DEVELOPMENT OF INDOOR AIR QUALITY SUPERVISION SYSTEMS USING ZIGBEE WIRELESS NETWORKS

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ABSTRACT
Air quality has received a lot more attention recently as a result of rising environmental consciousness. In this study, a ZigBee wireless network-based indoor air quality monitoring system is suggested. The created system offers a straightforward method for controlling and monitoring indoor air quality (IAQ) for applications in residential buildings. Several sensors are used in the current setup to detect various gases, including carbon monoxide (CO), carbon dioxide (CO2), and fine particulate matter (PM2.5). Additionally, individuals could see the real-time status whenever and anywhere they wanted by utilising the built user interface APP.
Keywords: ZigBee wireless networks, Remote Supervision System, Indoor Air Quality (IAQ).

I. INTRODUCTION

Wireless sensor networks (WSNs) [1], which have been considered as one of the promising future technologies, has already been widely applied in a variety of fields, including smart home [2], urban transportation [3], industrial control [4], military application [5], and mobile sensing environments [6]. Features such as transmission distance, data rate, security, and battery life are the factors that users mostly care about. Although each kind of network has its own advantages, the energy problem has been one of the critical factors for constructing wireless networks [7]-[8].

As mentioned in [9], Wi-Fi, Bluetooth, and ZigBee are the specifications which were developed for low power consumption applications and have been applied in plenty of domains respectively based on their features. ZigBee [10]-[11], which is also renowned for its low cost, low data rate and long battery life characteristics, has been extensively utilized to create personal area networks (PAN), such as use for home automation, medical health care, and other small-scale projects with wireless connection needs.

In modern society, people are accustomed to staying in indoor spaces for a long time while working, relaxing, or living. Consequently, the indoor air quality (IAQ) [12], which refers to the air quality within buildings and structures, plays an influential role in our health. IAQ can be affected by gases, including carbon monoxide (CO), carbon dioxide (CO2), fine particulate matter (often referred to as PM2.5), and volatile organic compounds, or other microbial contaminants such as mildew and bacteria.

The sick building syndrome [13], introduced by the World Health Organization, is a phenomenon described by people who claimed they have experienced some discomfort effects which appears to be related to the specific buildings they used to stay in. Obviously, poor indoor air quality could cause building occupants respiratory diseases, skin irritation, neurotoxic and other health problems, which means the gases and particulates within and around us, may directly affect our safety silently and imperceptibly.

To cope with this problem, one of the effective ways is to create a space with good ventilation, which helps air to circulate in our room, bringing fresh and clean air inside, and keeping moisture and airborne pollutants outside. However, due to the high cost of related measuring instruments, and the inconvenience of wire distribution, approaches which wired networks formerly took cannot fully solve this issue.

In this paper, we will introduce a system that building occupants could understand the air composition of the room by just taking a look at their own handheld devices such as a notebook, smartphone, or tablet. Moreover, users could alsotake further steps to activate and control the ventilator directly with the user interface we designed. By diluting the concentration of contaminants, it could effectively reduce the potential health risks in such a simple and secure way.

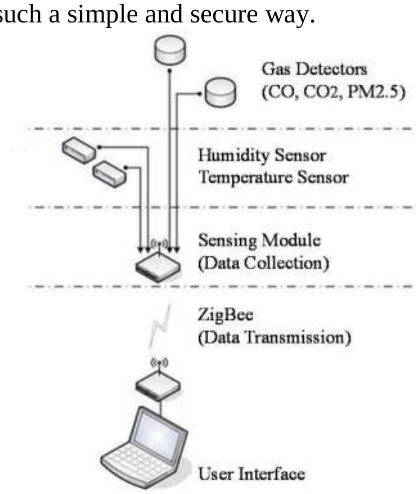

Fig. 1. Proposed supervision system scheme.

II. SYSTEM IMPLEMENTATION

In our design, we combined Arduino board with some gas (including CO, CO2) detectors, PM2.5 sensor, temperature and humidity sensor, and XBee transmitter into a sensing module, as shown in Fig. 1.

Fig. 2 shows the implementation of the supervision system. After collecting required information from the atmosphere, the next step is to transmit the data to our terminal computer via XBee network. Meanwhile, our program will compare the received data with the standard value announced by the Environmental Protection Administration (EPA). Afterward, the system will automatically operate the ventilation system if any figure exceeds the norm so as to refresh the air.

Furthermore, users are able to observe the current status of each item either on PC monitors or any devices that could log on to the internet and then link to a specific website. The overall operating process is shown in Fig. 3.

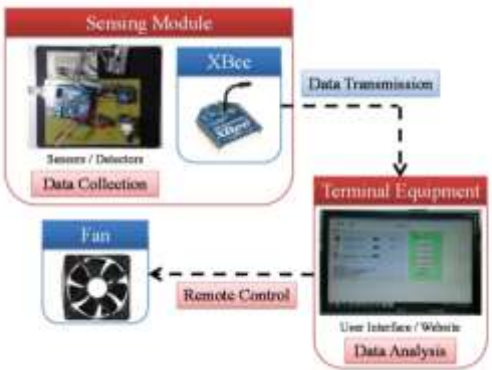

Fig. 2. Implementation of the supervision system.

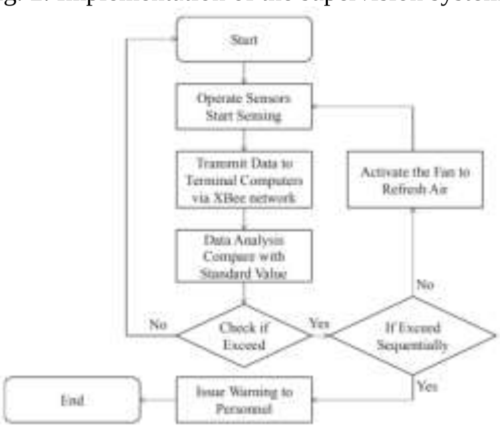

Fig. 3. Flowchart of the operational process.

A. Developed Hardware Platform

The structure of the sensing module is shown in Fig. 4, the Arduino UNO board and Ethernet shield provide users with the option to view the status on the website. Due to its small scale, people could easily find a place for it and quickly set it up.

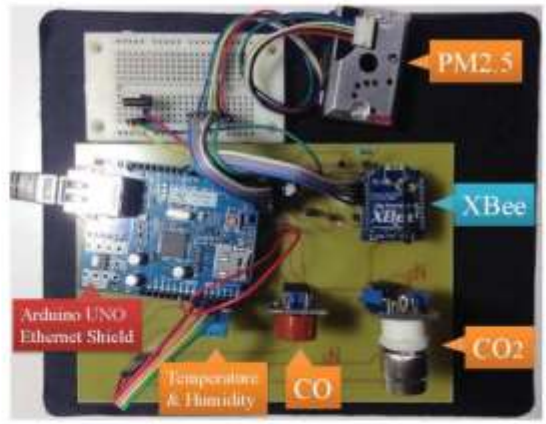

Fig. 4. The developed prototype system.

B. Developed Software Interface

The designed user interface for the computer is shown in Fig. 5. At the left part of the window (blue background) presents the current temperature, humidity, and the concentration of each gas. We divided the potential risk into three levels, including the green color represents safe, the yellow means harmless, while the red stands for danger. The ventilator will be operated automatically except for the safe (green) situation, so as to dilute the airborne contaminants immediately.

At the right part of the window (green background), users are able to remotely control the fan with three different optional speeds, including high, medium, and low speed. The default option is to change its speed automatically along with the variation of those objects.

Fig. 5. The developed user interface for remote monitoring and control.

In Fig. 6 shows the other way to observe the current situation. Users may control the fan speed at the bottom part of the webpage as well.

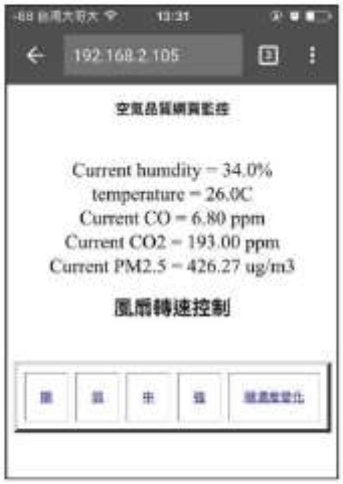

Fig. 6. The developed website for fan control.

III. EXPERIMENTAL RESULTS

A. Application Scenarios

We conducted the experiment in summer, sunny day. The place was in a normal laboratory, and the data were collected within the same period of time, about five minutes. In order to guarantee that if any of the concentration increased, the system could still function normally, we adopted some methods to simulate the situation of increasing of each gas.

For CO, we ignite an incense stick nearby the detector, for burning could generate CO into the air. As for CO2, we exhale to the detector in person, by generating CO2 artificially. For fine PM2.5, we drop a touch of dust on the sensor to stimulate it.

B. Experimental Results

The experimental results of each sensor are shown as follows. Fig. 7 presents the temperature (approximately 28ć) and humidity (approximately 34%~35%) at that time. Fig. 8 shows the variation of fine PM2.5 within the limited time, due to the keen sensitivity of the sensor, the data has changed dramatically. Fig. 9 and Fig. 10 present the variation of CO and CO2 respectively, when the concentration of CO or CO2 increased, the fan also changed its speed at the same time, as shown in Fig. 11.

Fig. 7. Variations of temperature and humidity.

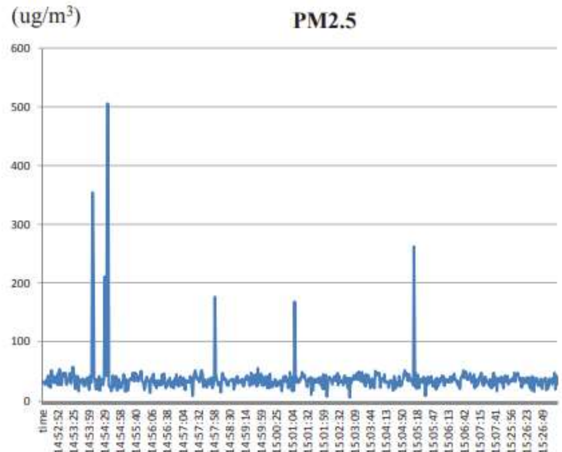

Fig. 8. Variation of fine particulate matter (PM2.5).

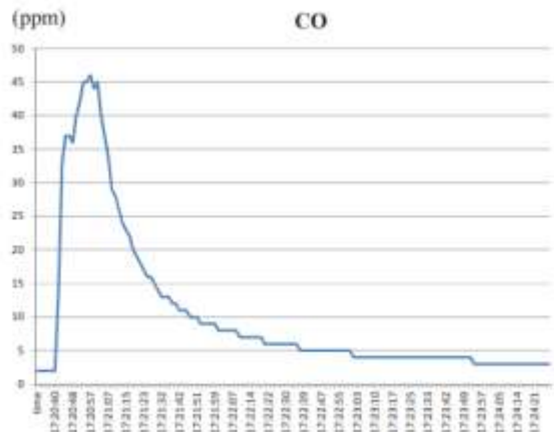

Fig. 9. Variation of carbon monoxide (CO).

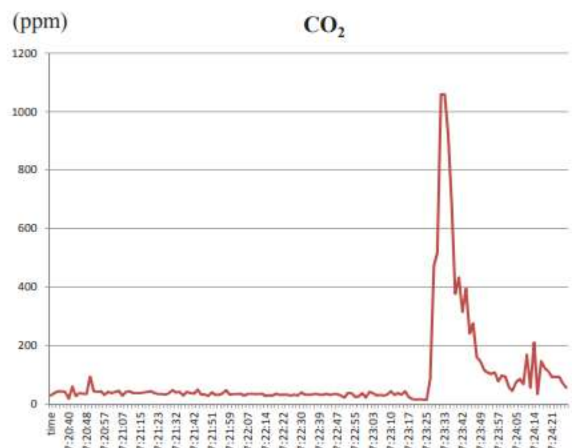

Fig. 10. Variation of carbon dioxide (CO2)

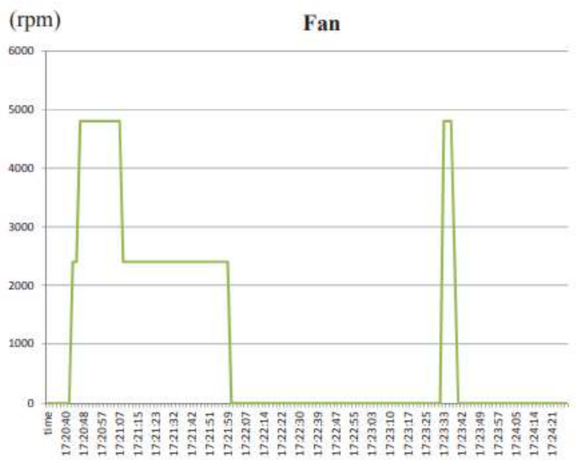

Fig. 11. Variation of fan speed to improve the air quality

IV. CONCLUSIONS

The air pollution problem has become a worldwide issue in recent years, living in a place with poor IAQ is even worse than smoking every day. The main purpose of constructing this supervision system is to provide a simple and secure way for building occupants to protect them from being endangered by the invisible menaces. This system comprises four sensors that could detect different kinds of gases, besides, we apply ZigBee wireless network technology that let users manipulate ventilators remotely, which is much more convenient. Additionally, by using our developed user interface and website, people could check up on the current status anytime and anywhere. Future work includes applying intelligent control approaches into the developed systems and integrating various sensors to achieve a smarter living environment.

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