An Aggregation Plateform for IoT-Based Healthcare: Illustration for Bioimpedancemetry, Temperature and Fatigue Level Monitoring

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Abstract. In this paper, we detail an in-home aggregation plateform for monitoring physiological parameters, and involving two objective physical sensors (bio-impedanceter and thermometer) and a subjective one (fatigue level perceived by the patient). This plateform uses modern IoT-related technologies such as embedded systems (Raspberry Pi and Arduino) and the MQTT communication protocol. Compared to many related works, monitoring is enterely achieved using a box as a central element, while the mobile device (tablet) is only used for controlling the acquisition procedure using a simple web browser, without any specific application. An example of a time stamped set of acquired data is shown, based on the in-home monitoring of healthy volunteers.

Keywords: IoT · Healthcare · Bio-impedancemetry · MQTT · Raspberry Pi · Arduino

1 Introduction

Internet of Things is a new paradigm offering a large number of possibilities, as underlined in a recent review [1]. In healthcare (see the recent overview [2]), such a paradigm facilitates the interconnection of medical devices and data, with various applications such as home tele-monitoring of patients or elderly people for instance. Many sensors are now available for monitoring many parameters (e.g. heart rate, blood flow, blood pressure, temperature, muscle contraction, weight...) with various technologies and distributed software architectures for communication purposes.

This paper focuses on the conception of an in-home aggregation plateform.

The main contribution regards the detailed description of both hardware and software aspects of the particular plateform that we developed, including various

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devices such as tablet, two particular sensors and the coupling of both Raspberry Pi and Arduino embedded systems. Our purpose is to show how such a plateform can be developed for specific applications. A part of this contribution regards the use of the MQTT protocol [3], particularly appropriated for IoT-based applications although rarely considered in healthcare, as recently underlined [4].

Another part of the contribution concerns the heterogeneous nature of monitored parameters: we consider both two objective parameters (i.e. measured by sensors) and a subjective one (fatigue level - can be considered as a subjective sensor). In our opinion, most IoT-based healthcare system focus on physical sensors although, for healthcare, additional subjective parameters such as fatigue level, pain level, ... may be meaningful from a clinical point of view. In this paper, note that we also consider a bioimpedancemeter, such a sensor being rarely considered (e.g. compared to previously mentioned sensors).

Section 2 briefly presents an overview of the developed system, while Sect. 3 focuses on its hardware and software architecture. Section 4 aims at discussing some aspects of this work.

2 System Overview

Figure 1 provides an overview of the proposed plateform, including a bioimpedancemeter, a temperature sensor, a mobile device (tablet) and a box for aggregating data and then posting them to the database using the MQTT communication protocol [3].

The bioimpedancemeter (Z-metrix developed by Bioparhom [5]) allows the measurement of various physiological parameters (fat mass, lean mass, total body water, extracellular water, ...).

The temperature sensor is part of the e-health sensor plateform developed by cooking-hacks [6]. Although the box is conceived to plug 10 sensors (i.e. ECG, SPO2, EMG, ...), only the temperature sensor is considered in the paper.

The mobile device is used to interacts with the box using a web browser. This allows to enter parameters that are required to perform measurements (weight and height in our case, being required for fat mass computation using bioimpedancemetry). The mobile device also enables to trigger measurements (i.e. bioimpedancemetry and temperature), acquired values being finally returned and rendered. Other information, useful for health state monitoring, can be entered by the patient, regardless any sensor (subjective sensor mentioned in the introduction). In our case, this concerns the fatigue level (value ranging from 0 to 100). Figure 1-bottom-left provides two snap-shots of the web browser, at the beginning (top) and at the end (bottom) of the acquisition procedure, with acquired values and a transmission acknowledgement.

All these components (temperature, bioimpedancemeter, mobile device) communicate through the central element: the “box”. The box aggregates all data (measurements from sensors, information entered by the patient such as the fatigue level) and post them to a distant database (Fig. 1-B) using the MQTT communication protocol.

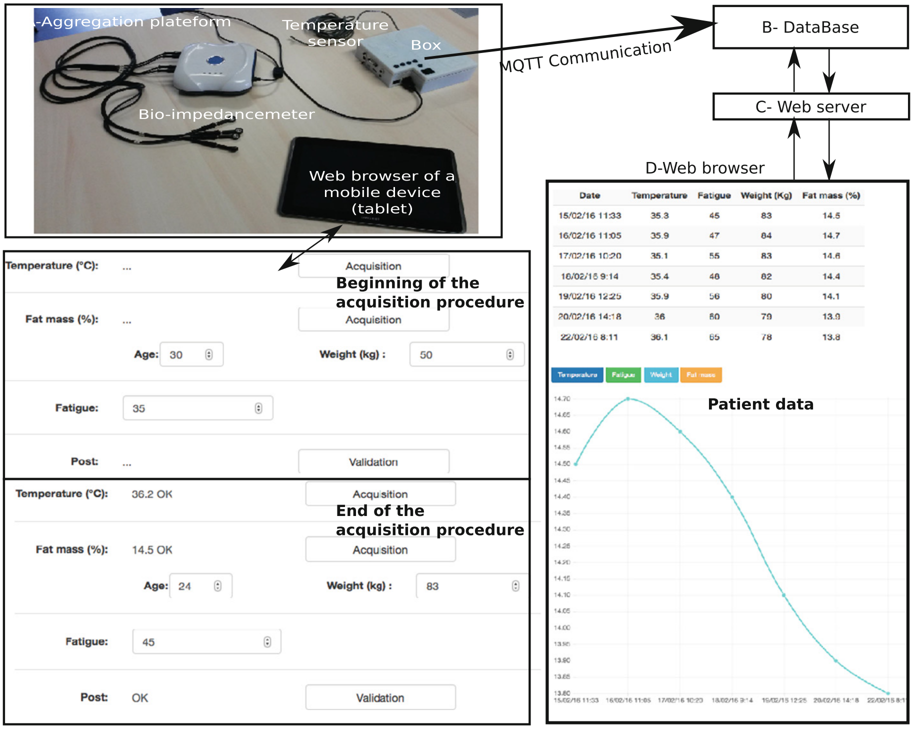

Fig. 1. Overview of the developed aggregation plateform (A) integrated a box (core element) and several external devices. This plateform communicates with a distant database (B) using the MQTT communication protocol, the content of which being rendered to render data within a web browser (D) thanks to web server (C).

A web server (Fig. 1-C) can finally be used to access to information stored in the database, for rendering purposes. Figure 1-D provides a snapshot of such rendering (time stamped measurements) thanks to the dedicated web server we developed.

3 Software and Hardware Architecture

Figure 2 provides a synthetic view of the implemented architecture. Section 3.1 details the composition of box, and Sect. 3.2 concerns the MQTT protocol.

3.1 Aggregation Plateform

In terms of hardware, the box mainly includes a Raspberry Pi and an Arduino controller together with the Arduino shield developed by Cooking Hacks,

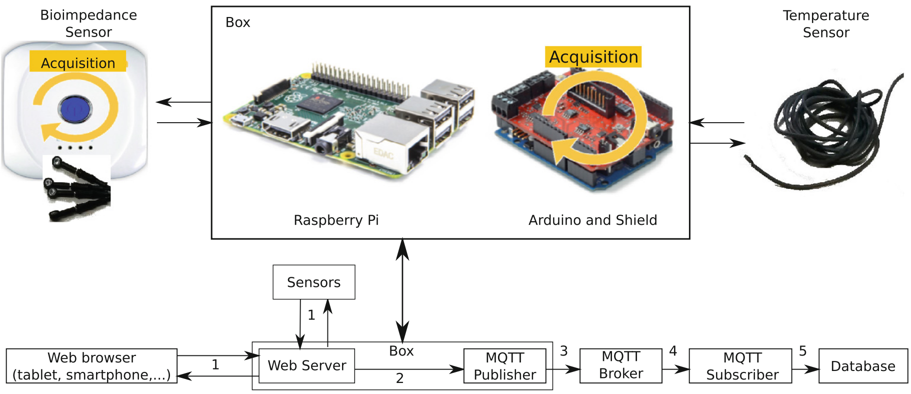

Fig. 2. Architecture overview, including software and hardware components.

for plugging related sensors (in particular the temperature sensor). The bio-impedancemeter is connected through a wired USB connection. Additional elements are packaged within the box (not detailed for clarity), such as two wifi dongles for communication (with the mobile device and with the database), a battery and an energy management system, so that the box can work in an autonomous manner. Note that, as underlined in Sect. 4, communication with sensors and mobile device can be modified or extended (e.g. both bio-impedancemeter and mobile device support bluetooth communication).

In terms of software, a web server runs on the Raspberry Pi so that the mobile device can get connected to the box using a web browser. Figure 2-1 models interactions between the mobile device (web browser) and the web server. It also models interactions between the web server and underlying sensors (i.e. acquisition is parameterized and triggered from the web browser as illustrated by Fig. 1-bottom-left). A REST architecture is considered for web server: each REST resource corresponds to a specific item (i.e. bioimpedancemetry, temperature, fatigue level), with related specific code, ensuring the separation of concerns and the modularity of the application. Note that the specific code related to the bioimpedancemetry embeds fat mass computation from electrical values returned by the sensor. For the temperature sensor, the related REST resource interacts with the Arduino board managing the acquisition (using the library developed by Cooking Hacks [6]).

When the acquisition procedure ends, the user triggers (dedicated REST resource) the post of the data to the distant database using MQTT.

All codes running on the Raspberry Pi are written with the Python language (web server, fat mass computation, communication with the Arduino and database with MQTT), using appropriate libraries.

3.2 MQTT

The principle and features of the MQTT protocol are described in [3] and has been recently considered in the context of healthcare [4]. Such a technology is particularly useful in the field of internet of things. One of the main feature is the related small code footprint and required network bandwidth.

Such a protocol is based on three elements: the publisher, the subscriber and the broker. The publisher publishes information on a certain topic, the subscriber subscribes to (a) topic(s) and receives related published messages. The intermediate entity is the broker, known by both subscribers and publishers. The broker filters all incoming messages and distributes them according to the topic and the subscriptions. Data exchange can be securized thanks to both encryption and authentication mechanisms, this being crucial for healthcare systems.

In our case, a topic corresponds to a patient (specific patient identifier). When the acquisition procedure ends, a REST resource triggers the diffusion (Fig. 2-2) of the acquired data on the related topic to the broker (Fig. 2-3). The subscriber receives the message (Fig. 2-4) and updates the database (Fig. 2-5).

4 Discussion

This system has been used by healthy volunteers for testing purposes. Acquisitions have been done daily for home during a couple of days. A single distant computer has been considered for running the broker (Mosquitto), the subscriber (Python), the database (MongoDB) and webserver (NodeJS): Fig. 1-bottom-right provides a snap-shot of the monitored data.

Hereafter, we shortly discuss two aspects: the use of a dedicated aggregator rather than the mobile device, and the ability to integrate additional sensors.

Many recent related works consider a mobile device instead of a dedicated aggregator [4,7] (the mobile device plays the role of aggregator and communicates with the distant broker). For instance, in [4] the mobile device acquires data from ECG and Oxymeter sensors using Bluetooth and a dedicated Android application. The mobile device also embeds the code for publishing data using the MQTT protocol. The advantage of such architecture is that no dedicated box is required, only a dedicated Android application is needed. In our sense, the main drawback of such architecture concerns the communication with sensors: although most mobile devices provide many communication components (e.g. wifi, sim, bluetooth, nfc, ...), their main limitation concerns the limited number of wired connections. In our case, as the local server considered in [8], the use of a box offering more connectivity (in particular wired connection) is therefore a relevant alternative. This furthermore allows to decouple the personal mobile device of the patient (e.g. including a GSM connection for general purpose and personal use) from the device used for health monitoring (e.g. which could provide another GSM connection but dedicated to health monitoring). Despite connectivity, such an aggregator involves a dedicated system no only for receiving data but also for performing computations such as fat mass in our case (possible using personal mobile device but at the cost of additional energy consumption). Our proposal has similarities with the local server presented in [8].

In terms of evolutivity, any new sensor can be integrated within the proposed plateform by connected the device to the Raspberry Pi either a wired connection, or a wireless connection (e.g. bluetooth). At software level, this involves the integration of the corresponding REST resource to web server running on the Raspberry Pi (binding between the tablet and physical sensor). The mobile device basically remains a "touch screen" interacting with the box (through the web browser).

5 Conclusion

This work provides a detailed example of in-home aggregation plateform using standard modern technologies. Next steps will concern the exploitation of this system real healthcare applications.

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