Smart Indoor Air Pollution Monitoring Station

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Abstract— **The term "Air Pollution" generally refers to the outdoor air pollution, mainly caused by combustion of fossil fuels by industrial plants, smog, and emissions from cars and trucks. But the air indoors can also be polluted. Indoor air pollution refers to the contamination of indoor air. It may cause harmful health issues. The main sources of indoor air pollution are pesticides, chimneys which contain pollutants such as particulate matter, biomass smoke, fireplaces, moulds, and environmental tobacco smoke. The pollutants are nitrogen dioxide(NO2), Ammonia, sulphur dioxide(SO2), radon, carbon monoxide(CO), carbon dioxide (CO2) and benzene. In this Internet of Things(IoT) project, wireless air pollution monitoring system is built, which sends alerts to the user by using the Internet, when the concentration of pollutants measured goes beyond safer level. This system can be preferred over the existing systems because the alerts sent by the system can be received by the user on mobile phone from any distance irrespective of whether it is connected to the Internet. The microcontroller used is the NodeMCU Dev board v1.0 which consist of ESP8266, Wi-Fi enabled chip. The sensor used is MQ135, air quality sensor, which along with microcontroller can be used to monitor the pollution indoors.**

Keywords—Indoor Air Pollution, IoT, NodeMCU

I. INTRODUCTION

Most of the human life is spent indoors, either at home, jobs or at schools. The air at these places must be properly monitored, as it is inhaled by human beings in large amounts during respiration. Indoor air pollution refers to the degradation of air at indoors [1], [2], [4]. The main sources of indoor air pollution are biomass smoke, fireplaces, stoves, biological contaminants like pollen, household products, moulds, chimneys which contain pollutants such as particulate matter, nitrogen dioxide(NO2), sulphur dioxide(SO2) and carbon monoxide(CO), pesticides, materials used in the buildings such as asbestos, formaldehyde and lead [2], [3]. Most of the indoor air pollution is of human origin and measured in OLF units (emission rate of air pollution from a standard person) [5]. In reality, 15% of the indoor air pollution is caused by humans and 85% from non-human sources [5]. Some other pollutants are radon, environmental tobacco smoke, Ammonia, carbon dioxide, and benzene.

It has adverse effects on health, i.e., exposure to high concentrations of certain pollutants may cause immediate death. According to WHO, nearly 2 million people die every year, prematurely, due to diseases caused because of usage of solid fuel [6]. Almost 50% of pneumonia deaths in children are due to particulate matter inhaled from the indoor air [6]. A lot of people die from chronic obstructive respiratory disease (COPD) that develop due to exposure to indoor smoke [6]. Indoor air pollution may cause several diseases like lung cancer, flu, respiratory irritations, loss of coordination, asthma, and allergic reactions [2]. Due to the serious effects caused by Indoor Air Pollution, there is a need for it to be monitored and controlled.

The CO2 level in air exhaled by humans is about 38,000 to 48,000 parts per million(ppm) [7], [8]. Since predictable levels of carbon dioxide is exhaled by people in the indoors, its amount in the indoor air can be used as a significant indication of the quality of air [9]. The adequacy of the supply of fresh air is often assessed by the level of CO2 in a room. An indoor CO2 concentration of less than 1000 ppm indicates the fresh air supply [10], [11]. The main sources of CO2 are human metabolic activities and combustion sources [5]. Some other sources are kerosene, gas space heaters, and tobacco smoke. This IoT project uses Air quality sensor MQ135 to monitor the air pollution in its surroundings. According to the datasheet of MQ135, the sensor is sensitive for CO2, Alcohol, Benzene, NOx, and NH3 [12]. But CO2 is the fourth most abundant gas in the earth's atmosphere with a concentration of about 350 ppm. This concentration is much higher than all the other gases the sensor detects. So, with the proper calibration of the sensor, the sensor can detect CO2 in the normal atmosphere.

TABLE I
CARBON DIOXIDE LEVELS AND HEALTH PROBLEMS [13], [7]

Concentration	Effect
250-350 ppm	Normal concentration in outdoor ambient air
350-1000 ppm	Concentrations of occupied indoor spaces with good air exchange
1000-2000 ppm	Poor air and causes drowsiness
2000-5000 ppm	Stagnant and stuffy air. Headaches, sleepiness, increased heart rate and slight nausea may also be present
5000 ppm	Workplace exposure limit
>40,000 ppm	Exposure may lead to serious oxygen deprivation resulting in permanent brain damage, coma, even death

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According to the National Institute for Occupational Safety and Health (NIOSH), the indoor air concentrations of carbon dioxide that exceed 1,000 ppm indicate inadequate ventilation [14]. In this system, the quantity of carbon dioxide in the indoor air is observed regularly and when the concentration goes beyond the safer level, i.e., 1000 ppm, the user will be notified through SMS alerts.

II. Related Work

Air Pollution has become the biggest problem in recent days, due to a variety of factors like increase in population, building houses by cutting down the trees (thus reducing the amount of oxygen in air), burning the biomass, usage of leaky stoves, reduced ventilation and so on. For Indoor pollution, effect on the health is more [4]. Some research papers related to the above problem are studied. In those designed systems, the air in the atmosphere is sensed by using one of the wide variety of sensors available to measure various gases. The sensitive material used is Tin Oxide(SnO2), whose conductivity is low when the air is pure and clean [12]. As the pollutants start accumulating in the air, which is sensed by the sensor, the conductivity of the oxide increases. Corresponding calculations are made to find the amount of pollutants in the air.

The microcontroller used in those systems is Arduino UNO. Cost and Size (makes circuit complex) of Arduino UNO is more compared to other microcontrollers with many advanced features like on-board Wi-Fi module. In order to transmit the concentration of pollutants to the internet, so that user can access it from anywhere, a wireless Wi-Fi module is required, i.e., Wi-Fi is an essential part of Internet of Things(IoT) projects. But there is no in-built Wi-Fi module on Arduino board. Hence, another component ESP8266 ESP01 is to be used externally, increasing the cost of the system [10], [11]. Since two components (Arduino UNO and ESP8266 ESP01) are to be used instead of a single microcontroller (with inbuilt Wi-Fi module), the size of the circuit also increases. But, there are several microcontrollers available with inbuilt Wi-Fi access at a low cost. Hence, in order to avoid such problems, another microcontroller, NodeMCU with relatively small cost and size, with inbuilt Wi-Fi access provider is chosen to develop the Indoor Air Pollution Monitoring system. Like air pollution.

III. Implementation Setup

A. Components Required

- ESP8266 based NodeMCU-12E
- MQ135 Air Quality Sensor
- Wi-Fi Access
- Mobile phone to receive messages
- Arduino IDE (software)
- ThingSpeak IoT Platform
- PCB

B. NodeMCU

NodeMCU (Node Microcontroller Unit) is a microcontroller with built-in support for Wi-Fi connectivity, which makes it more useful for IoT applications. It is built around a very inexpensive System-On-Chip, i.e., ESP8266, which contains all the crucial elements of a modern computer, like CPU, RAM, networking(Wi-Fi), a modern OS and SDK (Software Development Kit) [15]. Its features [15] are:

- It is available at low cost and consumes less energy
- It is a programmable Wi-Fi module
- NodeMCU can be powered either through a USB cable or by giving input to Vin, from an external power supply
- On-board 3.3V regulator connected to Vin
- Arduino-like (software defined) hardware IO
- The GPIO pins can be used as digital input/output pins (9) and for some special functions such as Transmitter, Receiver and for SD-card interfacing.
- A single analog input/output pin A0
- Wi-Fi networking (connect to the internet to fetch or upload data)

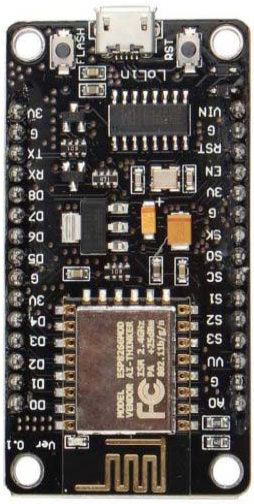


Fig. 1. NodeMCU

ESP8266 module searches for the available networks and connects to one of them by using username and password of the particular network. These details are provided to the Wi-Fi module through the code written in Arduino IDE. Thus, internet connectivity is established and the data is sent to the cloud through which user is notified when required.

C. MQ135 Air Quality Sensor

The sensor used is Air Quality sensor, MQ135. It senses the presence of different kinds of toxic gases such as Ammonia, Smoke, CO2 Benzene, alcohol, and NOx [10], [11], [12]. However, due to the abundance of CO2 compared to others, this sensor is used for measuring the concentration of CO2. Before measuring, the sensor is calibrated by running the calibration code in Arduino IDE, which uses getRZero function to find calibration resistance. It is run for 23-24 hours and the value of calibration resistance thus obtained is updated in the 'MQ135.h' code in the MQ135 library. One of the

important feature of air quality sensor is its fast response and high sensitivity.

TABLE II
SPECIFICATIONS OF MQ135 [12]

Parameter	Value
Operating Voltage	5.0 +/- 0.1V AC (or) DC
Detection Range	10 - few thousands of PPM
Sensitive Material	SnO2

The sensitive material used in this sensor is SnO2 (Tin Oxide). It has a very low conductivity in clean air. As the concentration of pollutants in its surroundings increase, the conductivity of the sensor increases. That is, the resistivity

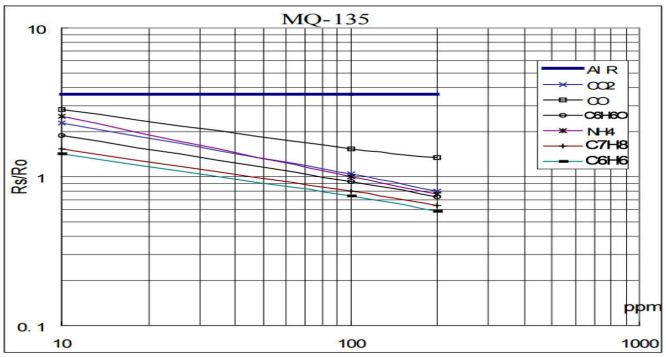


Fig. 3. Sensitivity Characteristics of MQ135 [12]

of SnO2 decreases with the increase in pollution. This is the principle based on which the sensor gives a voltage output. This output voltage is to be calibrated appropriately to get the amount of pollutants in ppm. For this, a library 'MQ135.h' is included in the code and an inbuilt function getPPM() is used.

D. ThingSpeak IoT Platform

The IoT platform used in this project is 'ThingSpeak', an open-source IoT platform to store and retrieve data using the HTTP protocol over the Internet. The data measured by the circuit is sent to this platform by NodeMCU, using channel ID, Write API Key and the field (in which it has to load the data) provided in the code. This open source platform allows the data to be analysed and visualised [16].

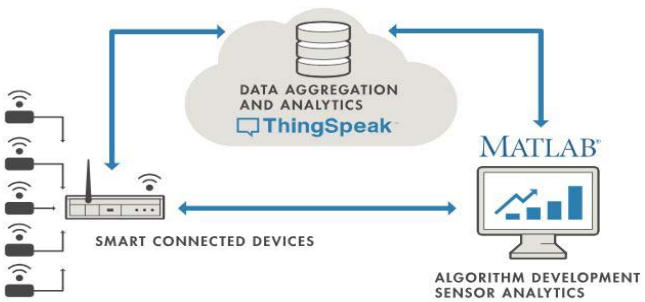


Fig. 4. ThingSpeak for IoT [16]

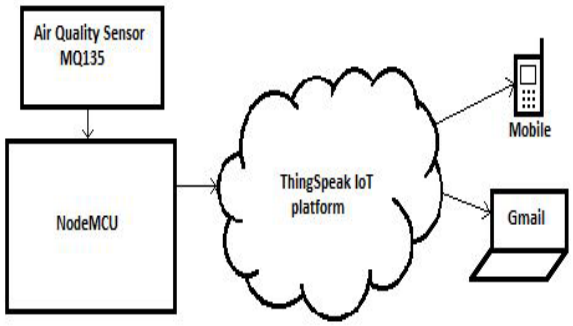
Whenever a new channel is created, a unique ID, called Channel ID is created. The API keys are generated for writing the data on the channel and for reading data from the channel. The entries from the microcontroller are plotted as a graph. When the measured concentration increases beyond the safer level (saved in React app of ThingSpeak), then alert is sent to the user's mobile using IF This Then That (IFTTT) application.

E. HTTP Protocol

In ThingSpeak, the data is sent and received through "Hypertext Transfer Protocol" (HTTP) protocol [17]. When a device sends the data via a HTTP request, it is processed by the ThingSpeak platform, which communicates with a virtual server. Both the server and the IoT platform communicate directly with the application. This data transfer can occur through plaintext, XML or JSON [17]. Then the data is uploaded onto the cloud. Based on the conditions set on the data, the messages will be send to the user. Messages from ThingSpeak are communicated to user via a HTTP GET request method, which retrieves information from the server [17].

IV. SYSTEM SETUP AND WORKING

The NodeMCU microcontroller can be powered by a 9V battery (since a 3.3V voltage regulator is present) or by computer through a regular USB cable. One of the three 3.3V pin on the microcontroller is used to power the sensor and the analog output pin of the sensor is connected to the analog pin. The Arduino IDE supports NodeMCU board. The programming is the same. But, corresponding libraries are to be downloaded and some settings like the board used, flash size and upload speed are to be changed accordingly. The block diagram of the system can be represented as in figure below.



The code is written and uploaded onto the microcontroller Wi-Fi access is provided. Now, the sensor starts measuring the quality of air and gives it to the microcontroller in voltage form, which is transformed into ppm by NodeMCU using inbuilt (library) code. Then the ESP8266 module on the board connects to Wi-Fi with the details provided in the code, using which the microcontroller sends the data to the IoT platform.

The data measured by the sensor is fed to the field in a channel of the ThingSpeak platform. Thus, the data measured at a place by a sensor can be accessed by the user from anywhere. The maximum allowable safer level of concentration of CO2 in the atmosphere that does not much affect human health is 1000 ppm.

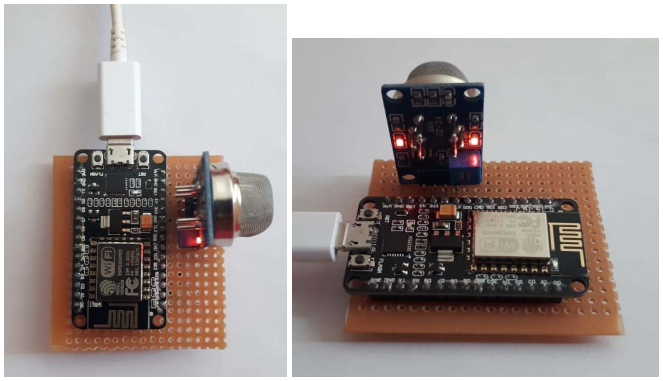
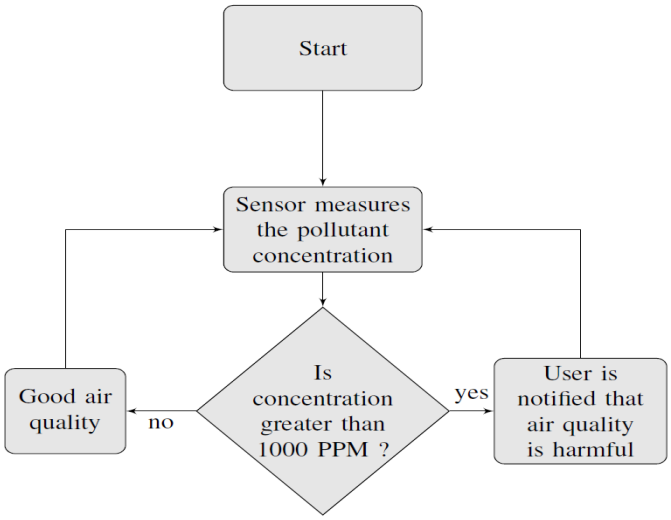


Fig. 6. Implementation Setup

A react (an app which works with ThingHTTP, ThingTweet, and Matlab Analysis apps to perform actions when channel data meets a certain condition) [18] is created which triggers another app, ThingHTTP if concentration crosses 1000 ppm. The ThingHTTP app enables communication among devices, websites, and web services without implementing the protocol on the device level [18]. A new ThingHTTP request is created and the actions are specified. It is triggered using React app when the concentration of carbon dioxide increases beyond 1000 ppm. Then an application IFTTT is used to send SMS to the user's mobile. Based on the alert, the user can do actions such as opening the windows and doors (or) to leave the place for some time. The system is thus built using NodeMCU and the quality of air in the surrounding is monitored.

V. FLOW CHART



VI. RESULTS

The designed IoT system computes the concentration of carbon dioxide in ppm, using the air quality sensor, from the atmosphere. Using ESP8266 based NodeMCU-12E [19] microcontroller, the system gets connected to Wi-Fi and sends the data to a channel in the ThingSpeak platform. The display on the IoT platform when the concentration of pollutants in air is normal is as below. The lamp is turned off at this concentration.

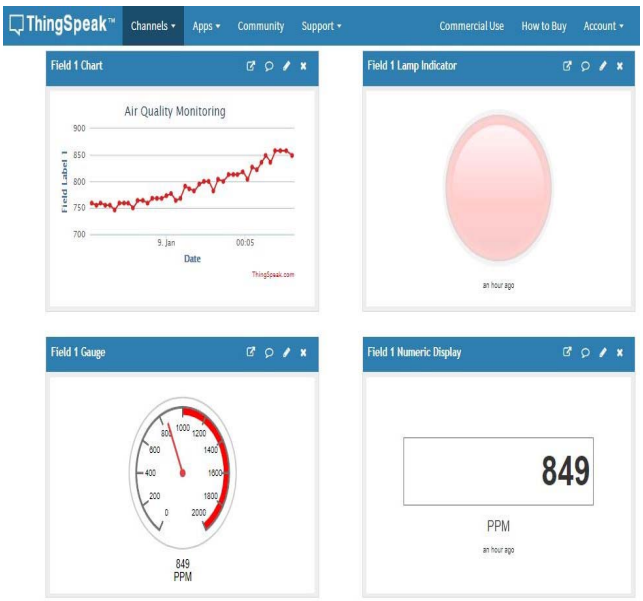


Fig. 7. Display on ThingSpeak when concentration is normal

When the concentration of pollutants increases beyond 1000 ppm, it is indicated by a glowing RED colured bulb display on the platform. Simultaneously, messages are sent to the user through Gmail and SMS to notify the poor quality of air.

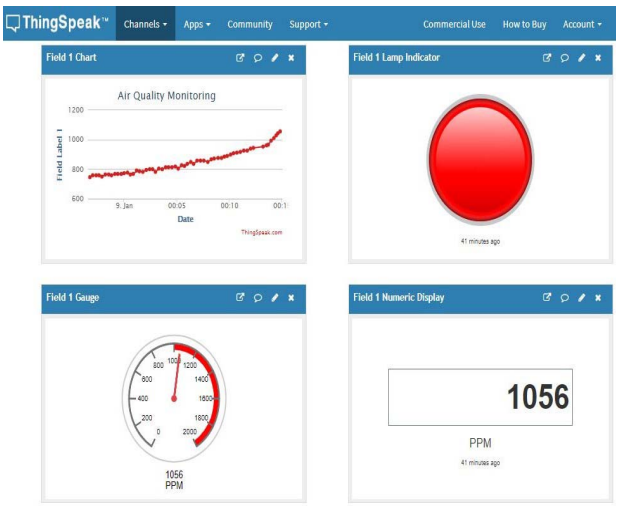


Fig. 8. Display on ThingSpeak when concentration is harmful

The message sent to the user through SMS application and Gmail through IFTTT application when the ThingHTTP request is triggered by the react app of ThingSpeak platform.

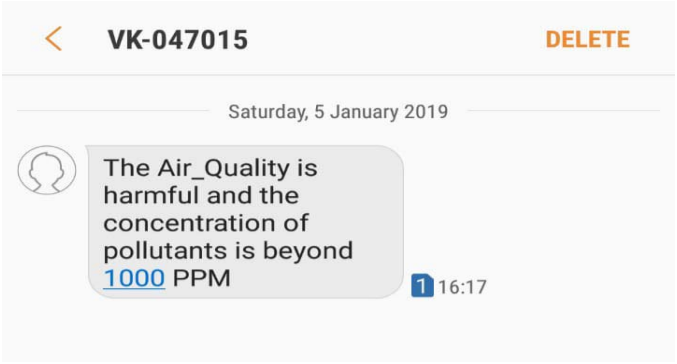


Fig. 9. Message to user's mobile

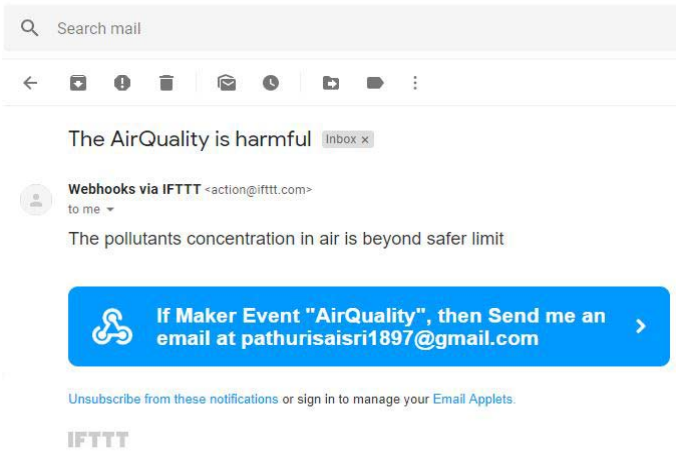


Fig. 10. Notification to user's Gmail

VII. CONCLUSIONS

The system to monitor the indoor air pollution is designed and the following advantages are observed in comparison to the existing models.

- The designed system is cost effective compared to the conventional air pollution monitoring systems available in the market.
- There is no requirement of any smartphone application installed in users mobile to receive the alerts from the system [3]. Only the system is to be connected to the Internet using NodeMCU microcontroller so that data is sent to cloud.
- The channel in the IoT platform can be set to private so that the data in the cloud is secured.

VIII. FURTHER SCOPE

The proposed system monitors the indoor air pollution and uses ThingSpeak as the IoT platform. Amazon Web Services IoT core is the similar type of platform, but with much more security and reliability. The AWS IoT device SDK allows the devices to connect, authenticate and exchange messages with AWS IoT Core using the MQTT, HTTP, or WebSockets protocols [20]. The circuit can further be developed by using MQTT and AWS platform. Sensors measuring other dangerous pollutants can be included in the system along with temperature, humidity sensors to make the system monitor the ambience of a place.

REFERENCES

[1] Indoor air pollution, March 2016. [Online]. Available: https://medlineplus.gov/indoorairpollution.html
[2] Causes and Effects of Indoor Air Pollution, Jan 2017. [Online]. Available: https://www.conserve-energy-future.com/causes-and-effects-of indoor- air-pollution.php
[3] R. K. Kodali, V. Jain, S. Bose, and L. Boppana, "Iot based smart security and home automation system," in Computing, Communication and Automation (ICCCA), 2016 International Conference on. IEEE, 2016, pp. 1286–1289.
[4] A. Kankaria, B. Nongkynrih, and S. K. Gupta, "Indoor air pollution in India: Implications on health and its control," Indian journal of community medicine: official publication of Indian Association of Preventive & Social Medicine, vol. 39, no. 4, p. 203, 2014.
[5] W. M. Alberts, "Indoor air pollution: No, no2, co, and co2," Journal of allergy and clinical immunology, vol. 94, no. 2, pp. 289–295, 1994.
[6] World Health Organization, Indoor air pollution and health, Jul 2017. [Online]. Available: http://www.searo.who.int/thailand/factsheets/fs0002/en/
[7] What is Carbon Dioxide, Dec 2013, [Online]. Available: https://www.co2meter.com/blogs/news/10709101-what-is-carbon-dioxide
[8] Human Respiration, May 2011. [Online]. Available: https://www.vernier.com/innovate/human-respiration/
[9] E. Toolbox, Carbon Dioxide Concentration - Comfort Levels, 2008. [Online]. Available: https://www.engineeringtoolbox.com/co2-comfort-level d1024.html
[10] R. Nayak, M. R. Panigrahy, V. K. Rai, and T. A. Rao, "Iot based air pollution monitoring system," Imperial Journal of Interdisciplinary Research, vol. 3, no. 4, 2017.
[11] P. Pal, R. Gupta, S. Tiwari, and A. Sharma, "Iot based air pollution monitoring system using Arduino," Vol-3, Issue-4, 2017.
[12] MQ135 datasheet, Jan 2014. [Online]. Available: http://www.dreamgreenhouse.com/datasheets/MQ-135/index.php
[13] Bonino, Carbon Dioxide Detection and Indoor Air Quality Control, Apr 2016.[Online].Available: https://ohsonline.com/articles/2016/04/01/carbon-dioxide detection and-indoor-air-quality-control.aspx
[14] Wikipedia, Indoor air quality, Dec 2018. [Online]. Available: https://en.wikipedia.org/wiki/Indoor air quality#Carbon dioxide
[15] Electronic Wings, Introduction to NodeMCU. [Online]. Available: http://www.electronicwings.com/nodemcu/introduction-to-nodemcu
[16] Learn More About ThingSpeak. [Online]. Available: https://thingspeak.com/pages/learn more
[17] Maureira, D. Oldenhof, and L. Teernstra, "Thingspeak– an api and web service for the internet of things," Retrieved7/11/15World Wide Web, http://www. Mediate chnology.leiden.edu/images/uploads/docs/wt2014 thing speak. pdf, 2011.
[18] Apps. [Online]. Available: https://thingspeak.com/apps
[19] R. K. Kodali and B. S. Sarjerao, "Mqtt based air quality monitoring," in 2017 IEEE Region 10 Humanitarian Technology Conference (R10-HTC), Dec 2017, pp. 742–745.
[20] Amazon, AWS IoT Core Features - Amazon Web Services. [Online]. Available: https://aws.amazon.com/iot-core/features/