An Interoperable and Standard-Based End-to-End Remote Patient Monitoring System

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INTRODUCTION

Remote patient monitoring (RPM) is one of the main services provided by e-Health systems. RPM systems allow physicians to remotely follow-up patients in different situations and locations. Patients can take care of their health using personal health devices (PHDs) at home, and seamless share information to all their health actors, such as caregivers, physicians and family. Also, physicians can create treatments based on each patient profile using RPM systems, establishing a directly connection with the patient.

Nowadays, there is a trend from PHDs manufacturers that prefer to implement their own proprietary protocols and services, which goes against the interoperability vision, and difficult the adoption of these systems by end-users. For example, if a patient buys a thermometer from one manufacturer that only works with one RPM service, that patient is stuck with that service, and must buy all other devices from the same manufacturer.

Considering these interoperability issues, and aiming the increase adoption of RPM systems by end-users, this chapter presents a complete end-to-end RPM system based on standards. This system, namely SigHealth Platform, was designed to be flexible and scalable. Flexible means to be able to create different healthcare applications over the same platform, making them available on mobile platforms and the web. On an architecture point-of-view, SigHealth has three main subsystems: Health Data Hubs (HDH), Internet Server Cloud (ISC) and Care Program Applications (CPA). Health Data Hubs are portable devices, such as smartphones and CE devices, used to wirelessly collect data from PHDs and synchronize the data with the Internet Server Cloud. The Internet Server Cloud is a cloud of servers, available 24/7 in the Internet, responsible for storing, sharing, and managing the user health data on a Personal Health Record (PHR). A Care Program Application is the instantiation of services provided by the Internet Server Cloud for a specific healthcare domain. Examples of domains include hypertension, diabetes, and pregnancy, among others. SigHealth Platform is complaint with Continua Health Alliance Guidelines, which make possible the platform to work with different PHDs and PHR systems.

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This chapter, therefore, explores and describes the SigHealth Platform Architecture. Specifically, it describes multiplatform mobile application APIs based on HTML5 technology, which make possible to develop a single health application and deploy it on different platforms, such as Android, iOS and Linux. It also presents how HDH mobile applications are able to receive data from IEEE 11073 PHDs, as also, from legacy PHDs through the use of a transcoding mechanism available in the platform. In the ISC, it is described the approaches used to deploy health servers in the Cloud, as also, how to create different Care Program Applications over the same platform, showing what options are available for it, such as an alarm system based on thresholds and triggers for health measurements that are out of bounds.

BACKGROUND

Connected health systems make possible to collect Personal Health Information (PHI) from Personal Health Devices (PHD) and automatically export it to services in the cloud. In this scenario, some challenges are created when deploying a connected health infrastructure. Most of PHD manufacturers define and implement their own communication protocols, therefore, creating vertical solutions where their devices only communicate with their services.

Some work has been done defining mobile and connected healthcare systems. The work of Martínez (2008) proposed a u-health monitoring system based on standards. Other research works, such as Lasierra (2012), and Saranummi (2008), also proposes systems, challenges and solutions for mobile healthcare systems. Although based on standards, these works do not define reference architecture with open interfaces capable to seamlessly integrate PHDs, mobile and consumer electronic devices, considering scalability, flexibility and heterogeneity of devices and technologies.

There is an expressive effort from companies and individuals to create standards for PHDs. One of these effort groups created the IEEE 11073 set of standards declaring how those devices should talk to each other, where the main document IEEE 11073-20601 (2010) describes how each entity should behave. As also, a set of device specializations describing the characteristics of each medical device has been specified. This family of standards defines how health information is formatted independently of the transport layer. Other research group developed a set of standards, namely HL7 (2014), to exchange of clinical and hospital administrative information. This set of standards creates a common vocabulary for transfer of clinical information between different health entities, such as hospital and clinics, as described by Dolin (2006).

Based on these standards, some associations, such as Continua Health Alliance (2014), work in the definition of guidelines that promotes the standardization of interfaces. They envision a market of standard, affordable and readily connectable health sensors and services, as introduced by Carroll (2007) and Wartena (2010). Continua guidelines, defined in the document ITU-T H.810 (2014), present a reference architecture based on the definition of communication interfaces for each type of device involved in the transmission of health information. Figure 1 illustrates this reference architecture.

The main interfaces of Continua Architecture are the following:

- **PAN Interface**: It defines the transmission of health information from PHDs using Personal Area Network technologies, such Bluetooth and Bluetooth Low Energy (Bluetooth SIG, 2014). For this interface, Continua's guidelines recommend the use of ISO/IEEE 11073 standard for health information representation.