Development of SMS Gateway Information System for Detecting Air Quality

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Abstract. In present work, an SMS gateway information system for detecting CO, \( \text{O}_3 \) and Particulate Matter (PM) is designed and tested. The prototype of the system is developed using an electronic system with sensors of CO, \( \text{O}_3 \), and PM. The data is transmitted to the microcontroller as an electronic control to provide air quality status further. The prototype consists of sensor of MiCS-5524, MiCS-2614, and GP2Y1010AU0F, ATMega 328 Microcontroller, micro SD LCD data logger and modem circuit for SMS gateway based detection information. The test of the system indicates that CO gas is detected using the MiCS-5524 sensor, \( \text{O}_3 \) is measured using sensor MiCS-2614 and PM is detected using GP2Y1010AU0F Sharp sensor. Based on the result of electronic system test, each sensor has output analog voltage that able is read by ADC feature on a microcontroller with the output voltage \( V_{out} \) or ADC from sensor proportional to a gas concentration that is around the sensor. This prototype can provide information about air status. The response time to the SMS communication system averages about 5 seconds depending on signal quality and data traffic from cellular service providers.

1. Introduction

In general, air pollution is monitored by measuring concentrations of various pollutants such as carbon monoxide (CO), ozone (\( \text{O}_3 \)), and particulate matter (PM) at particular sites by using accurate and expensive instrumentation [1-3]. Site monitoring is determined based on the Air Quality Standards, which defines the minimum number of fixed monitoring stations for each target of the pollutant on the air pollution levels, population, and coverage area. Such sites spread around cities and provide temporal concentrations (typically hourly) of different pollutants. Cities in developing countries might have at least one official monitoring station which covers about 100,000 people as opposed to covering millions of people in cities of developing and highly polluted countries. Table 1 and 2 show air index and standard level of CO, \( \text{O}_3 \), and PM in the air as stated by Environmental Impact Management Agency (BAPEDAL).
Table 1. Index and ISPU categories.

| Index  | Categories       |
|--------|------------------|
| 1 – 50 | Good             |
| 51 – 100 | Neutral       |
| 101 – 199 | Harmful       |
| 200 – 299 | Very harmful   |
| >300   | Dangerous        |

Table 2. Standard air pollution.

| Pollutant     | Standard                                      |
|---------------|-----------------------------------------------|
| Carbon monoxide (CO) | 10 mg/m³ (9 ppm) during 8 hours               |
| Ozone (O₃)    | 235 ug/m³ (0.12 ppm) during 1 hour            |
| Particulate Matter | 50 ug/m³ during 24 hours                     |

However, they are insufficient to provide accurate information about the spatial distribution of pollutants or identify pollution hotspots, and even more insufficient in developing countries. Even though pollutant dispersion models can be used to address this issue, their accuracy is rather limited [4-6].

Recent advancements in the field of sensors, digital electronics, and wireless communication technology have led to the emergence of a new paradigm for air pollution monitoring [7, 8]. The paradigm aims to gather high-resolution spatiotemporal air pollution data by using a ubiquitous network of low-cost sensors for monitoring real-time concentrations of different air pollutants. The data can be then utilized for a variety of air pollution management tasks, i.e. (a) supplementing conventional air pollution monitoring, (b) improving the link between pollutant exposure and human health, (c) emergency response management, hazardous leak detection, and source compliance monitoring, and (d) increasing community's awareness and engagement towards air quality issues.

Several review articles have already addressed this emerging area of sensor-based air quality monitoring. A majority of these articles focus on the needs, benefits, challenges, and future directions of a sensor-based pollution monitoring paradigm for different applications [9].

Traditional approaches for measuring air quality based on fixed measurements are inadequate for personal exposure monitoring. The issues can be solved by the use of small, portable gas-sensing air pollution monitoring technologies is increasing, with researchers and individuals employing portable and mobile methods to obtain more spatially and temporally representative air pollution data. However, many commercially available options are built for various applications and based on different technologies, assumptions, and limitations.

Wireless Sensor Networks (WSNs) consist of small autonomous nodes that have the benefits of being small, efficient relatively low in price. Sensor networks have a major application of real-time monitoring. Latterly, the progress on sensing, processing, and communication technologies have reduced the cost of sensors, made them smaller in size and power efficient. However, the system performances of WSNs are still subject to unit computing speed, memory capacity, and stability of communication, etc. Together the limitations of the hardware, many issues on WSNs software have been discussed, such as routing protocols, media access control, coverage and power management.

2. Material and method

2.1. Design and installation

The SMS gateway system consists of hardware components and software as well, such as a microcontroller, sensors, and battery. The hardware and software used in this work are shown in Table 3. Meanwhile, Figure 1 presents a block diagram of the system. The system has three sensors, i.e., MiCS-5524, MiCS-
2614, GP2Y1010AU0F Sharp for detecting CO, O₃ and Particulate Matter (PM) in the air, respectively. The microcontroller as a function of calculating, filtering and converting the output voltage of the sensors into digital data. The system used a 12-volt battery and had a buck converter circuit with IC LM2576 to obtain the working voltage on a 5-volt circuit system. Also, the microcontroller also served as a 20x4 character LCD controller to display the value of ppm of each gas and store the data gas levels along with the retrieval of data obtained from the reading of RT1 DS7 module on micro SD module once every 1 hour. The last process is to send the CO, O₃ and Particulate Matter (PM) concentration information by SMS automatically.

### Table 3. Hardware and software of the system.

| Hardware                          | Software                      |
|-----------------------------------|-------------------------------|
| Microcontroller ATMega 328 SMD    | Arduino IDE 1.6.5             |
| MiCS-5524                         | Eagle 7.6.0 CADSOFT           |
| MiCS-2614                         | Corel Draw                    |
| Sharp GP2Y1010AU0F                | ISIS Proteus Simulator        |
| Module RTC DS1302                 |                               |
| Module Micro SD data logger       |                               |
| Modem                             |                               |
| LCD character 20x4                |                               |
| Module buck converter LM2576 5 vol |                               |
| Battery 12 volt                   |                               |

**Figure 1.** Block diagram of the system.

2.2. Testing the system

Prior to overall system testing, each sensor is tested to figure out their performance. Once the sensors are work properly, the overall system is tested at three different locations, i.e., location 1, 2, and 3. The data of concentration of CO, O₃, and PM in the locations are collected hourly. The detected level of CO, O₃, and PM are sent to the mobile phone via SMS gateway. Thus, the quality of the air is displayed on the mobile phone, i.e., good, harmful, or dangerous.

3. Result and discussion

Table 4 to Table 6 show the results of individual sensor testing electrically and the display of detected CO, O₃, and PM as displayed in Figure 2. Meanwhile, the result of overall system evaluation for detecting CO, O₃, and PM are given in Table 5.

### Table 4. Measurement of CO level using MiCS-5524 sensor.

| Num | CO level   | Ro    | Vout  | ADC |
|-----|------------|-------|-------|-----|
| 1   | 1 ppm      | 100 kΩ| 0.45 volt | 93  |
| 2   | 1000 ppm   | 1500 kΩ| 0.33 volt | 67  |
Table 5. Measurement of the O₃ level using MiCS-2614 sensor.

| Num | O₃ level | Rs  | Vout | ADC |
|-----|----------|-----|------|-----|
| 1   | 10 ppb   | 3 kΩ| 3.86 volt | 778 |
| 2   | 1000 ppb | 1000 kΩ | 0.04 volt | 8   |

Table 6. Measurement of PM level using GP2Y1010AU0F sensor.

| Num | PM level  | Vout | ADC |
|-----|-----------|------|-----|
| 1   | 0.2 mg/m³ | 1.7 volt | 348 |
| 2   | 0.4 mg/m³ | 3.0 volt | 614 |

The tests were conducted at 3 different monitoring locations. Table 7 shows that the sensor is able to detect CO, O₂, and PM levels at each test site, with an interval of 1 hour. Based on the test results of each sensor has the output of analog voltage read by ADC feature on the microcontroller with the output voltage of the sensor proportional to the concentration of gas around the sensor.

Table 7. Results of overall system evaluation.

| Num | Start | End  | Location 1 | Location 2 | Location 3 |
|-----|-------|------|------------|------------|------------|
|     |       |      | CO         | O₃         | PM         | CO         | O₃         | PM         |
| 1   | 06:31 | 07:31| 19 0.02 0.08| 20 0.01 0.07| 23 0.02 0.08| 20 0.01 0.07| 20 0.01 0.07|
| 2   | 07:31 | 08:31| 18 0.02 0.08| 17 0.02 0.07| 19 0.02 0.07| 20 0.02 0.08| 20 0.02 0.08|
| 3   | 08:31 | 09:31| 17 0.03 0.07| 17 0.02 0.07| 18 0.03 0.07| 18 0.03 0.07| 20 0.02 0.07|
| 4   | 09:31 | 10:31| 17 0.03 0.05| 16 0.02 0.05| 18 0.03 0.06| 18 0.03 0.06| 18 0.03 0.06|
| 5   | 10:31 | 11:31| 12 0.03 0.05| 11 0.03 0.05| 17 0.03 0.03| 18 0.03 0.03| 18 0.03 0.03|
| 6   | 11:31 | 12:31| 12 0.04 0.05| 11 0.03 0.05| 17 0.04 0.03| 18 0.04 0.03| 18 0.04 0.03|
| 7   | 12:31 | 13:31| 10 0.04 0.05| 12 0.03 0.05| 15 0.04 0.04| 18 0.04 0.04| 18 0.04 0.04|
| 8   | 13:31 | 14:31| 9 0.03 0.05 | 8 0.03 0.04 | 12 0.03 0.05| 18 0.03 0.05| 18 0.03 0.05|
| 9   | 14:31 | 15:31| 10 0.04 0.05| 12 0.04 0.04| 10 0.04 0.05| 18 0.04 0.05| 18 0.04 0.05|
| 10  | 15:31 | 16:31| 10 0.03 0.05| 11 0.04 0.04| 14 0.03 0.05| 18 0.03 0.05| 18 0.03 0.05|
| 11  | 16:31 | 17:31| 12 0.03 0.05| 16 0.02 0.04| 16 0.03 0.05| 18 0.03 0.05| 18 0.03 0.05|
| 12  | 17:31 | 18:31| 15 0.03 0.07| 17 0.03 0.08| 18 0.03 0.07| 18 0.03 0.07| 18 0.03 0.07|
| 13  | 18:31 | 19:31| 16 0.01 0.09| 19 0.02 0.08| 20 0.01 0.07| 18 0.03 0.07| 18 0.03 0.07|
| 14  | 19:31 | 20:31| 17 0.01 0.09| 20 0.01 0.08| 21 0.01 0.07| 18 0.03 0.07| 18 0.03 0.07|
| 15  | 20:31 | 21:31| 19 0.01 0.09| 22 0.01 0.08| 24 0.01 0.08| 18 0.03 0.07| 18 0.03 0.07|

Figure 2. Displays on LED screen.
Figure 3 conveys the message content containing the CO, O$_3$ and Particulate Matter (PM) index values detected via SMS. The format used to send the message must match the format specified in the design of the application.

![Figure 3. SMS displays on the mobile screen.](image)

4. Conclusion
The system can detect CO using MiCS-5524 sensor, O$_3$ gas using sensor MiCS-2614 and Particulate Matter (PM) by using the Sharp GP2Y1010AU0F sensor. The sensors based on an electronic test system where each sensor has output analog voltage which can be read by feature ADC on a microcontroller with the output voltage (Vout) or ADC from sensor proportional to gas concentration. The system can provide information with threshold values, GOOD (1-50PPM), MEDIUM (51-100PPM), NO HEALTH (101-199PPM), VERY UNHEALTH (200-299PPM) and DANGEROUS (above 300PPM). The average response time to the SMS communication system is about 5 seconds depending on signal quality and data traffic from cellular service providers. Differences in Vout and ADC measurements are caused by several errors, such as an ADC ± 2-bit output error, rounding ADC conversion error to volt, or due to errors in the measuring instrument used.

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References
[1] Sharma P, Sharma P, Jain S and Kumar P 2013 “An integrated statistical approach for evaluating the exceedance of criteria pollutants in the ambient air of megacity,” Delhi. Atmos. Environ. 70 7–17.
[2] Holmes N S and Morawska L 2006 A review of dispersion modeling and its application to the dispersion of particles: an overview of different dispersion models available.
[3] Kumar P, Ketzel M, Vardoulakis S, Pirjola L and Britter R 2011 “Dynamics and dispersion modeling of nanoparticles from road traffic in the urban atmospheric environment—a review,” *J. Aerosol Sci.* 42 580–603.

[4] Vardoulakis S, Fisher B E, Pericleous K and Gonzalez-Flesca N 2003 “Modeling air quality in street canyons: a review,” *Atmos. Environ.* 37 155–182.

[5] Hagler G S W, Solomon P A and Hunt S W 2013 *New technology for low-cost, real-time air monitoring* (EM Magazine Air & Waste Management Association).

[6] Castell N, Viana M, Minguillón M C, Guerreiro C and Querol X 2013 *Real-world application of new sensor technologies for air quality monitoring* (ETC/ACM Technical Paper).

[7] Snyder E G, Watkins T H, Solomon P A, Thoma E D, Williams R W, Hagler G S, Shelow D, Hindin D A, Kilaru V J and Preuss P W 2013 “The changing of the paradigm of air pollution monitoring,” *Environ. Sci. Technol.* 47 11369–11377.

[8] White R M, Paprotny I, Doering F, Cascio W E, Solomon P A and Gundel L A 2012 “Sensors and 'apps' for community-based atmospheric monitoring,” *EM: Air and Waste Management Association's Magazine for Environmental Managers* 5 36–40.

[9] Departemen Kesehatan 2012 *Parameter pencemaran udara dan dampaknya bagi kesehatan, Depkes* (http://www.depkes.go.id/downloads/udara.pdf). Accessed on March 20, 2016.