Smart air monitoring for indoor public spaces using mobile applications

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Abstract. As people spend approximately 90% of their time indoors, monitoring the quality of indoor air is crucial in protecting public health. In recent years, technologies such as Internet of Things (IoT) and cloud computing have introduced new measurement capabilities in a variety of environments. Low-cost sensor technology can significantly help in the field of air pollution monitoring, providing data on air quality levels and indoor air emissions. The work presented herein focuses on a cloud computing server able to analyse data in real time and present the results obtained with visual effects which illustrates the prevailing indoor air conditions, making data easier to understand and more interesting to the user. In addition, the server can alert mobile application users or facility managers when air quality is poor so that remedial action can be undertaken immediately.

1. Introduction

The World Health Organization (WHO) has identified air pollution as the most important environmental threat to human health, in agreement with published studies that attribute 1 out of 10 deaths on a global scale to its effects [1].

Although traditionally the focus has been on outdoor air pollution, it has recently become clear that indoor air can be much more polluted, especially as the effort to save energy and combat the effects of climate change means that buildings are in effect hermetically sealed, relying solely on mechanical ventilation to recirculate indoor air [2]. The quality of indoor air is affected by several factors, such as the external concentrations of pollutants, the quantity and quality of ventilation, as well as human activities, such as cooking, smoking and heating [3].

As is well understood, air pollution leads to respiratory diseases (e.g., asthma) and increases cancer risk. Moreover, the so-called Sick Building Syndrome (SBS), caused by the presence of volatile organic compounds (VOCs) in indoor air, has significant economic implications, as costs associated with absenteeism from work are significantly higher than operating costs associated with a building's energy use [4].

This is particularly worrying, as people around the world spend more than 90% of their time indoors, be it in homes, shops or the workplace. Thus, it is important to investigate the levels of pollutants present in the premises of various buildings in order to improve the air quality of the indoor air environment and thermal comfort of occupants [5]. Important parameters that need to be monitored also include room temperature and pressure, relative humidity, and levels of CO_2 [6].

In recent years, technologies such as IoT and cloud computing have introduced new measurement capabilities in a variety of environments. Low-cost sensor technology can significantly help in the field of air pollution monitoring, providing data on air quality levels and indoor air emissions [7]. For these reasons, several studies focusing on IoT architecture for measuring indoor pollution have been published [8]. However, these studies focus only on real-time measurement of indoor air quality. The work presented herein focuses on a cloud computing server able to analyze data in real time and present the results obtained with visual effects which illustrates the prevailing indoor air conditions, making data easier to understand and more interesting to the user. In addition, the server can alert mobile application users or facility managers when air quality is poor so that remedial action can be undertaken immediately.

2. System architecture

The system architecture is shown in figure 1. It consists of three parts: (1) data collection, (2) cloud data processing and (3) mobile view presentation. An analysis of the system's architecture is presented in the following sub-sections.

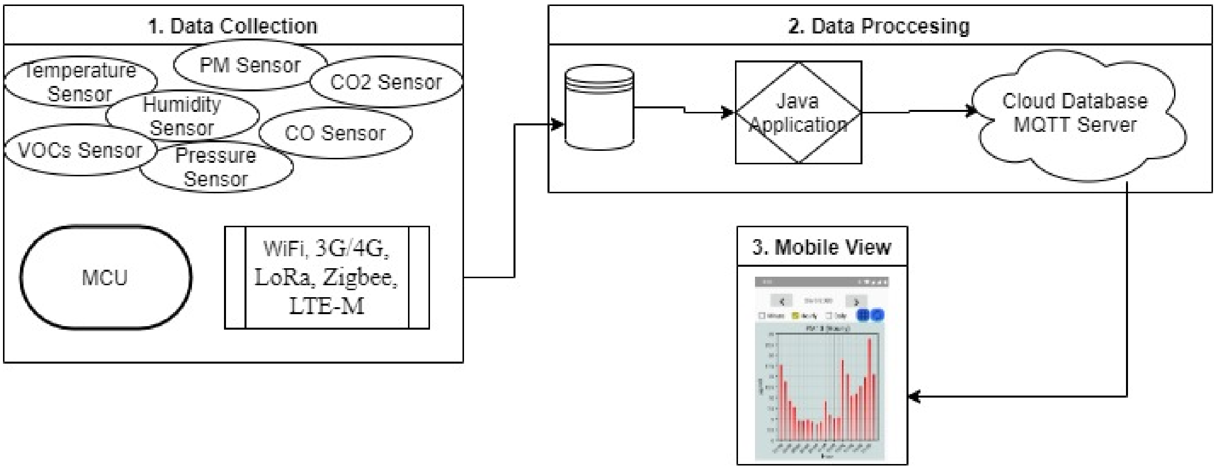

Figure 1. System architecture.

2.1. Data collection

In the work presented herein, indoor air quality was measured by a calibrated cost-effective gas sensor-systems (Ecomzen, ECOMESURE INC. [9]) (figure 2). The French company ECOMESURE, which specializes in measuring air quality, designed the low-cost sensor station to monitor the basic parameters for indoor air quality. This sensor station, measures with individual sensors the concentration of particulate matter (PM_{10}, $PM_{2.5}$, PM_1), CO_2, VOCs, CO and environmental factors such as temperature, relative humidity and atmospheric pressure, indoors.

The operation of the ECOMZEN station is based on the Internet of Things and is automatically connected to the company's online platform, where there are many services such as direct data, air quality profiles, downloads, warnings, and reports. Once it is connected to the Internet using one of the communication ports (Wi-Fi, 3G/4G, LoRa, Zigbee, LTE-M), the hyper-local data are automatically transferred to a secure 24/7 web platform. The advantages of this sensor station are many. At first, it is small and light, while being able to record many parameters simultaneously and has an ever-evolving quality of measurements. Ecomzen can be installed quickly, and the data can be accessed in real-time from any location. Maintenance is limited to changing the sensor cartridge. Also, the station is simple, accurate, economical and the maintenance and calibration of the individual sensors is straightforward, and their replacement can be easily achieved. The following Table 1 presents the operating characteristics of the sensors.

Figure 2. The ECOMZEN sensor station.

Table 1. Operational details of ECOMZEN.

Parameter	Detection range	Detection limit	Accuracy
$PM_{2.5}$ and PM_{10} sensor (optical)	0-3.000 $\mu g/m^3$	2 mg/m^3	4 mg/m^3
CO_2 detector (infrared)	0-5.000 ppm	10 ppm	10 ppm
VOCs detector (PID)	0-5.000 ppb	3 ppb	5 ppb
CO detector (electrochemical)	0-8.000 ppb	10 ppb	10 ppb
Temperature	-20^o C-+50^o C	-	0,01^o C
Relative humidity	0-100%	-	0,04%

2.2. Data Processing

The data is sent for processing and storage in ECOMESUREs database in the cloud after collecting it. Following the automated data correction, it is possible to access it through the ECOMESUREs website or download it via FTP or Rest API protocol.

For the work presented herein, the data is obtained through the Rest API protocol with a program developed in Java. The program checks measurements for high values or poor thermal comfort. In case of exceedance or poor thermal comfort, it sends an alarm message to the users who have the mobile application installed on their smartphone.

The messages are sent using the MQTT protocol with freely available servers on the internet. MQTT is a Client Server publish / subscribe messaging transport protocol. It is lightweight, open source, simple, and designed for easy implementation. These characteristics make it ideal for use in many situations, including IoT contexts where a small code footprint is required and / or network bandwidth is at a premium (https://www.oasis-open.org/committees/tc_home.php?wg_abbrev=mqtt). Because of these features it is ideal for sending notifications to users as users receive push notifications via native mobile application.

After checking the values, the data is stored on a specially configured database in MySQL Server in the cloud for the mobile application to access them. The MySQL software is use for the acquired data from the web server for processing. It is a relational database management system which is based on Structured Query Language (SQL).

2.3. Mobile application

Mobile application was developed using B4A which is a free and open-source development tool (www.b4x.com). The app consists of two parts. The first is the implementation of an MQTT client that takes care of the communication with the MQTT server. It works as a service and can always receive a message from the server without having to continuously ask the server for new messages. This means that it uses a very small amount of data.

The second part of the app is the data presentation application. The home page shows the positions of the measuring points on a map. The user can click on the location dot to check the status (figure 3). By clicking on it, the user can see the measurements of each sensor in a graph or table for the current day. An earlier date can also be selected to present historical data.

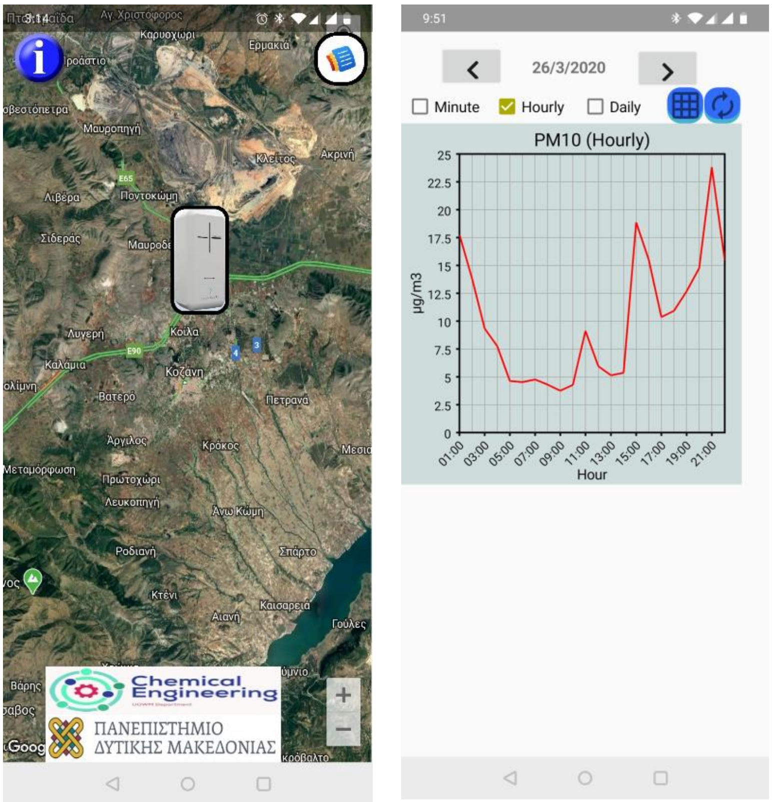

Figure 3. Mobile application.

The application is currently available for use on mobile running the android operating system. For a pilot application we installed an ECOMZEN station inside a building of the Department of Chemical Engineering of the University of Western Macedonia. Initially, the application did not have the warning system installed, with the result that users were not being informed when they should be. Thus, experience has shown that using an on-time notification system without users having to visit a site or open the application is effective. The application is available for download by students and university staff from the department's website [10].

3. Conclusions

As people spend most of their time indoors, monitoring indoor air is crucial to human health. The work presented herein, reports on an IoT-based system for indoor air quality monitoring. Mobile technology in combination with the use of economic IoT-based solutions for the monitoring of the internal environment can effectively help to protect human health. The notification system (messaging) that was implemented helped the users obtain more effectively the relevant information.

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