Monitoring Health Factors in Indoor Living Environments Using Internet of Things

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Abstract. Indoor air quality parameters are extremely important to create a productive and healthy indoor environment however in many cases the air quality parameters are very different from those defined as healthy values. Considering that we spend about 90% of our lives indoors, it is extremely important to monitor the indoor air quality in real time to detect problems in the quality of air and plan interventions in the building, or in the ventilation systems in order to improve air quality. This paper aims to present a solution for indoor air quality monitoring based in Internet of Things Architecture (IoT). This solution is composed by a hardware prototype for ambient data collection and a web and smartphone compatibility for data consulting. This system, denominated by iAQ Wi-Fi, is based on open-source technologies. It is a totality Wi-Fi system, with several advantages compared to existing systems, such as its modularity, scalability, low cost and easy installation. This system performs real-time data collection that is stored in a ThingSpeak platform. The system has smartphone compatibility which allow easier access to data in real time. In this application, the user can check the latest data collected by the system and access to the history of the air quality parameters in graphical representation. iAQ Wi-Fi uses a open-source Arduino UNO as processing unit, a ESP8266 for Wi-Fi 2.4 GHZ as communication unit and incorporates an temperature and humidity sensor, a CO2 sensor, a dust sensor and a digital light sensor as sensing unit.

Keywords: Indoor air quality · Monitoring · IoT (Internet of Things) · Energy efficiency · Smart cities · iOS

1 Introduction

Indoor air quality is a significant determinant of personal exposure to pollutants because people spend about 90% of their time in indoor environments. In the case of older people and new-borns who are most likely affected by this pollutant may spend all their time in indoor environments [1]. The assessment that indoor air quality indicators must thereby determine how well indoor air (a) satisfies thermal and respiratory requirements, (b) prevents unhealthy accumulation of pollutants, and (c) allows for a sense of well-being is proposed by [2].

In the USA, indoor and outdoor air quality is regulated by Environmental Protection Agency (EPA). This organization consider that indoor levels of pollutants may be up to

Á. Rocha et al. (eds.), *Recent Advances in Information Systems and Technologies*,
Advances in Intelligent Systems and Computing 570, DOI 10.1007/978-3-319-56538-5_79

100 times higher than outdoor pollutant level and ranked poor air quality as one of the top 5 environmental risks to the public health [3].

The problem of poor indoor air quality is of utmost importance affecting especially severe form the poorest people in the world who are most vulnerable presenting itself as a serious problem for world health such as tobacco use or the problem of sexually transmitted diseases [4].

High-quality research should continue to focus on the quality problems of indoor air in order to adapt legislation, inspection and creating mechanisms that act in real time to improve public health, both in public places such as schools and hospitals and private places and further increase the rigorousness of the buildings construction rules. In the major cases, simple interventions provided by home-owners and building operators can produce great positive impacts in indoor air quality such as the avoidance of smoking indoors and the use of natural ventilation are important behaviours that should be taught to children through educational programs that address the indoor air quality [5].

Although the importance of indoor air quality for public health exists a lack of interest in the scientific new methods to improve indoor air quality in developed countries [6]. Indoor air quality real-time monitoring is assumed as an essential tool of extreme importance to study and analyse the indoor air quality in order to plan interventions for enhanced occupational health.

A dedicated, miniaturized, low-cost electronic system based on metal oxide sensors and signal processing techniques that is capable to measure carbon monoxide, nitrogen dioxide in mixtures with relative humidity and volatile organic compounds by using an optimized gas sensor array and highly effective pattern recognition techniques is presented by [7]. Another wireless solution for indoor air quality monitoring that is capable to measure the environmental parameters like temperature, humidity, gaseous pollutants and aerosol is proposed by [8]. A monitoring system that uses a low cost wireless sensor network, to collect indoor air quality information developed using Arduino, XBee modules and micro sensors, for storage and availability of monitoring data in real-time is presented by [9].

This paper aims to present the iAQ Wi-Fi, a solution for indoor air quality monitoring based in Internet of Things architecture. This solution is composed by a hardware prototype for ambient data collection and web/smartphone compatibility for data consulting. This system uses a open-source Arduino UNO as processing unit, a ESP8266 for Wi-Fi 2.4 GHZ as communication unit and incorporates an temperature and humidity sensor, a CO2 sensor, a dust sensor and a digital light sensor as sensing unit.

2 Materials and Methods

In general, the quality of indoor environments covers the visual and thermal comfort but also the air quality. In this context, environmental parameters such as temperature, humidity, air speed, lighting level and pollutants concentrations are crucial for a proper evaluation of indoor environments.

The iAQ Wi-Fi is a real time indoor air quality monitoring solution that is capable to measure temperature, humidity, PM10, CO2 and luminosity in real time. It is a completely wireless solution, where the wireless communication is implemented using the ESP8266 module which implements the IEEE 802.11 b/g/n networking protocol, a family of specifications developed by the IEEE for WLANs. The IEEE 802.11 standard supports radio transmission within the 2.4 GHz band [10].

This solution is based on open-source technologies it uses an Arduino UNO [11] as a microcontroller and a ESP8266 module for data communication. The data collected by the system is stored in a ThingSpeak platform. ThingSpeak is an open source "Internet of Things" application that provides developers with APIs to store and retrieve data from sensors and devices using HTTP over the Internet [12].

The end user can access the data from the web page provided by ThingSpeak platform or can use the smartphone app developed in SWIFT, an open-source programming language with XCODE IDE created for iOs operating system.

Providing a history of changes, the system helps the user to analyse precisely and detailed information about the indoor air quality and this data could support him to decide on possible interventions to improve indoor air quality.

The iAQ Wi-Fi system architecture is based on Internet of Things. This paradigm is present by [13] as a concept that is based in pervasive presence of a variety of things or objects which are connected to the internet using a unique address. Figure 1 represents the system architecture used by the authors.

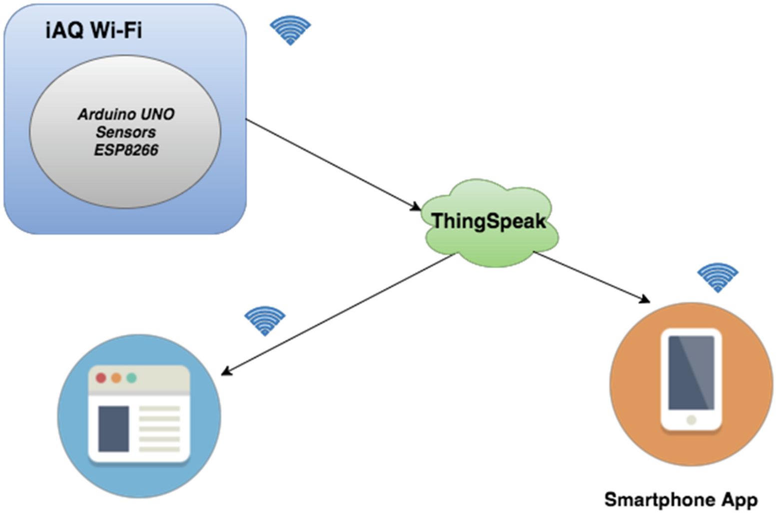

Fig. 1. iAQ Wi-Fi system architecture.

The iAQ Wi-Fi can be divided in three major parts: a processing unit, a sensing unit and a communication unit (Fig. 2). This system is built using the embedded Arduino UNO microcontroller and an open-source platform that incorporates an Atmel AVR microcontroller [11] as processing unit. The sensing unit incorporates a i2C temperature and humidity TH2 sensor, a dust concentration sensor, I2C light-to-digital converter

TSL2561 sensor and a MG-811CO2 sensor. It also incorporates a ESP8266 as communication unit.

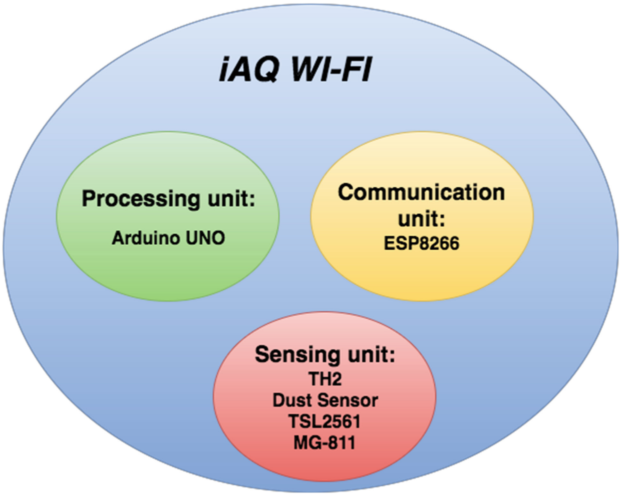

Fig. 2. Schematic diagram of iAQ Wi-Fi

Figure 3 represents iAQ Wi-Fi prototype, a brief description of the used components is presented below.

- TH2 –is a temperature and relative humidity sensor that provides reliable readings when environment humidity condition range 0–100% RH, and temperature condition range 0–70 °C. Supports a wide operating voltage range (3.3 V–5 V), have i2C host interface and a accuracy of ±4.5% RH in humidity sensing and ±0.5 °C in temperature sensing and have also a low power consumption 350 µA during RH conversion;
- Shinyei Model PPD42NS Dust Sensor – is a sensor that can measuring the dust concentration in the air. It has stable and sensitive detection as it is responsive to a PM of diameter 1 µm and major. The Particulate Matter level (PM level) is measured by counting the Low Pulse Occupancy time (LPO time) in given time unit. LPO time is proportional to PM concentration [14].
- TSL2561 – is a i2C digital light sensor that transform light intensity to a digital signal. It has a high resolution of a 16-Bit digital output at 400 kHz I2C and fast-mode. Support a wide dynamic range: 0.1–40,000 lx and a wide operating temperature range: –40 °C to 85 °C [15].
- MG-811 – is a CO2 sensor which is highly sensitive to CO2 and less sensitive to alcohol and CO, low humidity and temperature dependency [16]. In iAQ Wi-Fi we used a df robot module that have a on-board heating circuit brings the best temperature for the sensor operation. Internal power boosting to 6 V for heating sensor best performance. This module provides a analogic interface output [17].
- ESP8266 – is a Wi-Fi chip with integrated antenna switches, RF balun, power amplifier, low noise receive amplifier, filters and power management modules. It support

802.11 b/g/n protocols, Wi-Fi 2.4 GHz, support WPA/WPA2, has a integrated low power 32-bit MCU, a integrated 10-bit ADC, has a standby power consumption of <1.0 mW (DTIM3) and can operate at temperature range –40 C–125 C [18].

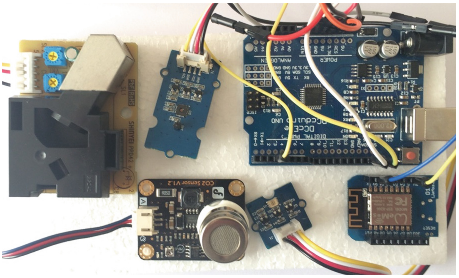

Fig. 3. iAQ Wi-Fi prototype

The firmware of the iAQ Wi-Fi is implemented using the Arduino platform language in the IDE ARDUINO. It belongs to the C-family programming languages. The Arduino UNO is responsible for data collection and is connected to the communication unit (ESP8266) by serial communication. The Arduino UNO send a string with the data from the sensors to the ESP8266 and this is responsible to upload this data to the ThingSpeak platform (Fig. 4).

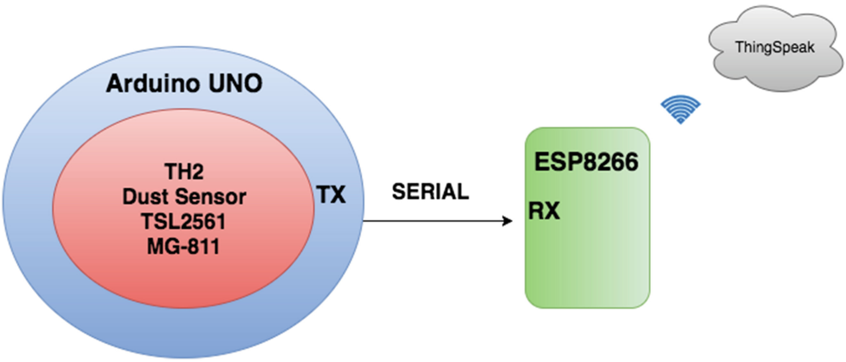

Fig. 4. Arduino UNO and ESP8266

The ESP8266 has an important functionality that provides to the end user an easy configuration of the Wi-Fi network to which it will be connect. The ESP8266 is by default a Wi-Fi client but if it is unable to connect to the Wi-Fi network or if there are no wireless networks available the ESP8266 will turn to hotspot mode and will create a Wi-Fi network with a SSID “IAQ”. At this point the end-user can connect to this Wi-Fi network which permits to configure the Wi-Fi network to which the iAQ Wi-Fi is going to connect through the introduction of the network SSID and password (Fig. 5).

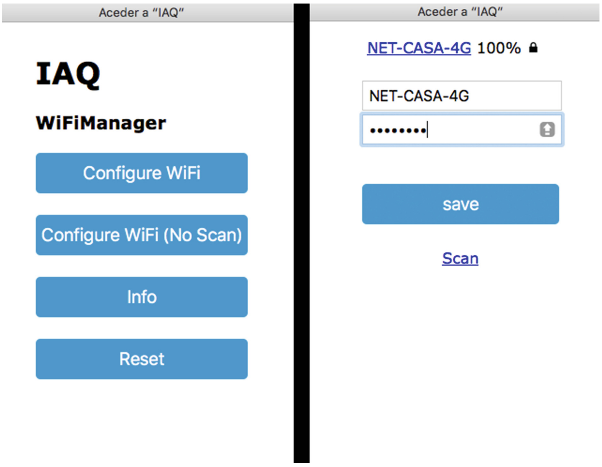

Fig. 5. Wi-Fi network configuration

The smartphone application iAQ-Wi-Fi Mobile is created in Swift programming language in XCODE IDE and its compatible with iOS 7 and above [19]. This app has two major functionalities as it permits not only real time consulting of the last data collected by the iAQ Wi-Fi but also access to the history of the air quality parameters in graphical representation.

3 Results and Discussion

The iAQ Wi-Fi allows viewing the data as graphical and numerical values by using a web browser or a smartphone app. A sample of the data collected by iAQ Wi-Fi is showed in Figs. 6, 7 and 8. Figure 6 represents luminosity data measured in lux, the Fig. 7 represents temperature data measured in Celsius and Fig. 8 represents dust sensor data measured in μg/m^3. It should be noted that the graphs displayed the results obtained in real environment with induced simulations.

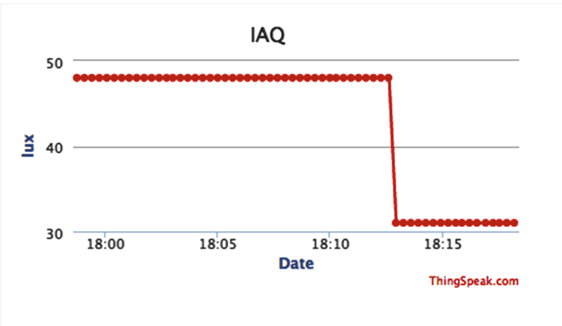

Fig. 6. Luminosity (lux)

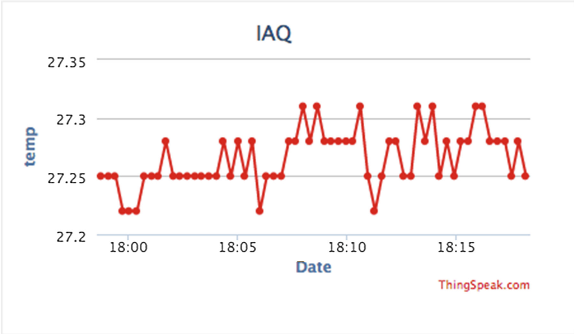

Fig. 7. Temperature (°C)

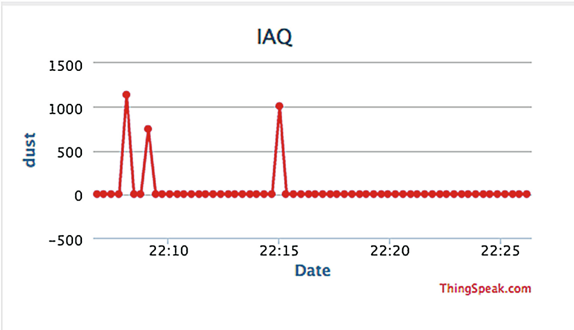

Fig. 8. Dust sensor PM10 (μg/m^3)

The smartphone application allows a quick simple access, intuitive and real-time access to the monitored data in numerical and chart forms (Fig. 9). Mobile computing in U.S. has had an exponential growth as adult smartphone device ownership was at 33% in 2011, 56% at the end of 2013 and 64% in early 2015 [20]. In the Netherlands, 70% of global population and 90% of the adolescents own a smartphone [21], in Germany 40% of the population use a smartphone [22] and 51% of adults owned smartphones in the UK [23]. About 36–40% of smartphone owners use their smartphone 5 min before bed and in the next 5 min after wake up [11]. Actually, smartphones have excellent processing and storage capabilities and people carry them in their daily lives. For all these reasons a mobile application was been created in order to allow the end user a quick, easy and intuitive access to the monitoring data. In this way the user can carry the indoor air quality data of their home with him for everyday use.

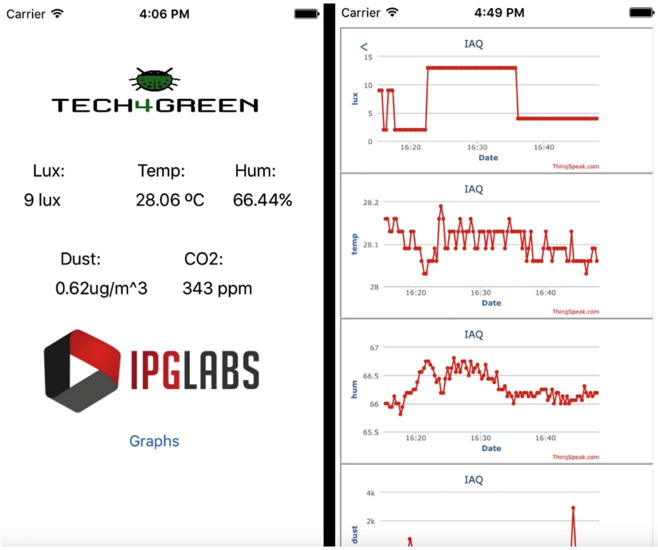

Fig. 9. iAQ Wi-Fi mobile app

The graphic display of the air quality data allows a greater perception of the behaviour of the monitored parameters than the numerical display format. On the other hand, the web and smartphone software also allows the user to access the data, which enables a more precise analysis of the detailed temporal evolution. Thus, the system is a powerful tool for analyse air quality consumption and to support decision making on possible interventions to improve a healthy and more productive indoor environment. As future work the main goal is to make technical improvements, including the development of important alerts and notifications to notify the user when the quality of indoor air has serious deficiencies. Compared to other systems, the iAQ Wi-Fi system has the following advantages: modularity, small size, low cost construction and easy installation [24, 25]. Improvements to the system hardware and software are planned to make it much more appropriate for specific purposes such as hospitals, schools and offices.

4 Conclusion

This paper had presented a complete wireless solution for indoor air quality monitoring based in Internet of Things Architecture. This solution is composed by a hardware prototype for ambient data collection and a web and smartphone compatibility for data consulting.

The results obtained are very promising, representing a significant contribution to indoor air quality monitoring systems based on IoT. In addition, to this validation study, physical system and related software improvements have been planned with a view to adapt the system to specific cases. Despite of all the advantages in the use of IoT architecture, still exist many open issues as scalability, quality of service problems and security and privacy issues. The system should find ways to respond to these problems. Compared to existing systems, it has great importance due to the use of low cost and open-source technologies. Note that the system has advantages both in easy installation and configuration, due to the use of wireless technology for communications, but also because it was developed for to be compatible with all domestic house devices and not only for smart houses or high-tech houses. This system is particularly useful for the analysis of indoor air quality. As future work is expected to introduce new sensors to this system for monitoring other indoor air quality parameters as well as the development of a platform that allows to share in a secure way the collected data to health professionals.

We believe that in the future, systems like this will be an important part of the interior spaces. The data of indoor air quality can be extremely useful to provide support to clinical analysis by health professionals. Only through air quality monitoring indoors is that it is possible to perceive correctly the ventilation conditions that influence the health of occupants plan interventions to increase the air quality if needed.

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