An IoT Based Coastal Weather and Air Quality Monitoring Using GSM Technology

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Abstract. One of Sustainable Development Goals (SDGs) declared by United Nation is Climate Action. Integrated climate change measurement is one of the point in this goal. The solution in this form is low cost and open source hardware to monitor weather and air quality real time. This study goals is developing Arduino platform to monitor wind speed, air temperature, air humidity, and smoke. All circuit board, electronic component specifications, and programming software are open source and freely available for anyone to use and modify. Inexpensive sensors and Arduino Uno were used to develop low cost system. This system send data to Thingspeak as Open Internet of Things (IoT) platform which provide real time data collection, data processing, and data visualization to users. This system provide a low cost solution (system cost around one million Rupiah) to monitor weather and air quality that easily deployed in the desired geographical area. The results are plotted in graphs to ease the users monitor data both locally and remotely. This system use Arduino Uno as main processor, Real Time Clock DS3231 to provide time information, anemometer to provide wind speed, DHT22 used as humidity and temperature sensor, MQ-2 used for smoke detection and CO level, and SIM900 as GSM shield for sending data to server. Results of measurements demonstrate the usefulness of this system in weather and air quality monitoring.

1. Introduction
Climate change is the defining issue in this time and the greatest challenge to sustainable development. United Nation has declared Sustainable Development Goals (SDGs) to achieve a better and more sustainable future for all. One of SDGs is Climate Action. One of the points in this goal is integrate climate change measurement [1]. Coastal area have many set of hazards that can threaten lives, property, and economies. Natural disasters and shoreline erosion are two of the main threats that coastal communities face. Coastal communities are vulnerable to hurricanes, storm, coastal flood, and high winds, these disasters can present major dangers to people along the coast [2]. Monitoring system needed to anticipate and respond to disasters. One of the kind is weather and air quality monitoring.

Weather and air quality data must be collected based on Government Regulation of The Republic of Indonesia number 46 of 2012 concerning on the implementation of meteorological and climatology observation and data management and Head of State Ministry for Environment decree number KEP-107/BAANAL/11/1997 concerning on technical guideline of calculation, reporting, and information standard index of air pollutants. Parameters of weather which should known are solar radiation, air temperature, air pressure, wind speed, air humidity, mass of cloud, rainfall, ocean waves, sea surface temperature, and tides. Parameters of air quality need to be measured are sulfur dioxide, nitrogen oxides and nitrogen dioxide, ozone, carbon monoxide, and chemistry composition in water.

Arduino as open source hardware has been used to produce instrument. One of the reason is efficiency in cost, large community and resources, documentation, and the ability to improve the
system [3]. Arduino has been used to monitor temperature, humidity, light intensity, and smoke [4,5]. Adding wireless communication such as GSM, WiFi, and satellite in the system can be used for sending data to remote server [6–8]. Thingspeak is considered as open Internet of Things (IoT) platform consist of web services for IoT that allow users to connect their instruments and send the data to this service. Thingspeak provide real time data collection, data processing, and data visualization to their users [9].

In this paper, we propose a low cost and open source IoT system which can collect data and send it to server. Data collected in this system are wind speed, air temperature, and air humidity representing weather parameters and smoke represent the parameter of air quality. The objective of this paper is to introduce researchers and practitioners for implement Arduino platform in weather and air quality monitoring applications. Specifically, we 1) describe the Arduino development platform, 2) demonstrate monitoring system developed for weather and air quality monitoring, 3) gather data real time and online in Thingspeak.

2. System design

Weather and air quality monitoring system consist of Arduino Uno, DS3231, anemometer, DHT22, MQ-2, and SIM900. Table 1 summarize components used to measure time, wind speed, air temperature, air humidity, smoke detection, CO level, and sending data to Thingspeak.

This system designed using Open Source Fritzing (www.fritzing.com). This software is free of charge and can be used free. Fritzing used to design pin connection between Arduino Uno with other components. Figure 1 shows the components schematic design of weather and air quality monitoring system. We used Open Source Software Fritzing (www.fritzing.com) to design the pin connection between Arduino Mega2560 with other components. The following sections describe important components of this system and software architecture, including: Arduino hardware and software (Section 2.1); time keeping (Section 2.2); Temperature and Humidity (Section 2.3); Smoke and CO (Section 2.4); Anemometer (Section 2.5); GSM Module (Section 2.6); Thingpseak IoT platform (Section 2.7) and Software Architecture (Section 2.8).

Table 1. Summarized description of the components used in weather and air quality monitoring system.

| Component     | Description                              | Function                                  |
|---------------|------------------------------------------|-------------------------------------------|
| Arduino Uno   | Microcontroller board                    | Manage, arrange, and transmit data        |
| DS3231        | Real time clock module                   | Provide time information                  |
| DHT22         | Digital temperature and humidity sensor  | Record air temperature and humidity       |
| Anemometer    | Wind speed sensor                        | Record wind speed                         |
| MQ-2          | Smoke and CO sensor                      | Record smoke detection and CO level       |
| SIM900        | GSM module                               | Send data to Thingspeak                   |

Figure 1. Weather and air quality monitoring system schematic design using Fritzing
2.1 Arduino Hardware and Software
Weather and air quality monitoring system utilize Arduino prototyping platform as the main core/brain of the instrument. Arduino known as open source platform which developing both software and hardware [10]. Arduino provides an integrated development environment to write, edit code, and convert the code into instructions that Arduino hardware understands. Arduino IDE is based on the Processing language. Arduino board is where the code executed [11]. Generally, Arduino board using Atmel's low-power CMOS 8-bit microcontrollers based on AVR enhanced RISC architecture. as the main microcontroller.

Arduino have a large online community that providing libraries and stimulates engagement in developing open source hardware. Further, a large number of high-grade sensors and devices have custom Arduino libraries and active support from manufacturers for the platform [12]. The Arduino platform has been used successfully in several other similar data collection efforts including water quality via GSM, flood detection, and air quality [6,7,13]. These studies and others shows the ease of use and reliability of arduino platform for open source hardware development.

Arduino Uno was chosen as main board. Arduino Uno based on Atmel ATmega328p microprocessor. This microprocessor was chosen because have an adequate internal memory (flash memory 32 KB, SRAM 2 KB, EEPROM 1 KB) to run the program. ATmega328p has one USART that used for serial.

2.2 Time Keeping
Weather and air quality monitoring system use real time clock DS3231. This module run at 5 V. Maxim DS3231 used to provide time measurement (Maxim Integrated, 2015). RTC3231 library from used for receiving time information to Arduino Uno (Adafruit, 2019). RTC used to have consistent timekeeping that doesn’t reset when the Arduino power supply dies or reprogrammed. DS3231 use I2C communication to send time data. DS3231 SDA pin connected to pin A4 and SCL pin connected to pin A5 in Arduino Uno.

2.3 Temperature and Humidity
DHT22 used as temperature and humidity sensor. DHT22 sensor made of two parts: capacitive humidity sensor and a thermistor. This sensor give output calibrated digital signal. DHT22 operates in range -40°C until 80°C and 0 until 100 RH. This sensor has temperature accuracy of 0.5°C and humidity accuracy of 2% RH. DHT22 resolution around 0.1% RH and 0.1°C. power’s voltage should be 3.3-5.5V. 1-Wire bus is used for communicating DHT22 [14]. maximum error this sensor ranged from 3 to 7% of the real value [5]. DHT22 data pin connected to pin digital 8 Arduino Uno. Adafruit DHT sensor library used to receive DHT22 data [15].

2.4 Smoke and Carbon Monoxide
MQ-2 used as smoke and carbon monoxide sensor. This sensor works at 5 V. MQ-2 composed by micro Al₂O₃ ceramic tube, SnO₂ layer, measuring electrode and heater are fixed into crust made by plastic and stainless steel net [16]. this sensor connected to Arduino Uno pin analog. Mq-2 library from [17] used to convert analog data to smoke and CO level.

2.5 Anemometer
Anemometer used to get wind speed data. Three cup anemometer used because this type give fast and more uniform response. Cup anemometer shows linear behaviour between wind speed and the output frequency of the anemometer [18]. Optocoupler sensor used inside anemometer to calculate the wind speed. Optocoupler sensor produced several pulses. These oscillations of the rotor are transmitted through the shaft to the 18-hole perforated disk.
2.6 GSM Module
SIM900 produced by Simcom company used as GSM module. This module working at 3.2 V – 4.4 V with recommended voltage is 4.0 V. SIM900 communicate with Arduino Uno via AT Commands using serial communication [19]. SoftwareSerial library from Arduino IDE used to provide extra serial communication in Arduino Uno. Pin digital 7 set as transmitter and pin digital 8 set as receiver. SIM900 module used for sending sensors data to server using AT Commands for TCP IP Application Toolkit provided by Shanghai SIMCom Wireless Solutions (2010b). This module connects with Arduino Uno using baudrate 9600 kbps.

2.7 Thingspeak IoT Platform
Thingspeak is an IoT analytics platform service that allows you to aggregate, visualize, and analyze live data streams in the cloud. ThingSpeak enables engineers and scientists to prototype and build IoT systems without setting up servers or developing web software [21]. Device such as Arduino must support TCP/IP, HTTP or MQTT protocols [22]. Arduino send data to Thingspeak channels using write API Key provided in the website. GET method used to send data from Arduino Uno to Thingspeak.

2.8 Software Architecture
I-GAUGE built to achieve goals describe at previous section and can interact with user and server. Figure 2 shows flowchart diagram of Arduino Uno operation in weather and air quality monitoring system. Arduino program begin with serial initialization for usb debugging and GSM module, setting anemometer pin, MQ-2 sensor initialization, DHT22 initialization, and set pin digital 13 as LED output. Then Arduino Uno check RTC DS3231. If RTC not detected then Arduino Uno will print “Couldn’t find RTC” to serial, LED on, and next command will not executed. If RTC detected then time information will retrieved and send to Serial. Next step is checking GSM module. If GSM module not detected then Arduino Uno will print “GSM MODULE ERROR, CONTACT CS!!!”, LED will blink every 500 ms, and next command will not executed. After checking GSM module, Arduino Uno will check the GSM operator. If operator not detected then Arduino will print “ No operator found”, LED blink every 1 second, and next command will not executed. Next step after GSM operator detected is retrieve time information from RTC. Time information will set to the alarm. Alarm will be executed every 5 minutes. Alarm will execute get data function.

Get data function consist of retrieving sensor data until sending to server. Firstly, Arduino Uno will retrieve wind speed data. After that, CO level and smoke level from MQ-2 retrieved continued by retrieving temperature and humidity data from DHT22. Sensors data printed via serial communication. Next step is sending sensors data to server via GSM module using AT commands. After sending data, Arduino Uno will check the time. If time interval already elapsed then get data function will executed. This system firmware available at github https://github.com/ hollandacocobear/Coastal-Weather-and-Air-Quality-Monitoring.

3. Result
Weather and air quality monitoring system successfully installed at Kampung Bugis, Tanjungpinang (Figure 3). Kampung Bugis is a village near coast in City of Tanjungpinang. Figure 4 shows the placement of weather and air quality monitoring system installation. Sensors data visualization from this monitoring system can be access from thingspeak using this link https://thingspeak.com/channels/848384. Figure 5 shows sensors data graph realtime every 5 minutes. User can highlight sensor data point to see the detail of sensor data. Maximum data displayed in Thingspeak 300 data.

Weather and air quality monitoring system were installed from 24 August 2019 until 2 September 2019. Data from thingspeak downloaded into CSV format. From this observation we can see that humidity measure from 67.6 until 99.9% RH. Temperature range from 24.4°C – 35.1°C. wind speed range from 0 – 6.69 m/s. CO level from 0 – 546 ppm. Smoke level from 0 – 3728 ppm.
Figure 2. Weather and air quality monitoring system flowchart diagram.
Figure 3. Location of weather and air quality monitoring system installation.

Figure 4. Weather and air quality monitoring system placement in the location.
Figure 5. Sensors data visualization in Thingspeak Channel. Each sensor data visualize in different graph. Top left visualize relative humidity. Top right visualize air temperature. Middle left visualize wind speed. Middle right visualize CO level. Bottom left visualize smoke level. Bottom right visualize the location of installed instrument.

Humidity decrease from 8 AM until 6 PM. Humidity increase rapidly to 99.9% in the night. Temperature observation shows negative relation with humidity. Temperature decrease from when humidity increase. Relation between humidity and temperature shown in Figure 6.

Based on beaufort scale [23], maximum wind speed measurement (6.69 m/s) was categorized in Moderate breeze with characteristic small waves, becoming longer, fairly frequent white horses. CO level and smoke level still below the threshold from the regulation. CO level and smoke level still in Good category based on Head of State Ministry for Environment decree number KEP-107/BAPEDAL/11/1997. Maximum smoke level reached 3728 ppm. We assumed this happen because there was garbage burning by the local people. The maximum value just happen shortly not in long period.
### Table 2. Statistic parameters from humidity, temperature, wind speed, CO level, and smoke level observed from 24 August 2019 until 2 September 2019

| Statistic Parameter | Humidity (%RH) | Temperature (°C) | Wind Speed (m/s) | CO level (ppm) | Smoke Level (ppm) |
|---------------------|----------------|------------------|------------------|----------------|------------------|
| Mean                | 96.13          | 28.81            | 0.36             | 20.90          | 68.45            |
| Median              | 99.90          | 28.10            | 0                | 1              | 1                |
| Mode                | 99.90          | 27.90            | 0                | 0              | 0                |
| Range               | 32.30          | 10.70            | 6.69             | 546            | 3728             |
| Minimum             | 67.60          | 24.40            | 6.69             | 0              | 0                |
| Maximum             | 99.90          | 35.10            | 6.69             | 546            | 3728             |

Figure 6. Humidity (blue line) and temperature (orange line) comparison from observation data.

Thingspeak have strength is an open source platform and free to use. Thingspeak also have some feature like have free API and free logging. Thingspeak can make very easy for visualization of collected data using line charts. API thingspeak are therefore able to be integrated with any hardware device, including Arduino, Raspberri Pi, and any micro-controller. Another benefit of having an open source API, free hosting, and usage of HTTP POST and GET for the data is relatively easy for newcomers to web technology [24].

Weakness of Thingspeak are some feature is not free, so the user of thingspeak must able to upgrade their account to get more feature, limit data for a channel API, and make a custom graph need some web coding knowledge is needed. Another difficulty is ThingSpeak community is only moderately active. As a consequence, if one needs technical help from others in the community, it may be frustrating to wait a relatively long amount of time to receive a response [24].

Based on weather and air quality monitoring system have been developed, challenges need to be done is having sustainable energy to make this device works in remote area and make a shared standard for the description of sensors and devices interface so interoperability can be made.

From this study, we can see the future of IoT to help human get environmental data real time and can be accessed anywhere. With IoT we can save cost of implementation, deployment and maintenance by providing detailed measurements and the ability to check the status of devices remotely [25].

### 4. Conclusion

In this research, a weather monitoring system and air quality have been successfully carried out. The goals are to develop an Arduino platform to monitor wind speed (anemometer), air temperature and air
humidity (DHT22), and smoke detection (MQ-2). Data collected every 5 minutes and was carried out for 10 days (24 August 2011-2 September 2019), where every day data collection was carried out for 24 hours. From the measurement results it is known that the increase in humidity occurs at night, and inversely proportional to the temperature. If the humidity rises, the temperature will decrease, the increase in humidity occurs at night (99.9%).

The system developed is based on a low cost system, using an Arduino Uno microcontroller and sensors that are used to retrieve the data needed. Data is taken in real time and sent to the cloud through an IoT (internet of things) based application called Thinkspeak. Data that has been retrieved continuously in the process, which can later be seen by users directly anytime and anywhere using the internet network. In the use of Thinkspeak, if you want to make the most of it, you can upgrade, so that the previously locked features will open and the data that has been processed in more detail.

5. Future Work
Based in this study, development of low cost and open source weather and air quality monitoring system will expanded in other location to give more data in other location. This data will be useful for people near the coast, researcher, and government. Study on battery and solar power will be the focus of next development to provide a device which can give data real time and continuous.

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