Toward an Open-Source Flexible System for Mobile Health Monitoring

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Abstract. Project SHERPAM (Sensors for HEalth Recording and Physical Activity Monitoring) aims to provide an open-source, flexible, customizable system to monitor the health condition of patients affected by chronic diseases during their day to day activities at home or out of home, while detecting and reacting to anomalies automatically. This paper presents the architecture of the flexible system that is being developed in the context of this project, and illustrates how this system could be used through a realistic use case.

Keywords: M-health · Sensors · Monitoring · Mobile

1 Introduction

Quantified-Self (QS) applications and software development kits have flourished during the last few years. With such systems data acquired by wearable sensors (e.g., smartwatches, digital armbands, heart rate monitors, etc.) can be transferred to the cloud, where they can remain indefinitely, while being accessible for authorized users.

There are several reasons why such solutions can hardly be used in the medical field. (a) Most of the sensors available for QS applications are not approved for medical use [1]. (b) Each vendor distributes a model of sensor with its own dedicated application, which is usually unable to interact with any other kind of sensor. Developing a system capable of interacting simultaneously with different kinds of sensors is therefore a challenge. (c) Most applications can only upload data to a single, predefined remote site [2]. Users must therefore inherently trust the owner of this site, assume that their data will be safe on that site, and will not be shared without their authorization. (d) Most of QS applications can only display nice curves or statistics based on the data they collect, with very little or no advanced processing (e.g., pattern recognition). The medical field shows higher expectations regarding health data collection and processing. A system involving wearable sensors should be versatile (i.e., capable of interacting with various sensors, and running various analysis algorithms), extensible (i.e., capable of accepting new types of sensors and algorithms as and when needed), safe (i.e., preventing data alteration, data loss, and the fraudulent disclosure of data), and dependable (i.e., usable anywhere and at any time).

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Some of these requirements have already been addressed in the works presented in [3], but to the best of our knowledge no open-source, flexible, customizable system has ever been designed that can meet all these requirements at the same time. Developing such a system is one of the aims of project SHERPAM[1].

2 Use Case

Project SHERPAM's prime motivation is to allow patients affected by chronic diseases to perform their day to day activities, at home or out of home, with little or no restriction. A typical example is illustrated in Fig. 1. In this example, a patient is equipped with a wearable kit *(WK)* that includes sensors and a smartphone. The smartphone serves simultaneously as a controller for the equipped sensors, as a front-line data processing unit (data can be processed directly by local algorithms in order to trigger instant notifications to the patient when an anomaly is detected), and as a bridge between the patient and the aggregation server *(AS)*. Medical staff can review and analyse the data stored in the AS. In this scenario we assume that the AS is part of a hospital's private datacenter (*DC*), but it could actually be deployed anywhere in the cloud. The AS stores the data it collects from patients, and it can additionally forward selected data feeds to specialized processing units. Resource-greedy algorithms that couldn't run directly on smartphones can thus be executed on dedicated units. If an anomaly is detected in the data received from a patient, visual and audible notifications can be addressed to that patient, and a warning is issued to medical personnel.

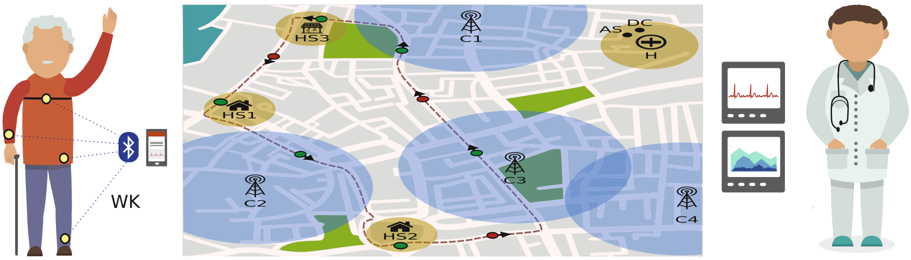

Fig. 1. Use case of the SHERPAM system

The transmission of data from the patients to the AS can rely on a combination of common wireless technologies, such as Wi-Fi and mobile data networks (i.e., 2.5G/3G/4G). Special attention is paid to tolerating networking disruptions without ever losing data. A Wi-Fi hotspot *(HS1)* is usually available at the patient's home, and this can provide a stable and continuous connection when the patient is at home. During the patient daily activities this connectivity turns out to be inconsistent and it becomes necessary to rely on another

[1] Sherpam: Sensors for HEalth Recording and Physical Activity Monitoring.

wireless connection to ensure the transmission. In an urban environment, free Wi-Fi hotspots *(HS2* and *HS3)* are often available, and mobile phone networks *(C1*, *C2* and *C3)* provide extensive coverage. However "white areas" (where no wireless connectivity is available) remain. To ensure that no data is lost when a patient moves in such areas, disruption-tolerant networking techniques have been integrated in the system. The data collected from the sensors are stored locally on the smartphone into "bundles" before being transferred to the AS when network connectivity is available. However, network operations (scanning, establishing connections, transferring data, etc.) may be power consuming and as the device used as a gateway has limited resources, special attention must be paid to the way network technologies are chosen and data are transmitted, balancing the continuity of the data transmissions with the system availability over time.

3 Architecture of the Sherpam System

The main software components of the Sherpam system are presented in Fig. 2. On the client side lies the application deployed on the wearable kit, and on the server side are several sub-systems dedicated to data aggregation, visualization, and processing.

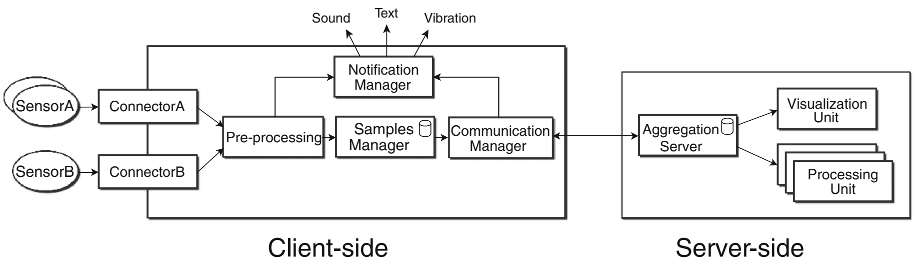

Fig. 2. General architecture of the system

On the client side, the data generated by the sensors enter the Sherpam system via dedicated connectors. A connector is a software component that can drive a specific kind of sensors, and each connector is *plugged in* the application as and when needed. Extending the application for a new type of sensor mostly comes down to implementing a new connector module. Data processing algorithms can be embedded in the pre-processing unit. Data filters and compressors can thus be used to reduce the amount of data that must be transmitted to the AS, and pattern recognition algorithms to detect anomalies and trigger notifications to the patient locally. These are processed by the notification manager, which can warn the patient through audible or visual signals. After being pre-processed, the data samples are forwarded to the sample manager. They are then assembled in bundles, encrypted, and stored locally in the smartphone until they can be sent to the AS. Communication with the AS is managed by the network manager, which is responsible for selecting the most appropriate radio technology (e.g., Wi-Fi, 2.5G, 3.75G, 4G) at any time, based on criteria such as network availability, power consumption, and transmission needs (i.e., nature and importance of the data to be transmitted).

On the server side, the AS receives bundles, and stores them in a database. Specialized subsystems can be deployed in the cloud to access this database through a dedicated API. Visualization subsystems can thus be used by medical staff to browse the database online, using a standard Web browser. Advanced pattern recognition algorithms can also be deployed on data processing subsystems, so as to process selected data feeds in real-time, and to send warnings to a patient and/or medical staff when an anomaly is observed.

4 Conclusion and Future Work

The Sherpam project aims to provide a flexible, customizable, open-source system capable of monitoring the health condition of patients affected by chronic diseases during their day to day activities. This system combines wearable sensors (for data acquisition), an Android application (for data gathering and preprocessing), and cloud-based units (for data storage and advanced analysis).

The development of the system is under way, although the main elements have already been implemented, and tested in real conditions. A one-year medical trial is planned in 2017. The system will thus be used to monitor patients with various chronic conditions (cardiopathy, arteriopathy, etc.).

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References

1. Schoenfeld, A.J., Sehgal, N.J., Auerbach, A.: The challenges of mobile health regulation. J. Am. Med. Assoc. **176**(5), 704–705 (2016)
2. Till, C.: Exercise as labour: quantified self and the transformation of exercise into labour. Societies **4**, 446–462 (2014)
3. Hende, A., Cem, E.: Wireless sensor networks for healthcare: a survey. Comput. Netw. **54**(15), 2688–2710 (2010)