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IoT-Based Air Quality Device for Smart Pollution Monitoring

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Abstract: IoT-based Air Quality Device for Smart Pollution monitoring is built to replace traditional way of air quality monitoring methods of broadcasting the information to the public. This project proposes the IoT and Wireless Sensor Network (WSN)-based air quality monitoring system. The system must adopt the standard Air Pollution Index (API) and use the MQ135 gas sensor to detect multiple air gas concentrations. The device can connect to the internet using NodeMCU ESP8266 Wi-Fi module to store data collected in a cloud-based system. The data 00will be shown on any mobile device using the Blynk framework in the form of line graph visualization. The program will use social media to pass on air pollution data to some region when that area hits the unhealthy level of air pollution.

Keywords: Air Quality Monitoring, NodeMCU ESP8266, Air Pollution Index, MQ135 Gas Sensor, Blynk, Twitter

1. Introduction

The good air quality can be described by the condition of environments' air clean and free from pollutants such as smoke, dust, and smog. A person inhaling approximately 11000 litres of air each day on average [1]. It can affect the health of individuals if toxins are present in this air [2]. If air pollution reaches high concentrations, people's health, crops, ecosystems and natural resources will be at risk. Around the populated area, air pollution becomes a concern for the environment. Heavy transport, urbanization and development in the industrial sector have led to the accumulation of air pollutants in a particular location. Vehicles responsible for 65.0 % of pollutant, stationary source produce 21.0 % and area sources contributes 14.0 % of pollutions [3]. That include dangerous substances, such as LPG gas, smoke, carbon monoxide, and methane [4]. That kind gas will damage lung and give a heart disease even within indoor environment [5].

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Several studies have shown that people spend up to 90.0 % of their time in enclosed spaces such as workplaces, classrooms, homes and shopping malls where air can easily penetrate [6]. Subatomic air pollutants can slip through the body's defenses and accountable for the death of 7 million persons worldwide each year or one in eight premature deaths yearly [7]. Pollution exposure causes bronchitis, cardiovascular infections, influenza, lung and exacerbated asthma [8]. The cause can trace toward crowded high construction and heavy transportation [9]. Authorities need to take action of the exposure pollution [10]. This project was developing the IoT (Internet of Things)-based Air Quality Monitoring System, which uses the Internet to monitor pollution on a web server and software applications in order to provide easy access and easier to operate. Based on MQ135 gas sensor that detect most of dangerous gas and continuously sending the data to the cloud for certain event trigger to alert the public about the pollutions.

2. Literature review

The air quality monitoring applied in many platforms. There were many types of gas sensors, microcontroller and indicators. IoT-based product air quality monitoring is still in the early stage of development as most papers have been released in the last year. Most researchers have used the Internet of Thing (IoT) concept to provide cloud information to ensure that real-time data are monitored. If the information reaches the dangerous AQI level, the sensor nodes are to send a signal to indicator devices.

2.1 Air Quality Sensor

Air quality sensors are instruments that measure the presence of air pollution in the surrounding area. These can be used in indoor and outdoor areas, which can be designed at home or acquired for some factories. There are different types of air quality sensors some of which are specialized in certain areas, most of which focus on five components; ozone (O_3), sulphur dioxide (SO_2), benzene, nitrous oxide (N_2O), and carbon monoxide (CO). Sensors in the past been very expensive, but these sensors become more accessible and wide-ranging throughout the community as technological developments occur. There are several types of air quality sensor can be used for monitoring the air pollution.

Table 1: List of type air quality sensor for monitoring

No.	Type of air quality sensors	Details	Picture
1	Metal oxide sensors	This metal-oxide sensor operates by measuring the air particles as they respond to the sensor surface, allowing the resistance to be measured. Using small ceramic plate and heat to a certain temperature and time, the plate will detect the resistance in air. MQ135 in Figure 1 was the most used sensor for air pollution monitoring. There other MQ-series sensor used for previous project such as MQ2 and MQ7 but MQ135 already cover for both sensors [1 - 5], [7, 8, 10]. There were also MiCS-5525 sensor that use Metal Oxide architecture. [9]	 **Figure 1 : MQ135 gas sensor**
2	Optical particle counters	This Optical particle sensor using light for emission detection. The sensor tests the dispersion of light by the ions of pollutants. Some specialized optical sensors are used to detect lethal harmful gases, such as carbon monoxide, or	

	particulates, such as carbon dioxide, by measuring infrared light absorption rather than visible light dispersion. Based on Figure 2, while this sensor had high sensitivity and stability, but it much bigger and expensive compare to some sensor. [4]	 **Figure 2 : ZH03A laser dust sensor**

2.2 Microcontroller

Microcontroller is a system that operates with SoC (System on Chip) and programmable option as a small computer. The MCU (Microcontroller Unit) also consists of one or more processor cores, embedded with memory and programmable input/output (I/O) peripherals. Microcontroller is a computer that controls another device to automatically produce the desired performance.

As the technologies are increasing, the microcontroller became smaller and multifunction in single board. To integrate with IR 4.0, most of microcontroller have an option to connect to the internet within single chip or additional option for MCU. There were multiple common MCU that use for IoT function and way to connect the device to the cloud.

Table 2: Types of Microcontroller

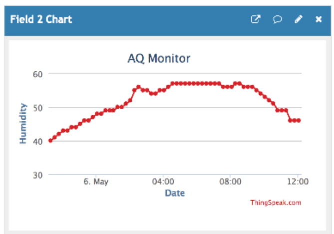
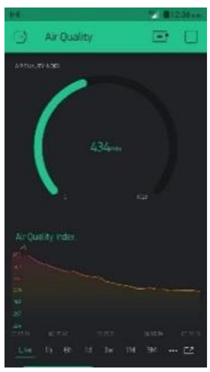
No.	Type of MCU	Description	Picture
1	Raspberry Pi Board	Most models are equipped with a Broadcom control system (SOC) with a processor-compatible GPU, ARM-compatible and CPU processing units. The speed of the CPU varieties varies from 700 MHz to 1,2 GHz for the Pi 3. In Figure 3, latest model board have 4 USB ports, video projection, HDMI and audio jack 3.5 mm. There is Wi-Fi and Bluetooth in some models. [5], [6]	 **Figure 3 : Raspberry Pi model 3**
2	NodeMCU Board	The NodeMCU in Figure 4 is an ESP8266/ESP32 Wi-Fi built-in TCP/IP protocol stack SoC that provides any microcontroller with connectivity to your Wi-Fi network. The platform is based on open source eLua projects. This is programmed using the Lua scripting language. The platform uses a large number of open source projects, like lua-cjson, spiffs. It also can be program through Arduino IDE with additional library. [4]	 **Figure 4 : NodeMCU ESP8266 v2**

3	Arduino Uno	A microcontroller based on the ATmega328P Microchip is an open-source microcontroller device. The board is designed with digitals and analog input/output pins, which can be interfaced to various boards and other circuits. Based on Figure 5, Arduino Uno don’t have any integrate wireless module. This mean Arduino Uno need to connect to external Wi-Fi module to use IoT system. The board has 14 digital I/O pins (six of which are capable of PWM-output). It can be program using Arduino IDE platform. [1, 2, 7, 8]	 **Figure 5 : Arduino Uno v3**

2.3 IoT Platform

IoT platforms are responsible for ongoing management and data viewing tasks to automate users ' environment. IoT platforms are often referred to as middleware solutions for IoT. Generally speaking, IoT or M2 M solutions are a mix of multi-vendor functions. Different platform had a different ability to function. The platform can in form of web-based or application.

Table 3: Types of Microcontroller

No.	Type of MCU	Description	Picture
1	ThingSpeak	ThingSpeak is an open source IT app used for internet storage and collection of data from sensor nodes and sent via Internet or a local area network using the HTTP protocol. ThingSpeak is a computerized network application and perform the analysis from data collected and display it in graph on webpage. Based on Figure 6 can plot the graph based on data received. [3 - 5], [7]	 **Figure 6: Example interface ThingSpeak webpage**
2	Blynk	Blynk software for the Things Internet. It can run hardware, display data from the sensor, store data, and view data remotely. Blynk application enables users to create incredible interfaces shown in Figure 7 with various control widget tools for projects. All mobile and hardware communications are responsible for sending data through Blynk server. The platform use for Blynk is application that can be install on IOS or android system. [8]	 **Figure 7: Example Blynk application interface**

3. Methodology

The design of this project was been made according to the objective. Using a simple and low-cost Metal-oxide sensor, MQ135 gas sensor that can detect various of gases including NH_3,NO_x, alcohol, Benzene, smoke,CO_2 ,etc. The microcontroller used was NodeMCU ESP8266 with integrated Wi-Fi module that can connect to Blynk server as IoT platform. The data viewed on smartphone using Blynk application. The detail process can be shown in flowchart in Figure 8.

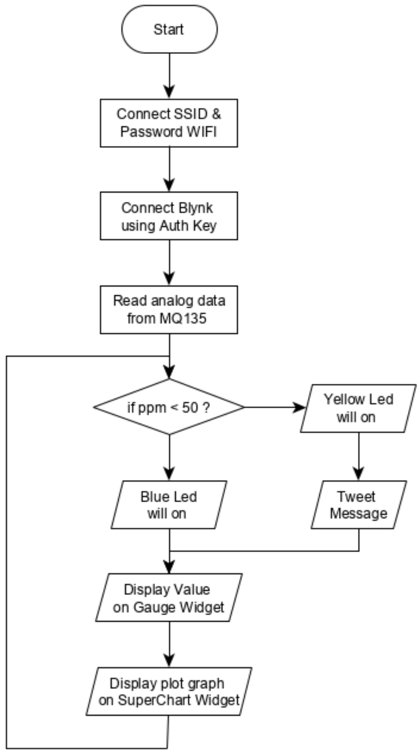


Figure 8: Flowchart of the IoT Air Quality Monitoring System

Based on Figure 8, the flow of the project starts with the power source of the project which use 5V power from any power source that use micro-USB type B. When the plug-in the power, the project will be running the program instantly. The program was start with connected to Wi-Fi connection using a set of SSID and password. Then it will use the auth key given by Blynk application that will connect with this project application interface. The MQ135 gas sensor will read constantly without any delay and sent to Blynk server. The data can be view live or can past information that collected. If the reading value surpass the 50 ppm (moderate air), it will turn on the yellow LED while if the reading below 50 ppm the LED will stay blue. Then the data will trigger the tweet bot and tweet the warning message for it spread the news. The value will keep display on gauge widget while the SuperChart widget will plot the graph of collected data. The process for this program will keep in loop until the user unplug the source power.

3.1 Block Diagram

The air pollution is monitored by the system based on Figure 9. The system will be updated frequently by sending real-live data using MQ135 gas sensor through NodeMCU to Blynk Application. The data read will be store and plot on Blynk Interface application. The Blynk will save the collected information in their server. So, it can monitor and view the information about pollution at that place anywhere via the internet. The Blynk software also tracks the latest emissions level.

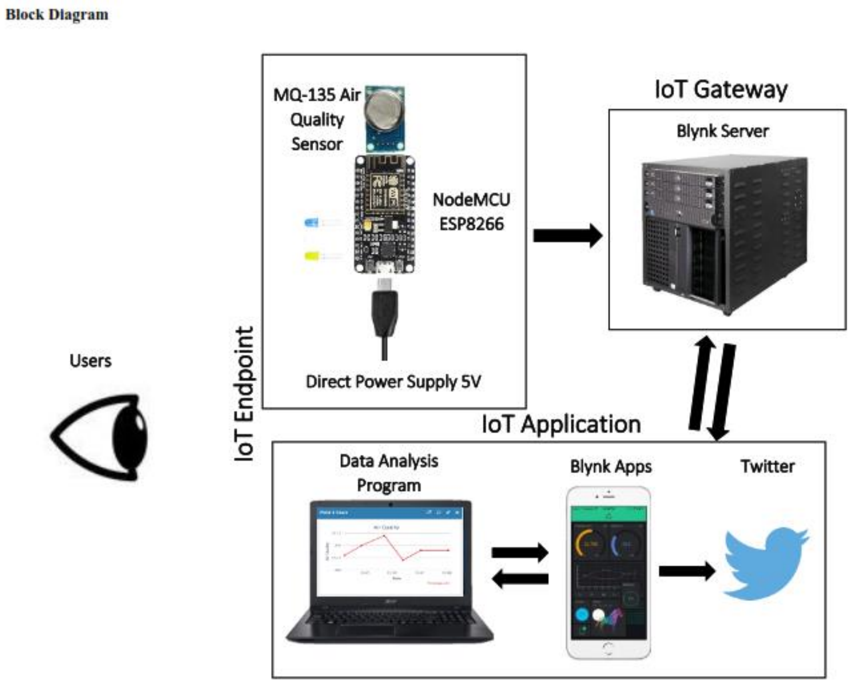


Figure 9: Block diagram of Air Quality Monitoring with IoT

In Figure 9, block diagram shows that MQ135 gas sensor and 2 LED which one indicate good air and another to indicate unhealthy air. Both LED and MQ135 will connect to NodeMCU board. The data from sensor will indicates which LED will turn on. It also connected to Blynk server through internet an analysis the data. The other indicator is by using Twitter account that will be announce through tweet the when particles in air become dangerous.

The measurement of the dangerous gas will be based on API. Based on Figure 10, the API using simple measurement with the value in ppm which indicate the level of pollution on Air. The API focus on four pollutant index component which is Atmospheric aerosol particles, carbon monoxide, ozone, nitrogen dioxide and sulphur dioxide.

API	Air Pollution Level
0 - 50	Good
51 - 100	Moderate
101 - 200	Unhealthy
201 - 300	Very unhealthy
301 - 500	Hazardous
500+	Emergency

Figure 10: The Air Pollution Index levels precautious level

3.2 List of materials

The IoT for this product serves as a monitoring device for the air quality. Tracking air quality using IoT technologies requires learning how to use applications as well as hardware. Microcontrollers, sensors (gas sensors) and modular Wi-Fi systems, connecting to IoT Cloud based on an analysis of the inputs, are the main device used. The device and software details can view in Table 4.

Table 4: List of require material

No.	Components	Function	Specification
1	NodeMCU ESP8266 v2	Its use to control data as programmable board that integrated with ESP8266 Wi-Fi module. This board ease to use and can be program through Arduino IDE. The board can connect to internet without additional component.	NodeMCU is an open source IoT platform with a firmware running on ESP8266 and an ESP-12 module-based hardware. The device has a 4 MB flash memory, an 80MHz system clock, a 50K usable RAM and a Wi-Fi transceiver on the chip.
2	MQ135 gas sensor	The MQ135 use metal-oxide plate. MOx plate use heat as a gases detection. By heating the plate, the gasses react to the plate resistance and later convert it into voltage output.	The MQ 135 gas sensor use 5V and can use both analog and digital pin. This MOx Gas sensors are used to detect or measure NH3, NOx, Alcohol, Benzene, Smoke, CO2 in air quality control equipment.
3	Blynk Application	IoT platform using widget as tool to conduct application on data collected. It can be used to trigger the indicator or use to save data into a graph.	The Blynk Platform use application that can be installed on any IOS and Android devices.

3.3 Software development

The developing program for this project used the Arduino IDE to program the NodeMCU ESP8266 v2 by using ESP8266 and MQ135 library. The program was structured to connect to the certain Wi-Fi connection and connect directly to Blynk server at default gateway. The data will continuously update on Blynk server with 1 second delay for each. If the air value in a certain range, the LED will indicate about the surround air pollution.

a

```
#define ANALOGPIN A0 //Pin MQ135 gas sensor
#define RZERO 510.75 //Calibrate value
MQ135 gasSensor = MQ135(ANALOGPIN);

int n; //Raw data from MQ135
float rzero; //Calibration value
float ppm; // The gas in PPM Value
```

b

```
ppm = gasSensor.getPPM();
delay(1000);
Serial.print("The ppm value : ");
Serial.println(ppm);
led();
```

Figure 11: Coding in Arduino IDE (a) The calibration value and the raw data (b) The real value for measuring gas in PPM

The program code using ESP8266 library for board installation and choose ESP-12E module as board. The library included the Blynk apps and MQ135 sensor. The Blynk library was to set up a connection between NodeMCU board with Blynk server. This connection uses the internet connection as a medium to exchange the information. The MQ135 library was used to get and converted raw data to actual gas concentration reading. In Figure 11(a), the calibration value will be stated. The sensor was heated for 24 hours to expose the gas to the plate and collect the calibration value within the room temperature for half an hour. The actual can be read use a set of instruction shown in Figure 11(c).

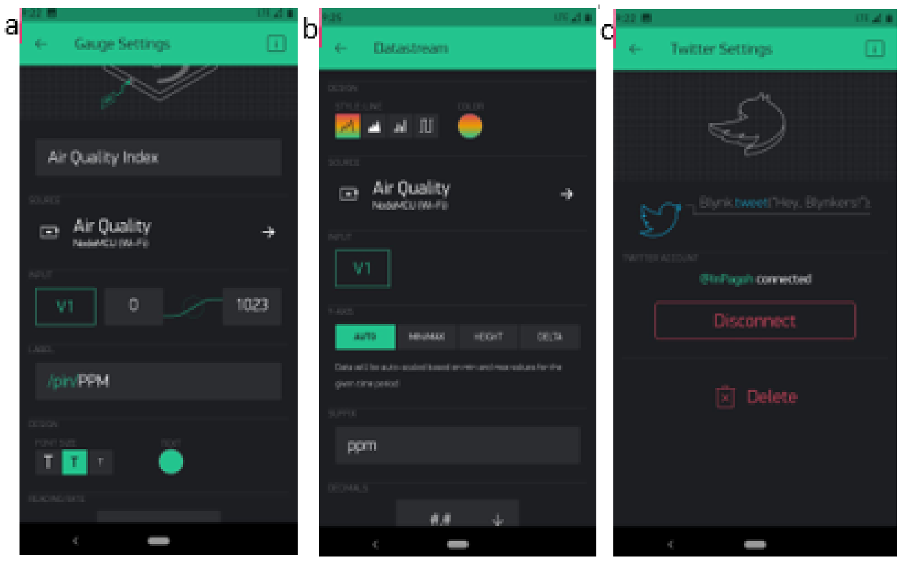


Figure 12 : Blynk widget setup (a) Setting for Gauge Widget (b) Setting the visual graph (c) Connect to Twitter account in Blynk application development

Blynk application setup will use the auth key that given through email and used that key in Arduino IDE program. When connect to internet, the NodeMCU will continuously sending data from analog pin (A0) to the virtual pin (V1) setup in Blynk widget tools in Figure 12(a). The data collected will put into visualize graph that plot for every data sent. The graph also connected with virtual pin set up as shown in Figure 12(b). The event trigger when the input from the sensor reach a certain value, the Twitter widget will connect to the Twitter account shown in Figure 12(c) and tweet about the dangerous level at a certain area.

4. Result and Discussion

The product was tested, and it was successful but there was limitation on this project. The sensor working fine on detecting the gases, but it lacks in accuracy of concentration gas in Particles Per Meter (PPM). The program setup was successful as the data continuously sent the data each one second and plot it on the graph in Blynk application. The event was created when the air pollution value surpasses 50 ppm, the connected Twitter account will tweet the dangerous message act as medium to warn the public about air pollution on the area.

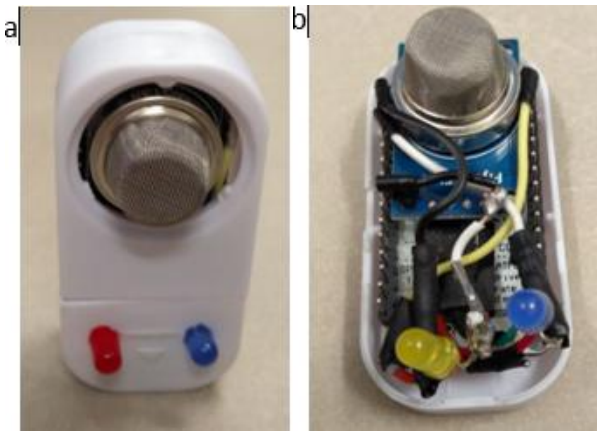


Figure 13: Hardware design (a) Full cover casing (b) Circuit inside the casing

The final product hardware consists of NodeMCU ESP8266 Devkit, MQ135 sensor, and two LED. The size of casing for the circuit was 6cm x 3cm x 2cm as shown in Figure 13(a). The circuit was connected though cable directly as shown in Figure 13(b). The MQ135 is put in a portable small case within NodeMCU. LEDs used for indicator for good and bad air quality.

Figure 14: The Blynk software interface (a) The reading of usual air environment (b) The reading detected harmful gas (Ethanol)

The interface for Blynk application consists the display value (Gauge) widget, Visual Graph (Chart) widget and Twitter Bot Widget. The data that collected through can save as .csv file for further analysis. Based on Figure 14(a), the reading of the air in room without any concentration of harmful gas. It the show the real-time data collected for plotting the graph. When tested using the ethanol or alcohol on MQ135 gas sensor, the reading was rapidly rising above unhealthy level on API as shown as Figure 14(b). This project used Gauge and Superchart widget to view a real-time data by created the push setting to send the data for every second.

Figure 15: The tweet message when triggered

Twitter account was connected through Blynk by using Twitter Application Programming Interface (API). This had been added through widget Twitter from Blynk function. The Twitter message will trigger when the reading value reach 50 ppm. The program will automatically tweet a message such in Figure 15 to warn about condition of air pollution.

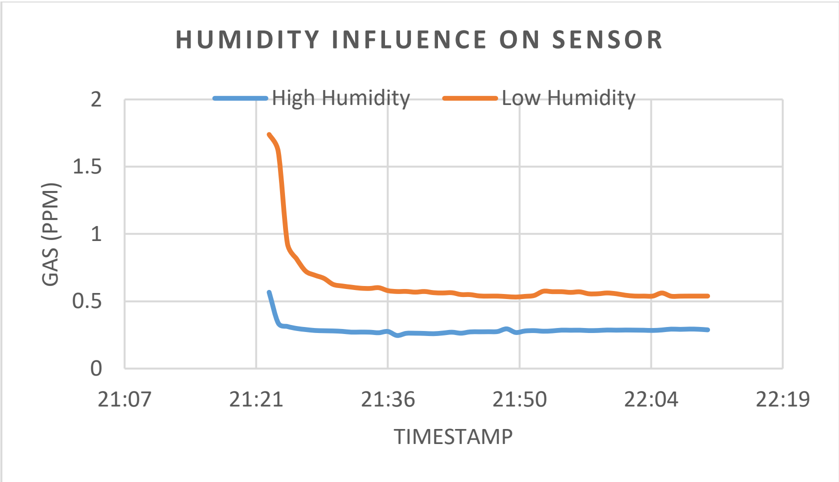


Figure 16: The influence of humidity toward sensitivity of gas sensor

Based on Figure 16, the value of the air pollution index used by MQ135 gas sensor depend on temperature and humidity in air. The reason of this affect the accuracy was the MQ135 sensor using heat as a method for detecting gasses in air environment. By heat up the sensor, the value can be derived by reaction of burned gases toward the heat plate. The high humidity can lower the value reading while the lower humidity can affect of higher reading of MQ135 sensor.

Table 5: Concentration value for different type of gasses

No.	Type of gasses	Test object	Concentration value (ppm)
1	(Carbon Dioxide) CO_2	Car	252.1
2	Alcohol	Perfume	346.7
3	Butane	Lighter	429.3
4	(Nitrogen Oxide) NOx	Cigarette	178.8
5	Smoke	Burning paper	220.9
6	Aerosol	Mosquito repellent	310.9

The MQ135 can use to detect several harmful gasses. Based on Table 5, the different gasses have a different and various concentration. The sensitivity also can be affected by type of gasses. This test was conduct using home appliance that produce the gas. The exposure of these gasses was test in duration of three second. Based on the standard API level in Figure 10, the data collected during tested was surpass the unhealthy level. The cause of this gasses was harm to human body and also environment.

5. Conclusion

The air quality detector is very important to human nowadays because the air became more polluted as the industrial and transportation became a norm. Air particles was hard to detected and very dangerous for to surround environment. As the sensor for air quality became more available and cheaper, the engineer can design and develop the air quality product that can help monitoring and prevent the surround air. By using this air quality devices, the user can prevent or control the dangerous particles in air. The device was designed to be portable and ease to use compare to standard air quality detector which have a bigger size. The size for this product was reduce to 60.0 % and can be carried in the pocket. It can use to detect a different type of gasses that harmful human whenever or wherever. Even with the good air quality detector, the data must also need to be inform to the public with delay and efficient. By using this project, the air quality level can be view and share instantly in a new growing media outlet, social media. This can help the delivering information immediately and assume that 92% user retweet for the first hour, the news will spread more efficient compare to the traditional way of news. Therefore, this project was designed to achieve the minimal cause from air pollution for environment. By connect the hardware and virtual world, the data can be exchange and analysis for better outcome for earth environment.

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