Development of air quality mobile tools for observation

I T Hakim¹,², B Budianto¹, GS Immanuel¹, A Rakhman¹, S A K W Kinasih¹, R Boer¹

¹Center for Climate Risk and Opportunity Management in Southeast Asia Pacific (CCROM-SEAP), Bogor, Indonesia
²Department of Geophysics and Meteorology, Faculty of Mathematics and Natural Sciences, IPB University, Indonesia

ikhlastaufiqul@gmail.com

Abstract. Mobile weather stations are needed because of their better coverage balance than stationary stations. Center for Climate Risk and Opportunity Management in Southeast Asia Pacific (CCROM-SEAP) of Bogor Agricultural University (Institut Pertanian Bogor or IPB University) developed a low-cost mini observation system using Espressif ESP32 DOIT Development Kit V1 module, which based on the internet of things (IoT) to monitor real-time meteorological elements (such as temperature, humidity, and pressure), CO₂, PM₂.₅, and PM₁₀ concentration for Bogor (Center of Bogor City). With Firebase (database service by Google) integration, the system records data every 2 minutes and sent automatically to Firebase. We also create an unpublished android application called ServMo for exporting JSON to CSV format. The results show this system has a good performance for real-time monitoring purposes for a better balance of measurements coverage.

Keywords: observation, IoT, atmospheric monitoring, esp32, firebase

1. Introduction

Atmospheric monitoring is used to measuring meteorological elements. It plays a vital role in determining weather changes and is also needed for weather prediction. Atmospheric monitoring has been done by many agencies [1]. In Indonesia, Meteorological, Climatological, and Geophysical Agency (BMKG) is one of the agencies which has installed a stationary observation system. However, there is some limitation regarding the coverage area, the maintenance, and the cost which tends to be expensive. A low-cost mobile observation system is needed to resolve this limitation.

Mobile and low-cost observation has been implemented by world researchers [2-5], and also by one of the Indonesian researchers, Budianto et al. [6]. Budianto et al. already designed mobile atmospheric monitoring system using low-cost sensors (DHT22, MHZ19B, SDS011) and a microcontroller (Arduino Nano). This system is designed to assist in monitoring air quality in near real-time over distributed areas and detecting sources of pollutions at specific points, which leads to better measurement coverage. However, we cannot monitor the result directly because the data is stored in Dropbox and needs to be processed before visualizing.

We developed a system that uses a bit different concept from Budianto’s system. We are using ESP32 DOIT DEVKIT rather than Arduino Nano because it has built-in WiFi and Bluetooth module, so it
doesn’t depend on a smartphone to upload the data like Budianto’s system does. We choose the Firebase database service by Google rather than Dropbox because of its ability to process real-time data while displaying them to a website (which also provided by Firebase) [7]. The website we have built is named servmoccrom.web.app.

2. System Design
We developed this system through two main steps (Figure 1). The first step is receiving measurement data from all sensors and upload it to the Firebase database, and the second step is showing the real-time data to the website.

2.1. Schematic
We use DHT22 for measuring temperature and humidity (white-colored sensor), MHZ19B for measuring CO₂ concentration in ppm (yellow-colored sensor), SDS011 for measuring particulate matter (PM₂.₅ and PM₁₀) (black-colored sensor), and BMP180 for measuring pressure (blue-colored sensor).

Figure 1. The architecture of the system

Figure 2. The schematic diagram of the system
2.2. Firebase upload
The system needs an internet connection to upload the data to the Firebase. Because of its measurement method, the SDS011 sensor needs to go to a sleep state for a while after a successful measure. This sleep state will take about 1 minute, and the measuring state is about 30 seconds. While this cycle happens, the other sensors are measuring approximately every 2 seconds. Thus we are using the average result from every measurement and remove every outlier except for the SDS011 data. Our system can upload directly to the Firebase, so it does not depend on a third party.

![Firebase nodes](servmocrom.default.rtdb > node02_2)

**Figure 3. Firebase nodes**

2.3. Web Service
The web services run using Javascript. It shows real-time measurement in the form of a graph. We can monitor the data directly as an advantage to check the sensors’ conditions (e.g., which sensors need to recalibrate). However, the graphs display the data from when users open the webpage, and users need to keep the page open to tracking the data. Currently, we have three sets of stations to check the sensors’ calibration and keep them validated.

![Real-time graph in website](servmocrom.web.app)

**Figure 4. Real-time graph in website (servmocrom.web.app)**
2.4. Android Application
We are developing an unpublished android application named “ServMo” to create CSV file directly from the Firebase and store it in firebase storage (Figure 5). This is a provisional application, and its purpose is only for creating CSV files. However, it helps us speed up the graphics creation for checking all of the sensors’ results because Firebase only provides an export feature for JSON formatted data.

Figure 5. ServMo app interface

Figure 6. CSV files created by ServMo app

3. Applications
The presence of this system helps spatial monitoring in specific spots and also beneficial for early management systems. Because of its low-cost advantage, this system can be applied to any user including home installation. Figure 7 shows the sensors’ performance and explicitly explains that the concentration of CO₂ is rising because of addition from particulate matter. Figure 8 also shows the comparison between all of the system’s particulate matter measurements, which can be used for validation.

However, this system has some disadvantages regarding its low-cost status. For example, the sensitivity of the DHT22 humidity sensor. The humidity measurement can be stuck at 100% if the capacitive sensor is exposed to droplets or the environment humidity is always high.
Figure 7. System performance

Figure 8. System particulate matter comparison
3.1. Future Development
We are still finding the best solution to achieve the best result and feature from this system. The future possibilities to develop this system as follows:

- Switch the ServMo application with JSON to CSV convert feature in website
- The display of the graph should be historical
- Stability of the system communication
- Manipulate the DHT22 sensor to keep heated with some of electrical use
- We will combine with the air quality monitoring service for more comprehensive information for the future

4. Conclusion
This system presents real-time atmospheric monitoring, which is updated approximately every 2 minutes. The ESP32 board will reduce the cost of Bluetooth and WiFi modules. The Firebase database and storage service by Google helps the system maintain the real-time report for the website.

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