An example of homemade box forIoT-based in-home health 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. 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, 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 (Borgia-2014). In healthcare (see the recent overview (Yin-2016)), 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 (Jamin-2016).

The main contribution regards the detailed description of both hardware and software aspects of the particular plateform that we developed, including various 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 [1], particularly appropriated for IoT-based applications although rarely considered in healthcare, as recently underlined (Barata-2013).

Another part of the contribution concerns the heterogenous 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 althought, 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 section 3 focuses on its hardware and software architecture.

2. SYSTEM OVERVIEW

Figure 1 provides an overview of the proposed plateform, including a bio-impedancemeter, 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.

The bioimpedancemeter (Z-metrix developed by Bioparhom [2]) allows the measurement of various physiological parameters (fat mass, lean mass, total body water, extracellular water, ...).

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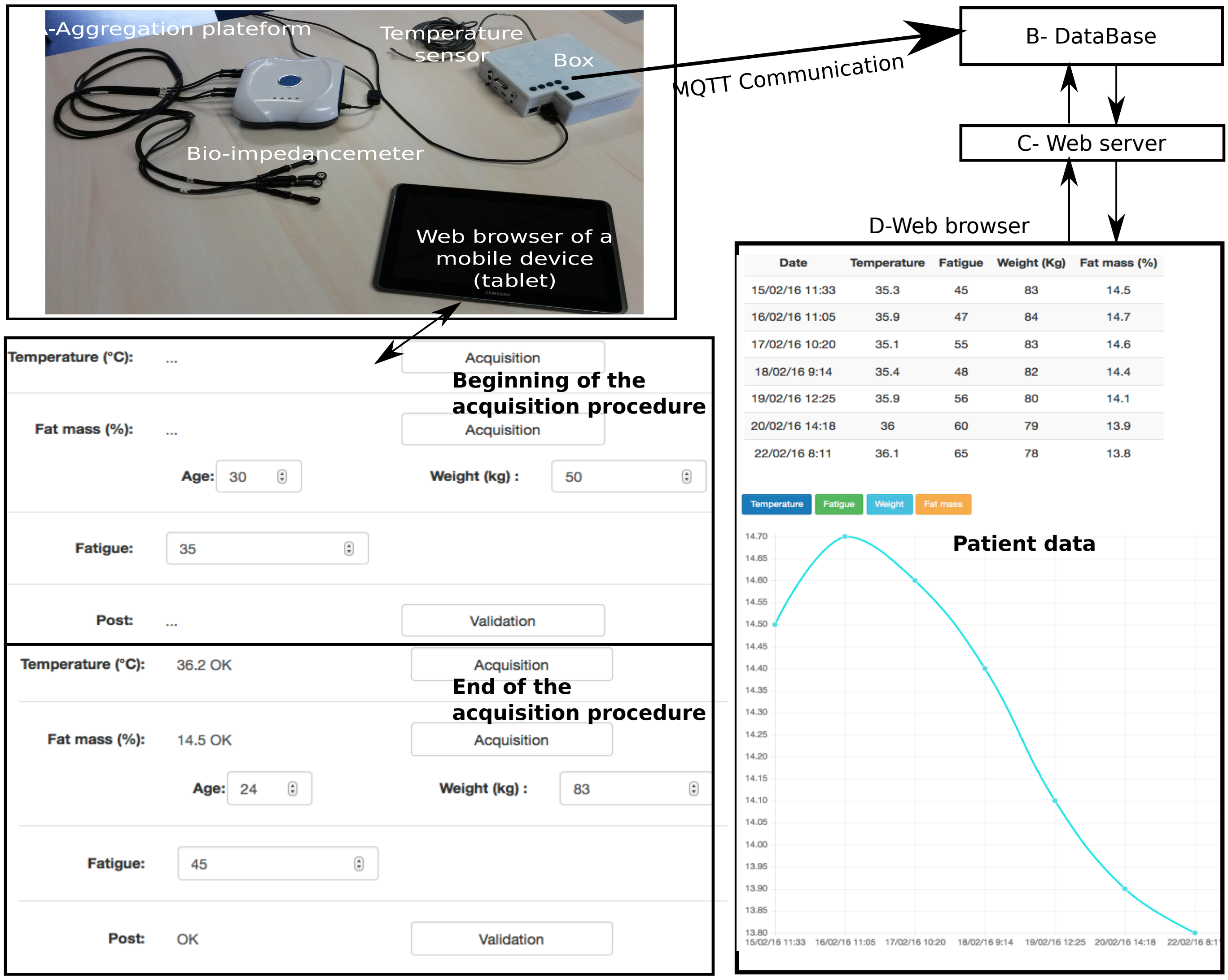
[1] Message Queuing Telemetry Transport (MQTT), http://mqtt.org, 2016,Visited on 28th of November, 2016

[2] Bioparhom, http://www.bioparhom.com/en, Visited on 28th of November, 2016



Date	Temperature	Fatigue	Weight (Kg)	Fat mass (%)
15/02/16 11:33	35.3	45	83	14.5
16/02/16 11:05	35.9	47	84	14.7
17/02/16 10:20	35.1	55	83	14.6
18/02/16 9:14	35.4	48	82	14.4
19/02/16 12:25	35.9	56	80	14.1
20/02/16 14:18	36	60	79	13.9
22/02/16 8:11	36.1	65	78	13.8

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).

The temperature sensor is part of the e-health sensor plateform developed by cooking-hacks [3]. Althought 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 (figure 1-B) using the MQTT communication protocol.

A web server (figure 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. This data have been acquired by healthy volunteers (daily at home) for testing purposes (figure 1-bottom-right provides a snap-shot of the monitored data).

[3] Cooking Hacks, e-health sensor plateform, http://www.cooking-hacks.com,Visited on 28th of November, 2016

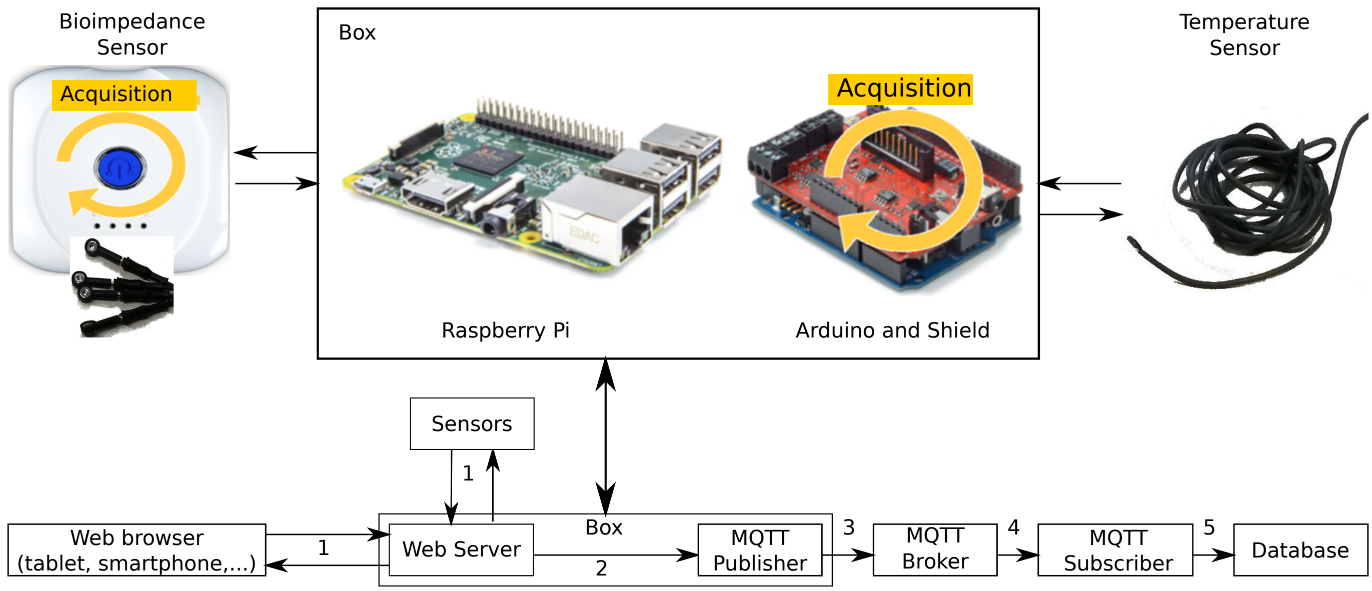


Fig. 2. Architecture overview, including software and hardware components.

3. SOFTWARE AND HARDWARE ARCHITECTURE

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

3.1 Aggregation plateform

In terms of hardware, the box mainly includes a Raspberry Pi and an Arduino controler together with the Arduino shield developed by Cooking Hacks, for plugging related sensors (in particular the temperature sensor). The bio-impedancemeter is connected through a wired USB connection. Additionnal 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 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 figure 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).

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 MQTT protocol has been recently considered in the context of healthcare (Barata-2013). 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 subcriptions. 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 (figure 2-2) of the acquired data on the related topic to the broker (figure 2-3). The subscriber receives the message (figure 2-4) and updates the database (figure 2-5).

4. 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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