Chapter 24
IoT-Based Indoor Air Quality Monitoring System Using SAMD21 ARM Cortex Processor

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Abstract In this paper, an IoT-based technology is demonstrated to efficiently monitor indoor air quality in real-time monitored online through Wi-Fi. The idea was derived from the issues of toxic gas poisoning that cause environmental pollution, general health as well as death due to excessive inhalation of toxic gases in a closed area. This paper proposed a device of air quality monitoring system which should be able to provide an alert for the presence of toxic gases effectively via any mobile applications. The device is composed of a SAMD21 ARM cortex processor as microcontroller, pollutant detection sensors and data transmit to a Web server. The device was designed to measure a concentration of carbon monoxide (CO) and temperature-humidity for monitoring the air quality. SD card has been integrated into a Seeeduino Xiao microcontroller for analyzing and visualizing the air quality data from the device. A Web-based mobile application was developed to monitor the air quality at anytime and anywhere. To demonstrate the feasibility, the device has been tested in three closed areas which are inside a room, inside a static car with

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burning fuel energy to power the car and a kitchen area that has cooking facility. The result indicates that CO gas produced from the kitchen area when the gas stove being used shows more than 63.75% and 82.5% compared to condition from inside a car and inside a room, respectively. Additionally, the device has been successfully implemented to provide notification for community to prevent from the areas that contaminated with toxic gases.

Keywords IoT technology · Indoor air quality monitoring · Seeeduino Xiao microcontroller · Sensor · Web-based

24.1 Introduction

Air quality is a major concern in developed countries and has been associated with ecosystem health effects. The scientific community reveals that pollutants affecting air quality are of major concern in urban areas, including with presence of carbon monoxide (CO), nitrogen dioxide (NO_2), unpredictable natural mixes (VOC), secondary gas pollutants ozone (O_3), smoke and some uncommon components [1, 2]. Numerous modern housing by close arrangements in urban areas have been the challenging concern for the indoor air quality issue. Closed or indoor spaces can provide a higher potential for pollution compared to open or outdoor space conditions. The effects of indoor air pollution can reach levels 100 times higher compared to outdoor air pollution [3]. Furthermore, polluted air in indoor space has brought direct impact on human health in which the air contaminants transmitted to the lungs, causing internal diseases, dizziness and multiple sensitivities. Thus, the situation is getting worse when indoor air pollution issue is not solved because most of the modern populations now spend about 80–90% of their time indoors [4–6].

Cooking and heating foodstuffs are common routine prepared in a household. Most households rely on solid fuels energy such as liquid petroleum gas, coal and biomass for the routine cooking and heating desires [7]. In poorly ventilated households, higher levels of various toxic compounds such as CO, NO_2 and particulate matter (PM) are indeed produced from the incomplete combustion of solid fuels energy in traditional cooking stoves. In addition, too much and continuous consumption of cooking fuel by using solid fuels can cause to a decreasing fuels energy resources and lead to a chronic health problems [8].

People need a situation of the surrounding air that is free from pollutants. This is regularly significant for substantial health and environmental benefits. Air pollution can causing climate change and severe diseases. Many people are unconcerned to the severity of air pollution or in recent times recognized the issue. Majority of the population now breathes polluted air. Based on the World Health Organization (WHO) report, air pollution is the cause of death for 7 million population every year [9].

The occurrence of individuals who died due to inhalation of excess CO gas at fireplaces and during fire incidents in enclosed buildings have been recorded several times in Malaysia. The impact of indoor air pollution is not limited to the incidents in enclosed buildings. In addition, there are also some cases of individuals drowned in the car while sleeping and has caused death due to inhalation of the CO gas that has entered the car from the burning fuel energy to power the car [10].

CO consists of one atom carbon and one atom oxygen which is a colorless and odorless less dense than air. CO is an omnipresent element of fire atmospheres produced when organic material is burned in an insufficient source of oxygen. In high concentration levels, CO gas is toxic to humans and animals as it induces disorders in the blood from the obstructing of the oxygen supply which potentially causing sudden death [11, 12].

To overcome the issues of toxic gas poisoning in a closed area, the development of indoor air quality monitoring system which is capable in providing notification updates on the air quality levels is very important. Therefore, an Internet of things (IoT)-based indoor air quality monitoring with low-cost energy by using SAMD21 ARM cortex processor based on integration of Web server is presented in this paper. IoT system is associated with the embedded air quality sensors, microcontroller unit (MCU) and electronically software frameworks to give correspondence data and information exchange. Furthermore, the data outcomes can be utilized by enhancing communication technology system to provide instant updates besides to monitor the impact of indoor air quality levels in the particular areas.

24.2 Methodology

The most important factor for an indoor air quality monitoring system is the accuracy to detect air quality platform. The primitive design of the smart air concept was motivated through the development by [1] that is a low-cost air quality sensor (LAQS) system known as DiracSense for surface O_3, NO_2 and CO measurement. Raspberry Pi-3 on the single board computer was the programmable system for the required air quality levels monitoring operation. The air quality levels were sent using IoT setup to the Web server such as Google drive or Dropbox for detailed monitoring.

The designs, communication technologies and hardware development must be determined in depth to handle data updates associated with air quality levels. Here, an IoT-based application was implemented remotely to monitor and get the notification updates for the air quality detection. Figure 24.1 describes the block diagram of the IoT-based indoor air quality monitoring system of this paper.

In this paper, the monitoring system includes several sensors, communication connectivity and MCU programmable by Seeeduino Xiao as the main part of the indoor air quality monitoring system. The data collected is further stored into a data storage system. Furthermore, the data is analyze and employed on data visualization for the end users to receive information updates of the indoor air quality levels. Figure 24.2 describes the flowchart functionality insights into the system.

Figure 24.3 shows the circuit diagram of the indoor air quality monitoring system. Arduino Uno libraries could be used in the diagram instead of Seeeduino Xiao

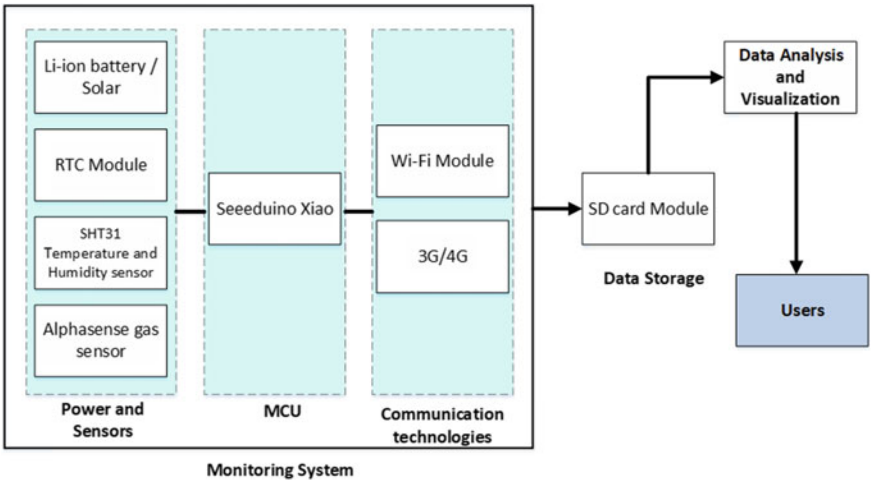


Fig. 24.1 Block diagram of the indoor air quality monitoring system

libraries for the unavailable module pin. In this paper, a low power microcontroller embedded with SAMD 21 ARM processor was selected. The core of the microcontroller is the high performance in processing with less operating power.

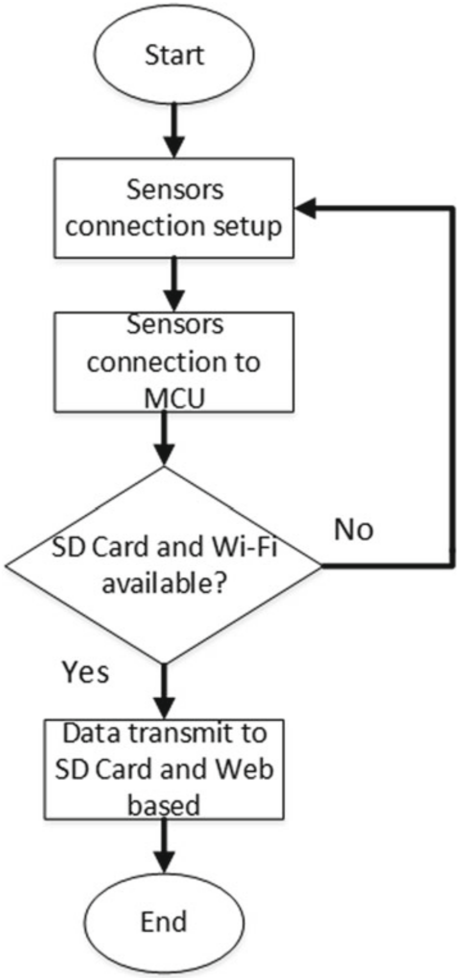
The reliability data measurements for temperature, humidity and CO concentration from the sensors during the monitoring application were observed. The data such as date, day, time, temperature in degree Celsius (°C), percentage humidity and CO concentration in parts per billion (ppb) were extracted from the SD card before display in Web server.

24.3 Results and Discussion

The paper presented a development and implementation of a monitoring indoor air quality system based on an Arduino compatible board in the Seeeduino Platform. Figure 24.4 shows the indoor air quality monitoring system prototype which is placed inside a covering box. The covering box needs to have a bit of holes to allow the surrounding air to enter inside the box. To test the sensors capabilities which are the SHT31 temperature-humidity sensor and Alphasense CO-A4 gas sensor, the air quality monitoring box has been placed in three different places which are; (1) inside a room, (2) inside a static car while the car's engine is turned on and (3) at the kitchen area that has cooking stove fume. The experiment was conducted in the three different particular areas during the day for around 2 h.

The data collected from the sensors used in the air quality monitoring system are shown in Figs. 24.5, 24.6, and 24.7. The average data results for CO concentration from inside a room is 1409.4254 ppb for the average temperature and humidity of

Fig. 24.2 Flow chart of system



30.96 °C and 84.0315%, respectively. The results show for the normal data of the surrounding conditions.

The average data results for CO concentration from inside a static car while the car's engine was turned on indicates 2901.03 ppb for the average temperature and humidity of 28.01 °C and 44.4038%, respectively. The average temperature is low because from the air conditioner that has been turned on inside car besides causing a slight more reduction of humidity percentage compared to the condition inside a room. However, the CO concentration from inside the static car indicates 51.42% higher CO concentration compared to the condition from inside a room.

The average data results for CO concentration from the kitchen area that has cooking stove fume is 8000.44 ppb for the average temperature and humidity of 29.44 °C and 82.0285%, respectively. The average temperature and humidity

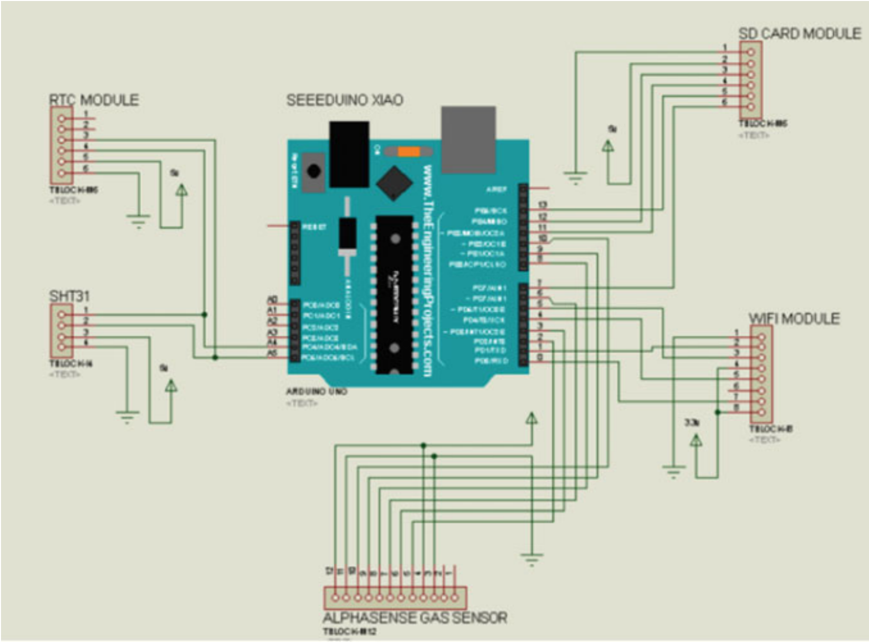


Fig. 24.3 Circuit diagram for the system

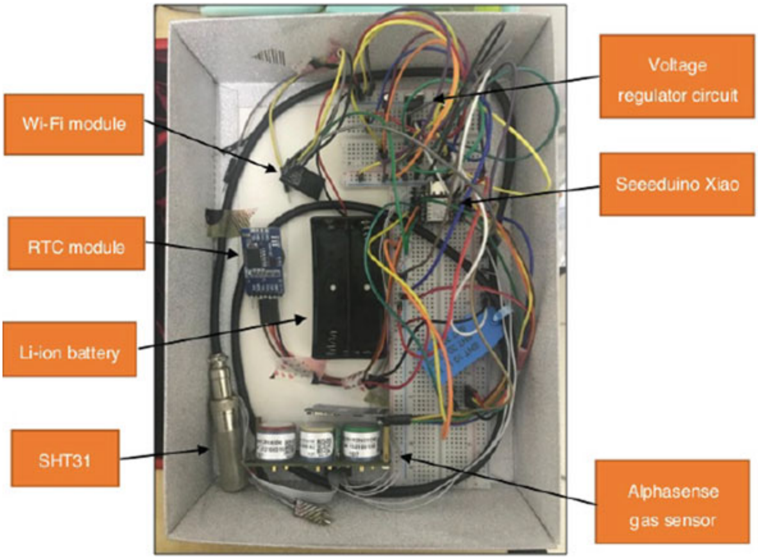


Fig. 24.4 Indoor air quality monitoring system prototype

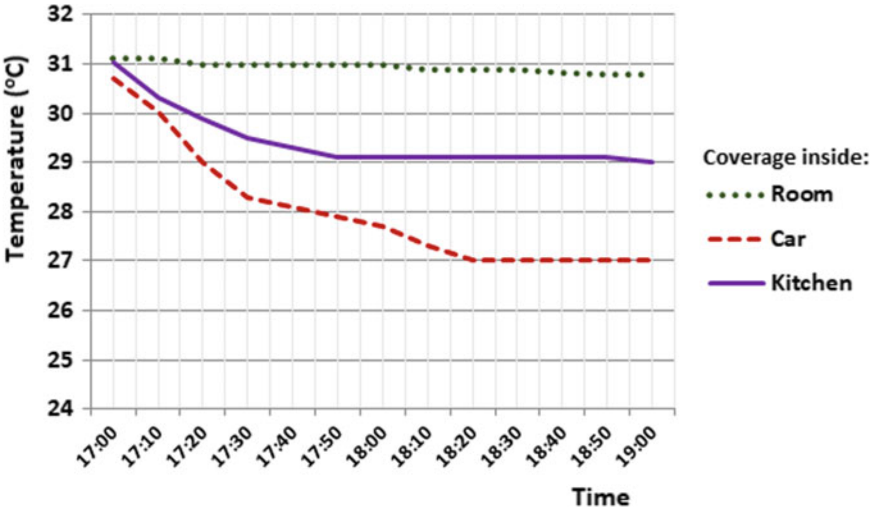


Fig. 24.5 Test results for temperature sensor

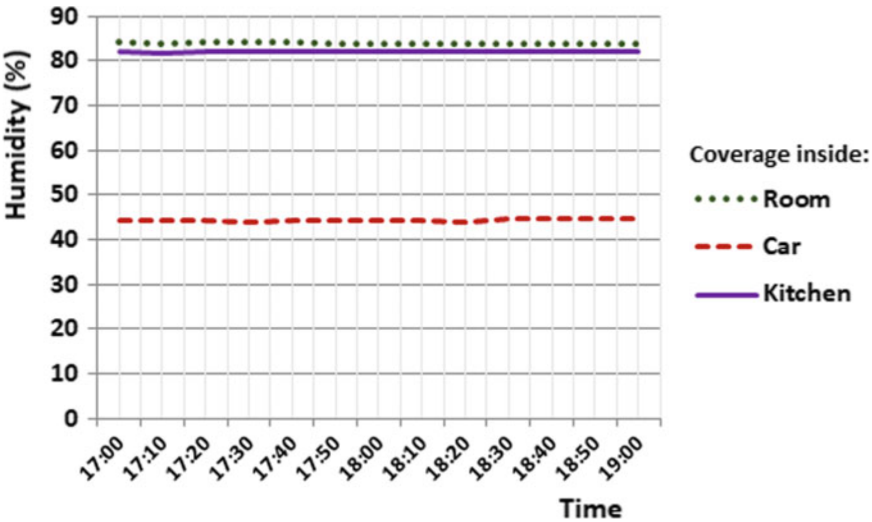


Fig. 24.6 Test results for humidity sensor

percentage show a value approximately similar to the condition inside a room. However, the CO concentration from the kitchen area indicates the highest CO concentration compared to the other conditions from inside the car and inside a room.

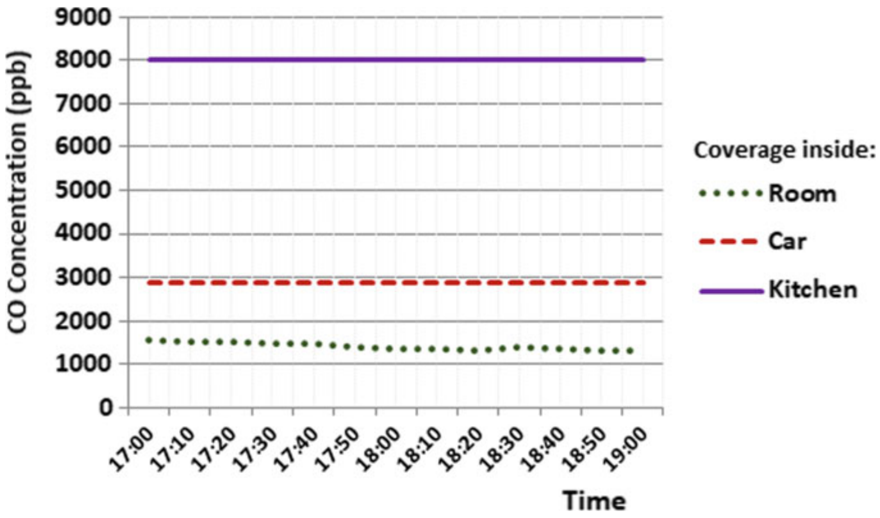


Fig. 24.7 Test results for CO concentration sensor

24.4 Conclusion

In this paper, the development of an IoT-based indoor air quality monitoring system using SAMD21 ARM cortex processor is presented. The implementation by experimenting the system was conducted and demonstrated a suitable performance of the indoor air quality monitoring system. Several valuable achievements of the indoor air quality monitoring system were accomplished, including; (1) efficiently monitored indoor air quality in real-time and at anywhere by using an IoT and Wi-Fi network technologies, (2) the system used SAMD21 ARM cortex processor as a microcontroller was able to cut operational cost of the power consumption by the system and (3) expandable reliability and durability of the sensors used in the system allowing easy platform installation by the user to various appropriate monitoring surroundings.

In the future, further experiment on the precision of the system device will be involved. This paper focused on the reliability function of the system device in which more necessary testing were conducted to ensure data accuracy in long duration periods. Besides, the device can be future improved by connecting automated ventilation system in which the system can operates when detecting the presence of polluted air in surroundings.

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