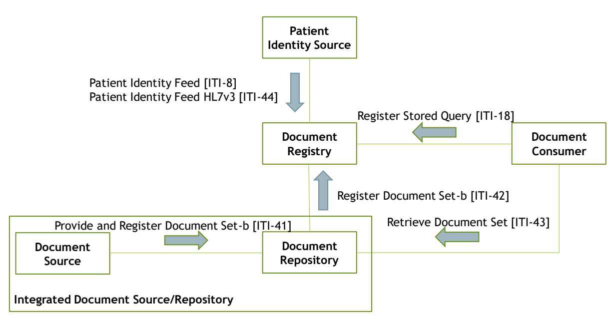

Figure 3. XDS roles and transactions.

The FHIR server also provides update functionalities to allow the patient to upload their own documents, medication statements, observations (e.g. from patient monitoring devices). As such, the FHIR Server provides:

- A complete *RESTful server implementation* for integration with external systems (i.e. PHR and HIS) on the operations mentioned above, which is compliant with the FHIR RESTful API specifications;
- A *FHIR service* that implements these service operations (read, search, update) as described in the specifications for a selected set of resources that are relevant to PHR-C;
- A *database* where resources, indexes and logging information are stored.
- An *XDS consumer module (FHIR to XDS bridge)* that will be described in the next subsection.

3) *FHIR to XDS Bridge.*

At their core, FHIR and XDS use different paradigms and methodologies in their specifications. While FHIR uses widely implemented and used RESTful APIs and methodologies to allow rapid implementation of under-constrained web services that run in resource-limited devices, the XDS profile is based on the SOAP messaging protocol to provide a more formally defined and secure framework for reliable and atomic transactions over the internet.

To that end, due to the wide adoption of both specifications in the healthcare industry, it was considered appropriate that an implementation of a FHIR-to-XDS message translating system would greatly increase the usability of the PHR-C platform by allowing the retrieval of patient documents stored in a XDS repository. The implemented FHIR to XDS bridge retrieves documents related to the patient request, maps the retrieved documents into FHIR resources and stores retrieved clinical data into FHIR Server in order to become available for the PHR requests to the FHIR Server.

More specifically, the FHIR-to-XDS' bridge that manages the FHIR-to-XDS message translation is implemented in a way compatible with any FHIR server. IHE Mobile access to Health Documents (MHD) profile [17] that defines one standardized interface to health documents for usage by mobile devices in order to access an XDS Repository, is used to implement FHIR-to-XDS bridge. The translator system acts as an XDS Document Consumer and is responsible for mapping the attributes of FHIR request (e.g. the patient's ID to XDS-based SOAP elements) and then to send a transaction message to the XDS Document Registry to query for the requested patient's documents. As soon as it receives the response from the registry, containing the location of all documents for the specified patient, it queries the repositories listed in the bundle to retrieve the corresponding documents. Finally, after receiving the documents, the translator service converts the retrieved documents to a "*DocumentManifest*" FHIR resource and sends it back to the FHIR server that requested it.

IV. CONCLUSIONS

This paper describes an infrastructure facilitating interoperability by enabling citizens to use a personal health app of their choosing for accessing own medical record information stored at multiple sites. Although this work focuses on the technical and technological aspects, it is evident that further work is needed to address practical implementation issues, as well as regulatory ones.

ACKNOWLEDGMENT

Work presented in the paper is part of the KRIPIS project "Novel technologies to monitor, support and improve the quality of life of patients and other vulnerable user groups (Quality of Life)" funded in the context of the National Strategic Reference Framework (NSRF) 2014-2020, European Regional Development Fund.

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