Using FHIR to develop a healthcare mobile application

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Abstract— **Fast Healthcare Interoperability Resources (FHIR) is considered to be an emerging Health Level 7 (HL7) standard that takes advantage of the positive elements of its ancestors HL7 v2 and HL7 v3. Moreover, FHIR is based on the REST architectural style, thus being suitable for lightweight devices. This paper presents the AidIT mobile application aiming at the effective management of patients' electronic personal health records via an easy to use interface which can be accessed by multiple actors, namely the patient, the doctor and the pharmacist. We discuss the implementation benefits of using FHIR in order to integrate the mobile client and the application's server side and we also provide insights into the access control mechanisms that should govern such applications.**

Keywords: Healthcare informatics; FHIR; REST; mobile application; access control;

I. INTRODUCTION

Information exchange in healthcare is a key factor towards the fruitful execution of medical workflows. However, the variety of involved actors, as well as the diversity of clinical data, turn the healthcare information exchanging process into a challenging integration issue, which is still not completely resolved despite the recent evolution in the domain of information systems. This lack of information can lead to inefficient medical treatment and can raise healthcare costs which pose a considerable burden to national economies throughout the world. As shown in [1], achieving interoperability across the healthcare information systems can be significantly cost beneficial; in the USA, for example, the benefit has been estimated at USD$77.8B.

There is still no unique technical standard covering all aspects of health data communication. Nevertheless, the Health Level 7 (HL7) organization has released a series of well adopted standards which are the most widely used by the current healthcare systems. At the same time, several organizations, most notably the Continua Alliance and the Integrating the Healthcare Enterprise (IHE), have defined guidelines that target the end-to-end integration of healthcare components, from the medical devices to the information management systems.

Discussing the HL7 standards, it is worth mentioning that HL7 Version 2, initially developed in 1989, is the most widely used healthcare interoperability standard in the world. It is used in over 90% of USA's hospitals and is supported to a great extent by the healthcare industry and community. The HL7 v2 messaging protocol is string and delimiters based. Even though it is flexible and able to provide solutions to numerous real life requirements, its legacy technology and specifications are not the most suitable choice concerning the goal of healthcare systems semantic interoperability. With respect to the HL7 v2's shortcomings, HL7 v3 was first released in 2005. HL7 v3 is based on a Reference Information Model (RIM) attempting to model all transactions in the healthcare domain as: "entities" that "participate" in "acts" under specified "roles". Despite using XML technologies and Object Oriented approach, HL7 v3 has not managed to be adopted by the industry, due to high complexity, directly associated with the highly complex nature of healthcare itself which is extremely difficult to be modelled entirely.

Having the HL7 v2 still dominant and recognizing the difficulties of the HL7 v3 wide adoption, there is a strong community interest in finding a new standard able to provide interoperability and integration with other state of the art technologies. What is now considered to be the most promising candidate is the emerging HL7 standard, called Fast Healthcare Interoperability Resources (FHIR) [2]. FHIR aims to follow the Representational State Transfer (REST) architectural style as presented by Fielding [3]. Thus, FHIR's target is to represent all participating entities or procedures in healthcare as resources [4]; indicative recourses include: *Patient, Medication, Practitioner, Device, Observation,* while a complete and up to date list of them can be found online at the official documentation site of FHIR [5]. Moreover, with respect to the RESTful architecture, applications or systems developed using the FHIR standard are based on RESTful interfaces [6], which are identified by the following features: i) the integration is achieved by using the well-known HTTP methods; ii) no session information is kept on the server side (stateless system); iii) each resource is mapped to a directory-structure URI; and iv) when transferring a resource representation, the data format is either XML or JSON based.

978-1-63190-014-3 © 2014 ICST
DOI 10.4108/icst.mobihealth.2014.257232

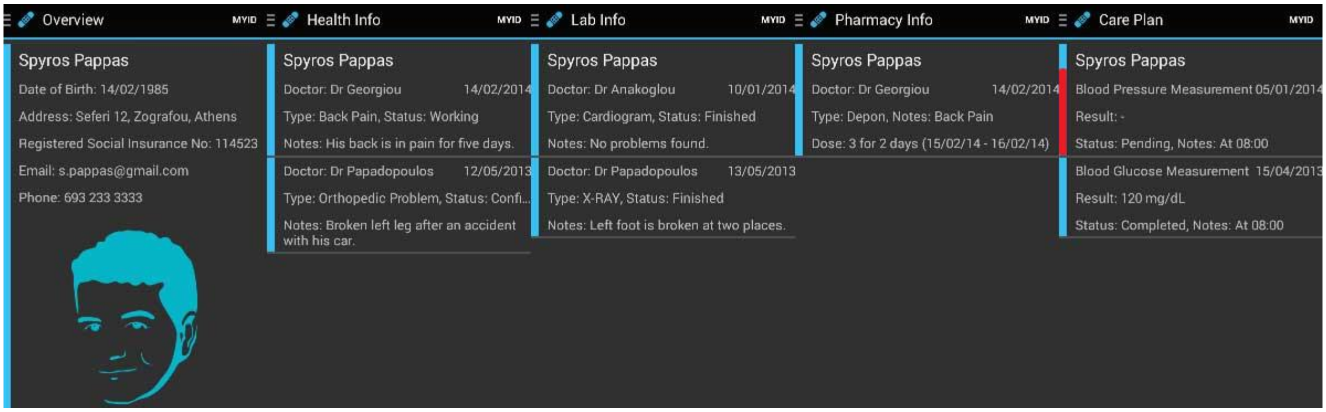

Figure 1 Screenshot of the personal health folder tabs

RESTful interfaces are more lightweight by design comparing to SOAP technologies [7] and that is a further reason to adopt them in medical sensors and mobile healthcare applications where processing capabilities are limited. Admittedly, mobile healthcare applications are attracting much interest recently, following the evolution of smartphones, the mobile data connectivity progress and the added value that they can offer [8], [9]. It is expected that such applications can open new horizons in the domain and support the vision of transforming healthcare system into a patient-centered system based on prevention, multi-level support and ubiquitous monitoring.

This paper provides insights into the usage of FHIR in developing a mobile healthcare application. We examine how an Android device can take advantage of the openness and simplicity of FHIR APIs, while in parallel we focus on all aspects of the application related to the personal privacy of the end users in combination with the access control mechanisms.

II. The AidIT Mobile Application

The AidIT mobile application aims to enhance the interaction between health professionals and patients by providing them with an interactive tool for a secure and efficient health information exchange. The application leverages the interoperable resources of the emerging healthcare standard HL7 FHIR in order to support the connectivity between healthcare providers as well as patients by making their full medical history available both at the point of care and at home. This enables patients to review and monitor their health, but also empowers health professionals to provide more personalized services, while reducing medical errors.

The AidIT mobile application aims at enhancing everyday life health service provision, e.g., a visit to a doctor or going to the pharmacy in order to purchase the prescribed drugs. It enables the sharing of patients' health history with health professionals and allows the definition and storage of electronic diagnostic reports, medication prescriptions and care plans. Despite the fact that the above interactions capture only a small subset of the supported interactions between entities in the healthcare environment, the application could be extended and take advantage of the HL7 FHIR standard resources for clinical, administrative and infrastructure–related interactions between organisations, e.g., hospitals and insurance companies.

To achieve the above, we assume that patients, health practitioners and organisations register to the National Health Organisation (NHO), receiving a unique identifier. All the parties involved view, process and extend patients' health folder by producing and consuming FHIR resources which are stored in the central NHO server, and are made available through the HL7 FHIR RESTful interface that it exposes.

A. Personal Health Folder

The personal health folder is the core entity around which the application evolves, as it organizes patient health data in the following 5 tabs (see Figure 1), through which it is possible to present, create, process and delete the relevant FHIR resources:

1) *Personal Info (Overview):* Presents basic information of the patient, e.g. address, date of birth, photograph as well as information regarding his/her insurance profile, e.g., his/her unique insurance identifier.

2) *General Health Info:* Presents patient's health history, that is, past injuries, chronic conditions, allergies and health-related encounters.

3) *Diagnostic Orders and Lab Results (Lab Info):* Lists past examinations and the relevant diagnoses of patient's health conditions along with the ordered lab tests and their results.

4) *Medication (Pharmacy Info):* Lists active and inactive medication prescriptions as well as the schedule, timing and quantity needed for each drug.

5) *Care Plan:* Presents the care plan designed by patient's doctors as a list of actions to be carried out by the patient. Planned actions that are still pending are shown in the UI with a different colour in order to be clearly noticeable by the users. Such an action is also present in the example screenshot of Figure 1, marked in red colour.

TABLE I. PERSONAL HEALTH FOLDER ACCESS CONTROL POLICIES

Role	Personal Info				General Health Info				Diagnostic Orders and Lab Results				Medication				Care Plan			
	C	***R***	***U***	***D***	***C***	***R***	***U***	***D***	***C***	***R***	***U***	***D***	***C***	***R***	***U***	***D***	***C***	***R***	***U***	***D***
Patient		X			X	X				X				X	X			X	X	
Doctor		X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pharmacist		X				X				X				X	X					

Users are allowed to interact with each tab in a specific manner (described in detail in the next section). For example, only a doctor may create a new diagnosis, write a medication prescription or design a care plan for a patient. These are communicated to the server using FHIR resources which may, then, be consumed by other users.

Although the information contained in each FHIR resource is directly presented in the relevant tab, a special case occurs on the consumption of *CarePlans* and *MedicationPrescriptions*. These are used to dynamically populate the Care Plan tab with daily actions that should be performed by the patient. For example, a *CarePlan* regarding weight loss goals will generate a daily calorie intake count, whereas active *MedicationPrescriptions* will generate a daily schedule for relevant medication intake and will notify the patient on the appropriate time.

B. Access Control

Given the sensitivity of the data that are distributed between the entities involved, explicit authorization for viewing and processing patients' health folder is necessary. Towards that direction, we distinguish two individual use cases that require appropriate handling, depending on the duration of patients' authorization validity.

On short term access scenarios, e.g., a visit to a pharmacist, we employ QR codes to share with the practitioner, patients' unique identifier and special access code. To do this, patients log in the AidIT application and dynamically generate a QR code, which consists of the patients' unique identifier and a session-based access code by clicking the appropriate button. Practitioners scan the QR code and receive patient's info and photo in order to authenticate patients' identity. Moreover, this access code is used in every call to the server and proves that the practitioner has been authorized to view and process patients health data.

In order to support long term access scenarios, e.g., a visit to a hospital, patients manage an access control list through the application. The list includes both organisations, e.g., a hospital, and individuals, e.g., next of kin or family doctor. For this, patients scan the QR code representing organisations or the practitioner's unique identifier (which could be printed for ease of use) and view their information before adding them to the list.

In addition to the above, we apply role-based access control to the interactions of health practitioners with patients' health folder. The policies presented in Table I, on the one hand, affect the user interface of the application by showing only the relevant buttons and tabs according to the logged in user, and, on the other hand, govern the execution of REST calls concerning the FHIR resources relevant to each tab.

Lastly, our system also takes into account break glass scenarios, where the patient isn't able to authorize the actions needed to be performed on their data. In this situation, the system issues a short term access code for a patient's health folder, which can be used by a practitioner to gain access to the relevant data. While the access code is active, the system logs each action performed with it and, on misuse, the practitioner will be hold accountable.

C. Implementation

The HL7 FHIR standardization initiative builds on the work of the previous HL7 standards and focuses on enabling its fast adoption by healthcare providers, allowing easy implementation and low integration costs. The standard defines lightweight resources that function as an interoperability base between communicating healthcare systems, while supporting resource extensibility and use of customized vocabularies and ontologies. Furthermore, the standard defines a REST interface, which consists of CRUD methods, offering a simple way to communicate FHIR resources.

The AidIT mobile application builds on the client-server model and uses the RESTful approach for exchanging FHIR resources. The mobile application is developed on Android 4.3 and was tested on both smartphones and tablets, whereas the server is a standard JavaEE application. For generating and parsing FHIR resources, we used the reference software library (XML/JSON messages) both on server and the client.

We have found that FHIR standard is especially friendly for developing mobile healthcare applications. On the client side, each CRUD operation of the REST interface can be easily bound to specific UI components, leading to AJAX calls running on background Android *Activities*. This is essential in mobile environments, where restrictions on both bandwidth and processing power apply. Firstly, it preserves the responsiveness of the application while fetching the relevant resources. Secondly, it supports on demand resource consumption and aggregation. On the server side, the REST interface facilitates the easy enforcement of the access control policies, by developing an HTTP filter handling all incoming REST calls. Moreover, FHIR resources and their relations are easily mapped to a relational database schema enabling their storage and retrieval.

III. Conclusion and Future Work

In this paper we presented a mobile application that leverages the emerging e-Health standard HL7 FHIR, which enables easy implementation and integration of healthcare systems, using technologies that are especially suitable for adoption in mobile environments. The AidIT mobile application, based on the interoperable resources of the FHIR standard, facilitates the interaction between healthcare professionals and patients and offers the means for the continuous and ubiquitous monitoring of their health. This vision is further empowered due to the popularity that wearable devices have gained since their integration with mobile phones.

The next step of this work is to integrate self-monitoring devices to the AidIT mobile application and enable efficient sharing of health measurement streams via FHIR resources. Furthermore, we aim to exploit ontology based resource descriptions in order to offer semantic search capabilities to the users. Moreover, we will focus on the security issues that are raised in healthcare systems and extend the application's Role-Based access control model to an Attribute-Based one, in order to enable fine-grained access control on the personal health folder. In this course, we aim to introduce the use of ontologies for the attributes. Such an approach is expected to expand even more the pervasiveness and the flexibility of the system, as each involved entity would be able to use its own vocabulary for expressing its attributes. In addition to the above, we have identified that an essential step for preserving the confidentiality of personal health data is to enable their encryption using state of the art techniques allowing for encryption both for storing and communicating the information. Therefore, we aim to adopt the use of the Ciphertext-Policy Attribute-Based Encryption (CP-ABE) for encrypting the personal health folder and secure it even on a possible breach of the mobile device or the server.

Acknowledgement

This work presented here has been performed in the context of the SPAGOS (Secure & Privacy-Aware eGovernment Services) project, funded by the EU and the Greek General Secretariat for Research and Technology, under the Action Cooperation II (2011) framework. The authors wish to express their gratitude to the other members of the SPAGOS Consortium for their support.

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