Designing a HL7 Compatible Personal Health Record for Mobile Devices

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***Abstract*—Personal health records (PHRs) support health self-management for any individual. Currently, smart phones and tablets are widespread among the population and can collect and visualize health data, and get home care plan instructions. In this paper we describe an Android based PHR system that guarantees technological and structural interoperability using technological and communicational standards, respectively.**

Grounded on the standard-based architecture by the Health Level Seven (HL7) organization, we describe a prototype implementing a HL7 compatible personal health record system. We considered some functionalities that may support the discovery of potential risk of cardiovascular diseases, the leading cause of death in industrialized countries according to the WHO (World Health Organization). This work aims at helping people raising their lives quality by participating in vital parameters' examinations. Individuals install a mobile Health app (called mHealth) on their devices and can directly exchange clinical and medical data with health care services through HL7 Fast Healthcare Interoperability Resources (FHIR).

FHIR compliant JSON (Java Script Object Notation) encrypted files implement the integration architecture. Direct and standard information exchange based on a regular home care plan between a PHR system used by patients and a healthcare information system used by physicians can boost the active contribution of patients and caregivers to a safe homecare management. The proposed solution may provide faster and better care, reduce economic costs for National Health Services (NHS), and increase quality of individual's life. Moreover, by delivering healthcare services through a mobile application we can also overcome temporal and geographical barriers.

Keywords—Personal Health record (PHR); Health Level Seven (HL7); Personal Health Record System (PHR-S); Fast Healthcare Interoperability Resources (FHIR); Regular Home Care Plan (RHCP).

I. Introduction

Regardless of any circumstance that might occur, humankind always pays attention to health conditions, and tries to prevent catching diseases. The collaboration of individuals and, in particular, of patients during their healthcare cycles [1, 2], is an important issue. Indeed, patients are key members of the healthcare team. Over the past years, many activities were carried out to highlight the patients' roles and to provide them with high quality fast care. Self-management on daily tasks and being in contact with healthcare providers for the most common chronic diseases such as cancer, diabetes, and heart disease is fundamental. Indeed, the delivery of good care and assistance services claims new home/individual services [3]. Using Personal Health Record Systems (PHR-S) the patients and, in general, any individual, can manage their health records themselves. PHR systems may work stand-alone, without sharing health data with healthcare providers (HCPs), or be integrated with HCP systems so that physicians can review the input data, and possible future diseases might be foreseen.

The PHR workgroup at Health Level 7 (HL7) organization clearly distinguishes between a PHR and a PHR System (PHR-S) [4]: "The PHR is the underlying record (e.g., data, information, sounds, graphs, pictures, or videos) that the software functionality of a PHR-S maintains". Use of PHR systems can increase efficiency and quality, and decrease the cost of healthcare processes. Given the widespread adoption of mobile devices, a possible solution is to have a mobile personal health record on such devices.

The paper is structured as follows: Section 2 provides the reader with a brief introduction to HL7; Section 3 describes the design choices we adopted; Section 4 describes the results we achieved, and the prototype system we developed; Section 5 sketches out some conclusions and highlights future research directions.

II. Overview of HL7

HL7 provides healthcare organizations with specifications for making their systems interoperable.Version2.x is currently the most used standard throughout the world. The newest HL7 standard FHIR (Fast Healthcare Interoperability Resources, [4]) is a next generation standard framework, created by HL7, leveraging the latest web standards and applying a tight focus on implementability: in particular, "Resources" are a set of modular components defining the structure of concepts such as patients, devices, medications, organizations, encounters, observations, and many others, to guarantee interoperability. FHIR extensions are discoverable by resolving the URI that defines the extension, to ensure that no interference will occur

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between independent systems. However, HL7 V2 provides an extensibility mechanism through the use of "Z-segments". The meaning of these extensions is opaque without prior manual explanation by the sender.

Another biggest challenge with HL7 V2 interoperability is the variation of implementation, even when identical scenarios are being handled in similar business environments. Therefore, using HL7 V2 requires more efforts than using FHIR to apply onto independent systems for achieving interoperability. For each single resource, FHIR needs human readable content to be supplied.

In addition to these standard versions, Clinical Document Architecture (CDA) is another document markup standard that specifies the structure and semantics of "clinical documents" [5]. However it solely focuses on clinical documents. Using CDA standards, it is not obvious how to represent concepts like blood pressure out of the box. CDA has its own XML Syntax for narrative content which is loosely based on HTML. On the contrary, using FHIR developers are able to use constrained set of XHTML [4].

From the implementation point of view, HL7 version 2.x is more workflow oriented [6] than being real time. For better illustration, imagine two independent medical systems: a Hospital Information System (HIS) and a Laboratory Information System (LIS). To translate data from the HIS to the LIS an import module needs to be implemented. An export module is also needed to translate data backward: prior knowledge of both systems is needed to design these modules. A third medical system such as a health mobile application can be involved in this imaginary environment in case its proprietary import/export module is correctly implemented. Instead, FHIR provides a more comprehensive solution which does not need this much effort to build our imaginary environment. With respect to an Application Program Interface (API), FHIR API makes any arbitrary system to be able to interact with another medical system that has been already equipped with FHIR API. The FHIR API can be considered as a line between independent systems whose data can be translated back and forth in real time over it.

III. DESIGN CHOICES

We aim at implementing a prototype of a PHR System based on HL7 FHIR Client APIs to communicate with any other medical system equipped by an HL7 FHIR Server API (e.g., Electronic Health Records, EHRs). As a proof of concept we develop an application implementing a Regular Home Care Plan (RHCP), which is a special process defined by a clinic to increase the quality of individual lives and help them controlling their vital signs regularly to prevent possible diseases. Typically, a care plan may include drug prescription and administration time, physical exercises, food requirements, and vital parameter measurements. Individuals collaborate with physicians by confirming the required actions (drug administration, physical exercises, food requirements), measuring the requested vital parameters, and finally by sharing the bundle of observations at the end of the prescribed cycle.

The whole process is described in the UML (Unified Modeling Language, UML TM) model of Figure 1 we designed according to [7]. The diagram defines roles, steps of the process, information exchange between client and server. The client is a PHR-S mobile app and the server a clinic web portal application. The process starts with the registration of a person/patient to the system of the clinic to join the RHCP program; he/she is assigned to a physician, who defines the care plan and assigns the RHCP prescription through the clinic web portal: in our prototype the plan includes blood pressure, blood glucose, and weight fluctuation controls. The RHCP prescription is sent to the PHR-s App, and the patient measures the requested vital parameters. At the end of the prescribed cycle, physicians are notified and can access the patient's data collected at home: the observed parameters are sent to the physician's system in the form of HL7 FHIR JSON bundles. In case the review result does reveal an unusual or suspicious issue, the patient is contacted and a new contribution might start, otherwise the process is ended.

Data are exchanged between the two sides through standard FHIR Resources, according to the current officially released version of FHIR 1.0.2. "Patient", "Observation", and "CarePlan" are the three FHIR resources (see http://www.hl7.org/fhir/resourcelist.html), used to implement the proposed scenario: they describe the profile of a patient, the measurements of vital parameters, and the plan proposed to the patient. In each JSON message's header, resource name and resource id show what exactly the exchanged information is. In particular, the *Patient* resource carries personal data about patients like gender, birthdate, address, contacts' details, etc. The *Observation* resources are simple name/value pair assertions with metadata to monitor progress and support diagnosis: for example, observations labeled with the LOINC (Logical Observation Identifiers Names and Codes) code 55284-4 carry blood pressure message with three components for Systolic (LOINC 8480-6), Diastolic (LOINC 8462-4), and Heart rate (LOINC 8867-4); observations labeled with the LOINC code 76629-5 involve fasting blood glucose, and the LOINC code 1521-4 identify postprandial blood glucose data, LOINC code 29463-7 the body weight [8]. The *CarePlan* resource is used to transfer the physician's prescription to the mobile PHR system. Observations and CarePlan resources refer to a specific Patient resource through his/her person identity (pID).

The implementation of the PHR system mobile App, HL7-compatible is performed in Java using Android Studio 1.5. This allows the development of FHIR API client in the PHR mobile App source code. To evaluate the feasibility of the communication tunnel, we use a public FHIR test server. The communication tunnel is graphically depicted in Figure 2. This figure depicts a communication based on HL7 FHIR standard. The clinic web portal exposes FHIR APIs; the PHR-S app can connect using the same API.

IV. RESULTS

The mobile health application (mHealth) allows individuals not only to share all the information including personal and health information, but also to save data on their side. Therefore, both stand-alone and integrated PHRs are supported using the mHealth. Moreover, individuals can receive on the mHealth all the information needed to execute the proper actions including: number of measurements per day to observe blood pressure; blood glucose; and weight. The patient logs in the App and after filling in demographics data, submits his/her observations on required vital parameters. The acquired data are sent to the web portal, whose EndURL has been set in the server configuration, through the App: patient's record gets updated, and the physician can review the observations submitted by the patient.

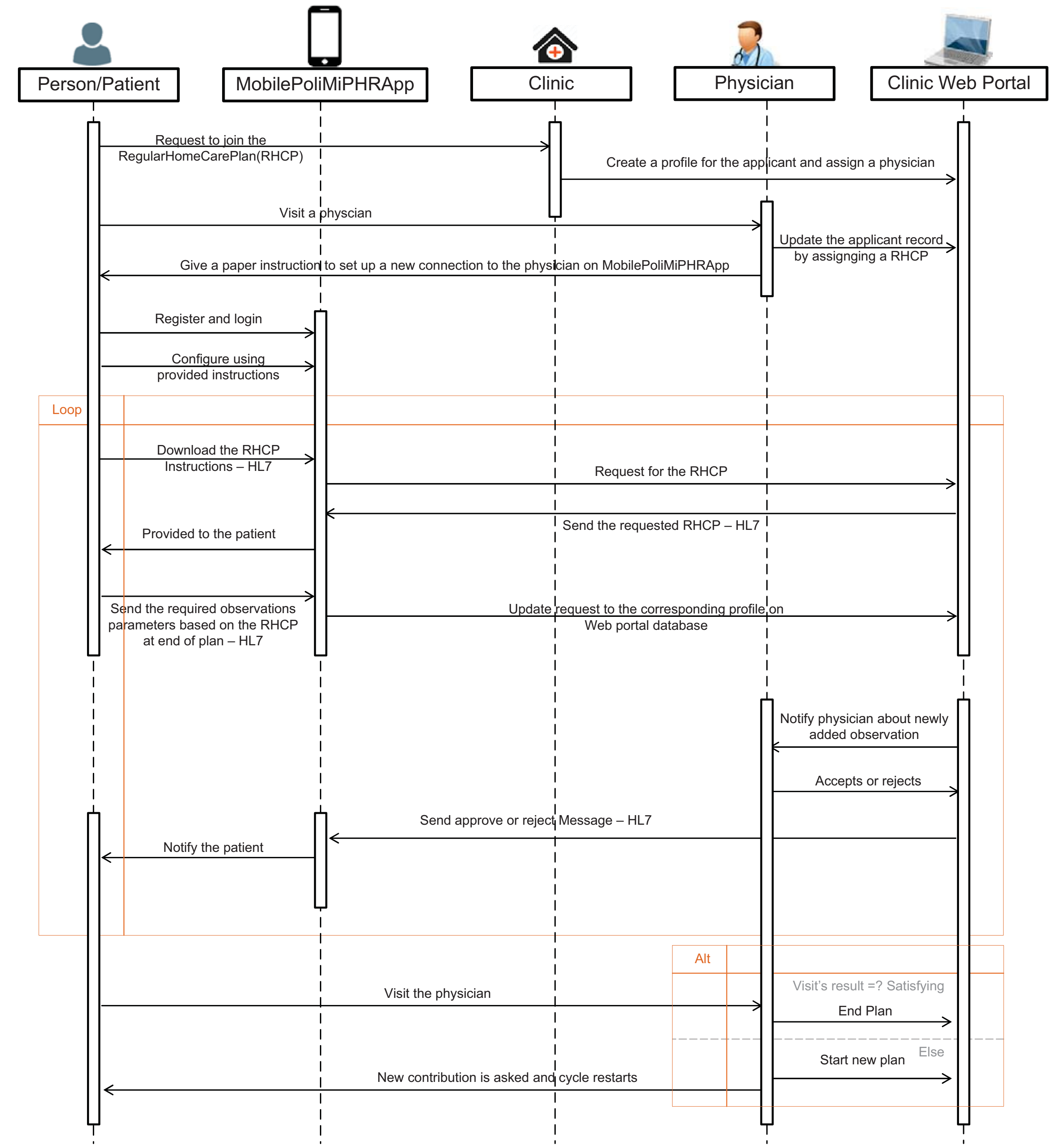

Fig. 1. The UML Sequence diagram implemented by the "RHCP (Regular Home Care Plan) process" prototype. It depicts the order according to which the involved objects may operate each other using different messages. The crucial parts of this sequential communication schema are the indications of HL7 when piece of health or administrative information is needed.

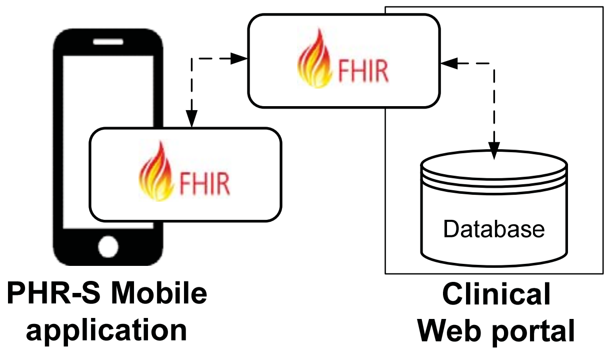

Fig. 2. Peer-to-peer data sharing through HL7 FHIR API (Health Level 7, Fast Healthcare Interoperability Resources Application Programming Interface)

The Android mobile App developed is named "PolimiPHR" (Figure 3), dedicated to any individual who cares about his/her health and of preventing from falling ill. Instead of showing up every day, individuals can easily communicate with the healthcare team while at home. This personal health record system features the following:

- "User authentication" page: providing correct credential user information, the individual can access the health App contents (Fig. 3.a);
- "Main Menu": after authentication, the user can access the main menu showing all the available functions (Fig. 3.b);
- "My personal area" page: the user can enter demographic data including: name, address, contact info, birthdate, and sex (Fig. 3.c);
- "Weight control", "blood pressure test", and "blood sugar test" pages: the user can submit their weight observations, blood pressure, and blood glucose based on the RHCP or freely and without any plan. Date and time should be reported as well, because they are necessary for the healthcare team to evaluate changes of measured parameters over time [1, 2]. Two types of blood sugar test which are supported in the app: Fasting Blood Sugar (FBS) and 2Hour Post Prandial (Fig. 3.d, 3.e, 3.f);
- "Chronogram" page: the mHealth can plot vital parameters fluctuation on a diagram, by accessing values stored along with their timestamp of measurement. The latest thirty observations of every type can be plotted (Fig. 3.g);
- "Sending PHR" page: the user can send medical and administrative data to the server which is under Healthcare Providers (HCPs) control. If the individual attended a RHCP program, he/she has to send measured values at the end of the cycle, which is automatically detected and need to be confirmed by the user. Sent data will then be reviewed by the physicians (Fig. 3.i);
- "App setting" page: the top right button is designed to access the mHealth set up menu. The user provides the EndURL with his/her identity code, so that the mobile App can interoperate with another health information system. From now on, the PHR system is called integrated/tethered PHR system (Fig. 3.h);
- "RHCP detail" page: the user can download the prescribed regular home care plan with instructions from the physician, including the list of tests, measurements and their frequencies according to the user's health condition (Fig. 3.j).

Also, the mHealth has some other functionalities, which most of the typical mobile application are equipped with, including retrieving forgotten password, backing up and restore, managing password.

On the other side, we design a web portal, to be used by the healthcare team who can access it through authentication. Individual who wants to participate in RHCP has to directly visit a physician. Before visiting a physician, a new record for the person/patient is created or, if already recorded, updated by the patient. During the visit, the physician/specialist prescribes a plan for the patient and updates the visit document by the prescription text.

Individuals would be provided with an EndURL which points to the web portal server. The healthcare team gets informed by the newly received data from the PHR App, and can review the information, update the patient's record by a suitable description. Further visits can be asked for, or the plan can end with no additional visit: the patient is notified by the mHealth.

V. CONCLUSION

In this work, we introduce a personal health record system which can communicate through the most cutting edge standard presented, namely FHIR by the HL7 organization. The application has not yet been deployed in real world: we tested the PHR App using a public FHIR test server (http://fhirtest.uhn.ca/baseDstu2). This is not a production server, so real personal health information, or any credential information, is not stored there.

The framework we propose aims at providing an interoperable application to support not only patients with cardiovascular problems, but also other people who care about their wellbeing and health. Using standards, such as HL7, DICOM (Digital Imaging and Communications in Medicine for medical images), NCPDP (National Council for Prescription Drug Programs for retail pharmacy messaging), and LOINC (Logical Observation Identifiers, Name and Codes for reporting of laboratory results), is the basis for achieving interoperability in healthcare. Reaching the standard interoperability in healthcare means fast, safe, accurate, complete, and more collaborative care pathways.

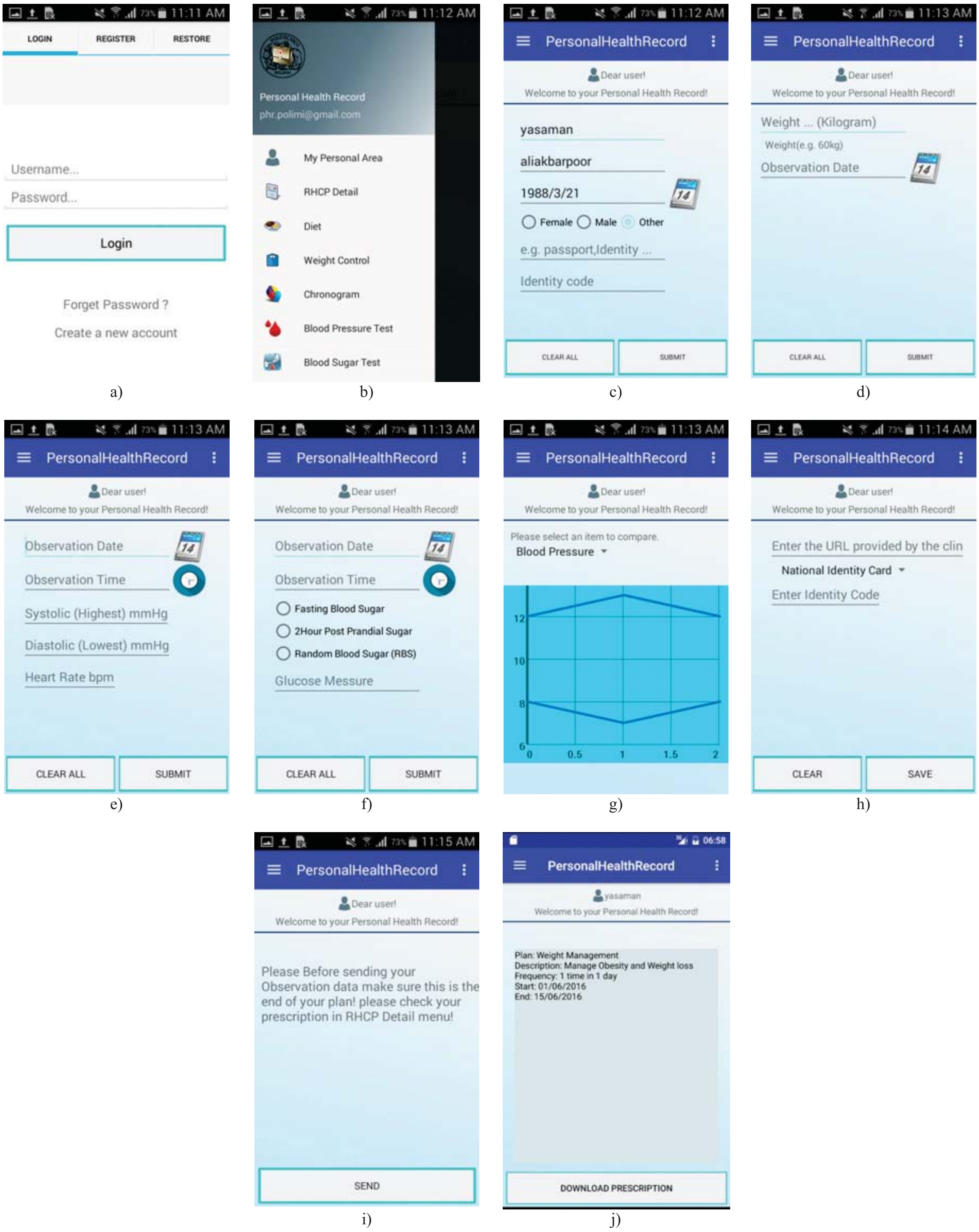

Fig. 3 PHR Functionalities: a) "user authentication" page, b) "main menu", c) "my personal area" page, d) "weight control" page, e) "blood pressure" page, f) "blood glucose" page, g) "chronogram" page, h) "app setting" menu, i) "sending PHR" page, j) "RHCP detail" page.

The novelty aspects of the prototype developed for this case study are: (1) the integration of the role of persons/patients with the prevention, even before starting the care pathway; (2) use of the latest methods for exchanging medical and administrative data in mobile App development. The mobile app can easily integrate with any type of medical repository which is equipped with FHIR APIs, without risk of fragmenting data. However, security issues still need to be taken into consideration in an accurate way. The bi-directional health information exchange between mHealth apps and EHR systems is a recent challenge from the technological point of view [9]. “With almost two billion people currently owning a Smartphone, and 50% of adults (globally) predicted to own one by 2018, mHealth provides the prospect of delivering efficient, affordable healthcare services to widespread populations both locally and globally. In particular, it has the potential to reduce socioeconomic disparity and alleviate the burden of cardiovascular disease [10]”. Literature reports many examples arguing and discussing about effectiveness and advantages of using mHealth applications to support people with cardiovascular diseases [11, 12, 13].

As the main concern of this work is developing an HL7 compatible application as a proof of concept, some aspects, especially those regarding the user interface, have not been considered in depth and developed in detail: thus some of these issues, including application’s security, require to be properly enhanced. Moreover, in order to better support people with cardiovascular diseases more options could be added. Having an healthy diet and sufficient body exercises everyday are with no doubt important factors helping to limit the onset and the effects of cardiovascular diseases: thus, connecting the application to a pedometer application to count the steps, adding a menu to compute the calories needed by the body, and adding an alert system to prevent the user from forgetting the everyday exercises are good enhancements of the current work. One next step of enhancement is the connection to blood pressure or blood glucose gadgets via Bluetooth, thus transferring detected values to monitor them by the smartphone. One more issue deals with security: as the HL7 organization announced, FHIR is not a security protocol, nor does it define any security related functionality. So it is better to specify precisely and decide how to overcome the risks that might have. Last but not least, the Clinic web portal right now is in design phase: implementing the clinic web portal in such a way that it can be interacted with the PHR-S mobile application can also benefit from the most cutting edge Hl7 standard.

A central challenge for healthcare standards is how to handle variability caused by diverse healthcare processes. Over time, more fields and optionality are added to the specification, gradually adding cost and complexity to the resulting implementations. The alternative is relying on custom extensions, but these create many implementation problems too. FHIR solves this challenge by defining a simple framework for extending and adapting the existing resources. All systems, no matter how they are developed, can easily read these extensions, and extension definitions can be retrieved using the same framework as retrieving other resources. In addition, every resource carries a human-readable text representation using html as a fallback display option for clinical safety. This is particularly important for complex clinical information where many systems take a simple textual/document based approach [4].

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