IOT BASED AIR POLLUTION MONITORING SYSTEM USING WSN

PROJECT REPORT

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(Associate Professor, Department of Electronics and Instrumentation Engineering)

in partial fulfillment for the award of the degree

of

BACHELOR OF TECHNOLOGY

in

ELECTRONICS AND INSTRUMENTATION ENGINEERING

of

FACULTY OF ENGINEERING AND TECHNOLOGY

SRM
INSTITUTE OF SCIENCE & TECHNOLOGY
(Deemed to be University u/s 3 of UGC Act, 1956)

S.R.M. Nagar, Kattankulathur, Kancheepuram District

MAY 2020

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Under Section 3 of UGC Act, 1956)

BONAFIDE CERTIFICATE

Certified that this project report titled "**IOT BASED AIR POLLUTION MONITORING SYSTEM USING WSN**" is the bonafide work of " **NATARAJAN.A.V [Reg No: RA1611017010075], RAHUL. T.V [Reg No: RA1611017010018], GOKUL. K [Reg No: RA1611017010009]**." who carried out the project work under my supervision. Certified further, that to the best of my knowledge the work reported herein does not form any other project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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ABSTRACT

The continuous monitoring of pollution level in urban areas is important for any city. Excessive suspended particles dispersed in the atmosphere is major concern. According to a report published earlier this year by the World Health Organization, air pollution now affects approximately seven million people annually, worldwide. It's important to first understand where the pollution is most concentrated, what elements are involved and how we can neutralize them. In order to do this, comprehensive air monitoring must be undertaken on a large scale. Among other pollutants, air monitors assess the amounts of carbon monoxide (CO), temperature, Humidity and air quality. This allows us to know the trigger behind pollution occurrences, so that we can not only actively avoid overly contaminated areas in our daily routines but also try to implement measures to curb such pollution. Our project is connected with several sensors, such as Air Quality sensor MQ - 135, and DHT11 temperature sensor, and MiCS-5524 Carbon Monoxide sensor. Result of this system can be used by government and policy makers as basic information to take further actions reducing pollution.

KEYWORDS

IoT, Air Quality, Pollution, comprehensive air monitoring, WSN, carbon monoxide (CO), MQ – 135, Sensors.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to my guide, Dr.G Joselin Retna Kumar. his valuable guidance, consistent encouragement, personal caring, timely help and providing me with an excellent atmosphere for doing research. All through the work, in spite of his busy schedule, he has extended cheerful and cordial support to me for completing this research work.

A V Natarajan

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ABBREVIATIONS

AQI	Air Quality Index
IDE	Intgrated Development environment
IoT	Internet of Things
WSN	Wireless sensor Network
Wi-Fi	Wireless Fidility
CO	Carbon Monoxoide
CO2	Carbon dioxide
PM 2.5	Particulate Matter of size 2.5 micrometers
PM10	Particulate matter of size 10 microns
SDK	Software Development Kit
APK	Android Package kit
HTTP	Hyper Text Transfer Protocol
MQTT	Message Queueing Telemtry Transport
WHO	World Health organisation
PPM	Parts Per Milion
ppb	Parts Per Billion
IP	Internet Protocol
APC	Air Pollution Concentration
RAQP	Recurrent Air Quality Predictor
ANN	Artificial neural networks
PCB	Printed Circuit Board

CHAPTER 1

INTRODUCTION

1.1 Air Quality and importance

Air pollution monitoring is very much obligatory to the present times as there is an increase in number of air contamination statistics. In an attempt to make air quality measurement easier to understand, the ministry of environment and forest launched a national air quality index (Air Quality Index (AQI)). It will pull out real time data about level of pollutants in the air and inform people about possible impacts on health. Government have added three more components to the new measurement process which are: (i) Particulate Matter 2.5(Particulate Matter of size 2.5 micrometers (PM 2.5))and PM10 (Particulate matter of size 10 microns (PM10)) , (ii) carbon monoxide (Carbon Monoxoide (CO)) and (iii) carbon-di-oxide(Carbon dioxide (CO2)). The index air quality simply as good, satisfactory, rarely polluted, poor, very poor, and severe. Each band is represented by a colour code to visualise the level of severity that people can grasp easily. The government of India has indicated that this classification will be implemented in metropolitan and growing cities like Delhi, Agra, Kanpur, Lucknow, Varanasi, Faridabad, Ahmedabad, Chennai, Bengaluru and Hyderabad.

The continuous monitoring of pollution level in urban areas is important for any city. Excessive suspended particles dispersed in the atmosphere is major concern. According to a report published earlier this year by the World Health Organization, air pollution now affects approximately seven million people annually, worldwide. It's important to first understand where the pollution is most concentrated, what elements are involved and how we can neutralize them. In order to do this, comprehensive air monitoring must be undertaken on a large scale. Among other pollutants, air monitors assess the amounts of carbon monoxide (CO), temperature, Humidity and air quality. This allows us to know the trigger behind pollution occurrences, so that we can not only actively avoid overly contaminated areas in our daily routines but also try to implement measures to curb such pollution. Our project is connected with several sensors, such as Air Quality sensor MQ - 135, and DHT11 temperature sensor, and MiCS-5524 Carbon Monoxide sensor. Result of this system can be used by government and policy makers as basic information to take further actions reducing pollution.

1.2 Origin of Research

Air pollution poses a great number of unanswered questions for us, both with regard to old problems whose complete solutions we have never attained, and new problems whose identity has just become apparent. People who have been working in the air pollution field for several years are finding that the makeshift solutions which were adequate in the past, are no longer suitable to the much more stringent requirements for clean air, which are characteristic of the past few years of development. The many people who are just entering the field have a need to know where their efforts can be most useful. The Air Pollution Control Association is an organization with the unique capability of pointing out the problems across the total spectrum of air pollution disciplines, and will be looked to for advice by people interested in performing research.

Climate change, ozone depletion, and other environmental ills are widely discussed effects of air pollution. Less well-known, at least in the developed world, are the lethal short-term public health impacts of breathing polluted air. In fact, up to 6.5 million deaths globally every year may be attributed to air pollution.

An excessive amount of pollution can represent a health danger to anybody, yet whether it is deadly or not generally relies upon the individuals hidden health status. The most elevated paces of mortality are among the old, or the individuals who for reasons unknown are defenseless to cardiovascular harm. Existing heart or breathing conditions can expand hazard. High concentrations of single contamination, for example particulate material or ozone, are all the more savage contrasted with littler synchronous concentrations of various toxins. For powerless populaces, even transient presentation can be deadly; one uncommonly polluted day can kill a defenseless individual. Notwithstanding, even low-level interminable introduction over delayed periods can lessen future.

In our Project we have combined the effectiveness of the Internet of Things (IoT) and the Wireless Sensor network (WSN) to accomplish the task of monitoring the air pollution in the SRM Campus.

1.3 Importance of Wireless Sensor Network

- A Wireless sensor Network (WSN) is a network consisting of sensor nodes. Each sensor can detect certain factors like air pressure, air composition, and water quality.
- WSNs are used in a wide variety of settings, including personal space, industrial floors, agriculture, home utility monitoring.
- The concept of wireless sensor networks is similar to that of smart objects, and much of the development in smart objects has occurred in the community around wireless sensor networks. Wireless sensor networks are composed of small nodes, equipped with a wireless communication device, that autonomously configure themselves into networks through which sensor readings can be transported.

1.4 Aim of the project

- To sense and monitor the air pollutants that are present in the SRM campus.
- To provide user with the statistics on individual contents of pollutants.
- To provide mobile app to monitor the system.
- To provide management with warning messages indicating to control the pollution.

CHAPTER 2

LITERATURE SURVEY

2.1 Internet of Things Mobile–Air Pollution Monitoring System (IoTMobair)

An IEEE internet of the thing journal published on june 2019 by Swati Dhingra, Rajasekhara Babu Madda, Amir H. Gandomi , Senior Member, IEEE, Rizwan Patan , and Mahmoud Daneshmand, Life Member, IEEE. The paper is mainly based on the air pollution monitoring by the usage of developing technology called Internet-of-Things shortly known as Internet of Things(Internet of Things (IoT)). IoT is the growing technology which as been implemented and using in the various fields like health care, automation, agriculture, automotive and so on. The main advantage of using the IoT is the various devices which are implemented for the particular task can communicate within them and the data from each devices can transferred and monitored. IoT also helps in the various control operation like its acts as the bidirectional way of communication between the device and the operator. The main advantage of the IoT is the person can get access of the device from any place in world through the internet communication. This makes the IoT to vast studying technology and thus makes the world to be operated from any place. In this paper the air pollution is measured through the various gas sensors which can sense the particular pollutant gases which is targeted to sense. All the sensors used here are analog output devices. The sensors like MQ7, MQ2 and MQ135 together is used to measure the pollutant content of the various gases like carbon-monoxide, methane and air quality. This forms the sensor node and we place the same kind of sensor nodes at different places this forms the wireless sensor network ((WSN)). It uses the wireless technology to acquire all the data from various sensors. Using WSN the number of sensors can be scaled up according to data to be measured. To gather all the data and process from sensor network the Arduino integrated development environment (Intgrated Development environment (IDE)) is used. The Arduino is programmed according to different sensors output which is connected to the Arduino as input. For programming Arduino hardware the Arduino IDE is used. Now the collected data is transmitted to cloud using the Wi-Fi module. The Wi-Fi module is integrated with the Arduino IDE for transmit the data to the cloud service. In this paper the large number of data are needed to read and publish. As the requirement of data is high the large storage facility is recommended for the cloud service. In this paper the Ubidots is used as the cloud service. Ubidots is cloud platform which as more advantage than other cloud services. It's the cloud platform where we can store and access the data and also its also communicate with various platform like android. In this paper the android application has been developed to present and monitor the data in our mobile. Since the smartphone as became the part of our daily purpose this developed android application helps in monitoring the air pollution content measured from various gas sensors. The programing languages like java, eclipse platform, android ADT and the Android Software Development Kit(Software Development Kit (SDK)) (htt2) are used in this paper to develop the IoT-Mobair Android application. By using this app which is incorporated with user location via GPS, IoT, gas sensors and standard websites the air quality data is presented. This application also warns the user when the air quality of the particular location is behind the threshold air quality standards. IoT-Mobair android Application is also analogous with google traffic or navigation system of google maps. If the user with the sensor kit travelling to destination the entire route pollution level is predicted and this data can be used to display the air quality and warn by google maps that pollution level is very high. Different gas sensor as different air quality range of concentration. In this paper depending on individual concentration of range different gases the commonly classified into 3 types of air quality – No effect, Risky, Very high.

2.2 Recurrent Air Quality Predictor Based on Meteorology- and Pollution-Related Factors

An IEEE transaction on industrial informatics published on September 2018 by Ke Gu , Junfei Qiao, Member, IEEE, and Weisi Lin , Fellow, IEEE. This paper is based on predicting of air quality with correlation with both meteorology and pollution related factors. Nowdays pollution levels in the cities is also emerging as the major considering factor as because increasing population in and around the cities. Due to the increase in urbanization and industries the pollution levels in the cities as been keeps on increasing. This leads to the various problems like air pollution, contamination of water and soil erosion. In this air pollution is major problem in the developing cities, also this leads to various health issues like respiratory inflammation. In this paper they are proposing an experiential re-current air quality predictor (Recurrent Air Quality Predictor (RAQP)) to infer air pollutant concentrations (Air Pollution Concentration (APC)). It includes fine particulate matters like PM2.5. Thus the major pollutant of air pollution in urban cities is PM2.5 which particulate matter sourced due to various factors like agricultural products burning, industrial ash contents, vehicular combustion, Coal and Oil combustion so on. Along with PM2.5 there are various pollutant contents which also contaminates air along with PM2.5. In contrast with PM10 causes more damage to human and it also easier to control by the government. PM2.5 causes more visibility problems in the urban cities. Not only visibility is the only parameter concern with PM2.5, but also study going along with other metrological factors like humidity, wind, pressure and temperature. In this paper they strongly recommending that there is correlation between metrological factors and current time pollution related factors for the prediction air quality. This achieved by applying some machine learning techniques with metrological data and pollutant related factors. Thus from the result acquired through the machine learning techniques we can predict the air quality indices of later time. But the problem facing through this technique is results acquired through the machine learning falls of air predicts for enlarged time interval of model. To overcome this problem in this paper they are using the 1-h prediction models along with machine learning. This model uses current records of metrology and pollution related factors to map the 1hr later air quality and uses that to estimate the air quality several hours. In this paper through conform results proposes that RAQP predictor is superior to all state techniques and non-recurrent methods. The proposed model is shown the fig given below. In this paper they are following the 2 steps to estimate n-hour of meteorological factors and Air Pollutant Concentrations. In the 1st step one hour regression modules is developed from nosied features and labels through machine learning modules. Then in 2nd step recurrently predict n-hour quality is done. The presently meteorological factors and air

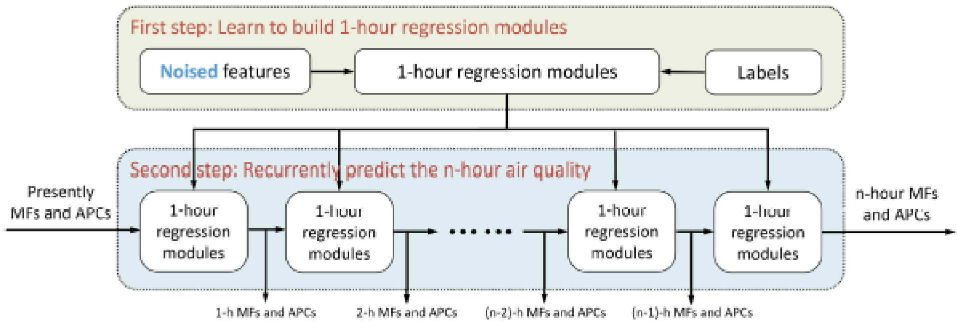

Figure 2.1: Image of the proposed model.

pollutant contamination data is given as the input n-hours of regression modules where the data is taken out as the serial in and parallel out patent. The air quality prediction is done in two types- direct prediction and recurrent prediction. Both the direct and recurrent predication modules as the individual calculation and formulas. The derived prediction are compered and the output is discussed in the form of graphs.

2.3 Optimal WSN Deployment Models for Air Pollution Monitoring

An IEEE transaction on wireless communication published on may 2017 by Ahmed Boubrima, Walid Bechkit and Hervé Rivano. This paper proposes the use of alternating approach of air pollution monitoring over the gas analyzing station which are costly. Presently use monitoring station are complex and heavy which uses the chemical analysis for monitoring. According to World Health Organization air contamination overwhelms a projected 7,000,000 individuals worldwide consistently. World Health Organisation (World Health organisation (WHO)) information shows that 9 out of 10 individuals inhale air containing significant levels of contamination. WHO is working with nations to screen air contamination and improve air quality. From brown haze hanging over urban areas to smoke inside the home, air contamination represents a significant risk to well-being. The consolidated impacts of surrounding (open air) and combined air contamination cause around 7,000,000 unexpected losses consistently, to a great extent because of expanded mortality from stroke, coronary illness, constant obstructive respiratory ailment, lung malignancy and intense respiratory diseases. Over

80% of individuals living in urban territories that screen air contamination are presented to air quality levels that surpass WHO rule limits, with low-and middle salary nations experiencing the most noteworthy exposures, both inside and outside. Air pollution has raised to emerging issues in the metropolis because of the urbanization, increasing industrial emissions, traffic jams on roads and also due to cooling heating of building too. In this paper instead massive air pollution monitoring system they are using low cost and automatic wireless sensor for the space and time of granularity of sensing. This generic development models are proposed in the literature are not suitable for dynamic nature of pollutant sensing. This paper mainly contributing to linear simulation models which are suitable for both time varying measurements and connectivity to the inner devices within models. The proposed model in the paper is tested in the greater London for real time monitoring. Proposed model in the paper as proved that it as greater collaborative coverage and complex and tight network connectivity with considerable execution time. In this paper they also simulated the model of effective results using engineering concepts for monitoring air pollution in urban cities. In this paper there are presenting an 2 optimization model for the connectivity and coverage of WSN. This idea in this paper came through some beginning ground works and from the paper "Optimal deployment of wireless sensor networks for air pollution monitoring" which is presented in ICCCN on august 2015. The main focus in this paper is to give optimal coverage of pollution and connectivity of network infrastructure with the less estimate of cost. This models are designed from the ILP formulation of coverage and network related studies. The proposed two models in this paper are Optimization model and Enhanced models of approaches. The first proposed model is the optimization model where the coverage of pollution and the network connectivity are modelled independently. The second model proposed next to the optimization model is Enhanced model. This model is more effective than the optimization model. This model uses the flow concept were there will be the joint collaboration of pollution coverage and network connectivity, thus reduced complexity reduces the computation time of system performance. The reduced computation model proposed in this paper helps easy tractability in very large cities scenarios. According to this paper both proposed models are taken into consideration and both are applied to handle the hard situation also with multiple weather conditions in the cities. Apart from this primary modelling of concept the atmospheric dispersion is also taken into consideration which uses some theoretical studies of basic fluid mechanics. This approached model is tested in the greater London and graph are analyzed with proposed way.

2.4 Efficient Data Gathering and Estimation for Metropolitan Air Quality Monitoring by Using Vehicular Sensor Network

An IEEE transaction on vehicular technology published on august 2017 presented by You-Chiun Wang, Senior Member, IEEE, and Guan-Wei Chen. The air pollution monitoring as became the important factor in our day-to-day life became of the growing population and people are aware of the hazards of air pollution. Air pollution level as became the premium consideration standard of people lifestyle. Thus the attention of people towards air polluting content in the urban cities as increased. Many studies are going on to develop different techniques of air pollution monitoring. Wireless sensor network is mostly viewed technique for the tractable of air pollution. Air quality measurement is usually done using placement of permanent monitoring stations in particular sites of the cities. But this type permanent monitoring station too have certain disadvantages. First it provides only the coarse grounded particle monitoring therefore the sampling rate of the air pollution is poor. Secondly lack of mobility sampling because of permanent stations. In this paper air quality monitoring is proposed on vehicular technology basis. This paper uses vehicular sensor network (VSN) to effectively monitor the air quality through the active mobility of vehicle in the streets of urban cities. Position and location of car is easy trace through GPS. For gathering the information from the each sensor nodes which is placed in the moving vehicle needs efficient server which computes all the data. In this paper they designed a device for this purpose called efficient data gathering and estimation (EDGE). The main objective of EDGE is to efficiently do sampling of data which gathered from each vehicle and acts as the edge device. Another main advantage is maintain the balance in trade-off between data monitoring accuracy and communication cost. Data which we measured needs as comparable standard reference so that we can know actual air quality of urban city. Formal air quality index is used as the standard of reference in this paper. The communication cost considered only by amount sampling of data, this needs driver to roam around all the areas and gets more sampling. To encourage the driver with more sampling we can give monetary rewards to driver. To achieve this in action EDGE propose the dynamic grid partition. This is done based on the variation of the pollutant contents concentration and sampling rate by the use of car traffic in each grid. Through this kind of approach we can do probabilistic reporting which helps car to potentially collect air quality data from different parts of city and also helps in the reduced potential congestion of network. When we need to take monitoring of large area in the cities the simulation models are used in this paper. The simulation which is proposed in this paper is SUMO (simulation of urban mobility). It is used to develop the car traffic in the cities. In SUMO all kinds of vehicle can simulated as it is in road and also the road environment around. In this paper they are developed the simulation model called ISC3 which helps in to simulate different kind of air pollution diffusion in air. All this models used together and the results are obtained in graph models and analyzed.

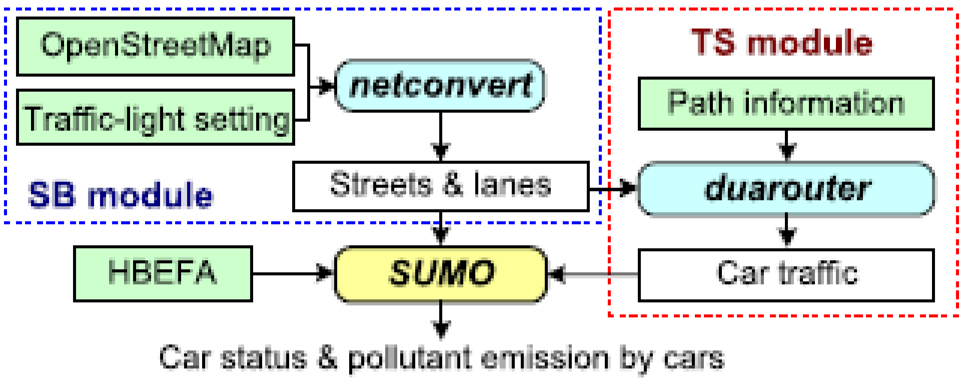

Figure 2.2: Image of the Vehicular sensor network proposed model.

2.5 Urban Air Pollution Monitoring System With Forecasting Models

An IEEE journal on sensors published on april 2016 by Khaled Bashir Shaban, Senior Member, IEEE, Abdullah Kadri, Member, IEEE, and Eman Rez. This paper presents an idea of monitoring and forecasting urban air pollution. Air pollution monitoring is the important factor in maintaining people living standards in the urban cities. Recent studies of WHO also survived that people who are exposed to the pollutant air are diseased to serious respiratory problems and also lung inflammation. This impact on the people due to the air pollution also affects the economic conditions by increased expensive on the healthcare services. A large change acquired in the atmospheric conditions due to the increasing air pollutants in air. Due to this impact of pollutants in the air, WHO as suggested certain guidelines to all the countries for healthy style of living. By this suggestion by WHO it as created some limitation for emission of certain gases. Polluting gases are Ozone (O3), Nitrogen Dioxide (NO2) and sulfur dioxide (SO2). In previous days air pollution is measured using setting up of permanent air pollution monitoring stations which are very expensive in installation and maintenance. Since the cost AQM (Air Quality Monitoring) is very many research have done to implement low cost air pollution monitoring stations. Result of which NGAM (Next Generation of Air Monitoring) came to market. The main aim of NGAM is to implement the monitoring configuration from meso to micro scale which has the improved spatiotemporal resolution and collection air pollution data. In this paper the main idea is of monitoring and forecasting urban air pollution. For this in this paper they have approached with low-cost monitoring motes which are designed with gaseous and metrological sensors. In recent research developments wireless communication has become most widely used technology. By implementing this idea in this paper motes are connected wirelessly to intelligent platform. These intelligent platforms consists of several modules which helps in storing of data, pre-processing and converting data into presentable information's. All the above working are done by the intelligent platform. From the above processed data forecasting of pollutants are done with help of historical data. The presentable model of the above is implemented by different channels like mobile applications, web portals and also through SMS. In this paper there are proposing machine learning algorithm for accurate forecasting models. This has been used for one-step and multi-step ahead concentrations of ground level O3, nitrogen di-oxide, and sulfur di-oxide. The machine learning algorithms are used in this paper are Support vector machines, M5P model trees and Artificial neural networks (Artificial neural networks (ANN)). In this paper two types of modeling are proposed – Univariate and Multivariate. In this paper many kinds of experiments done to have the standard results. For best evaluation of performance measure the following types are proposed- Prediction trend accuracy and Root mean square error (RMSE). The results from this paper shows that the multivariate modeling with M5P algorithm produced the best results than the uni-variate modeling. The idea of this paper is used for alarming purposes in the high level air polluting areas.

CHAPTER 3

SYSTEM DESCRIPTION

3.1 Methodology and Block Diagram Representation

The below figure 3.1 shows the block diagram representation of our proposed working model. The gas sensors such as MiCS 5524(CO), DHT11 (Temperature and Humidity), MQ135 (Air quality and Carbon-di-oxide). Since all these sensors are of analog type, they are connected to ADS1115 which is a 16-bit ADC that helps in conversion of analog sensor to digital type. Then it is connected to a NodeMCU which has ESP8266 chip mounted on it. The speciality of NodeMCU is that it is Wireless Fidelity (Wireless Fidility (Wi-Fi)) enabled which helps in online data transfer. The data from NodeMCU is sent to Raspberry Pi, where communication is through MQTT protocol which receives all the messages, filters them and publishes the messages to subscribed clients. An application named Mosquitto acts as broker between NodeMCU and Raspberry pi. Then the data from Raspberry pi is sent to cloud server named Thingspeak in which communication is through HTTP protocol. The collected data from cloud server is made into an android mobile application indicating the air quality in different stations by certain parameters such as Moderate, Healthy, Unhealthy and Hazardous according to the quality of air. There are three main layers in this architecture as shown in the below diagrammatic explanation. They are (i) the Sensor layer, (ii) the Communication layer and (iii) the Application layer.

3.2 Explanation of the proposed work

The gas sensors such as MiCS 5524(CO),DHT11(Temperature and Humidity), MQ135(Air quality and Carbon-di-oxide) are implemented. Since all these sensors are of analog type, they are connected to ADS1115 which is a 16bit ADC that helps in conversion of analog sensor to digital type. Then it is connected to a NodeMCU which has ESP8266

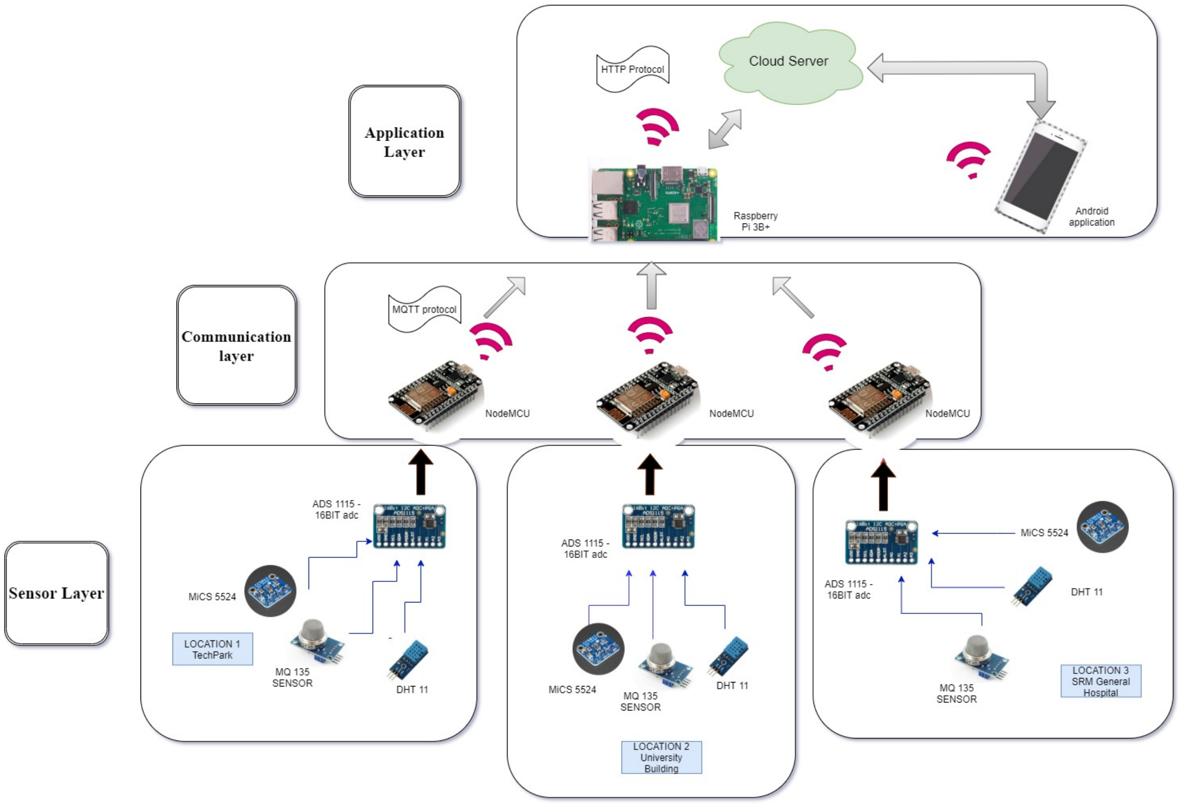

Figure 3.1: Diagram of the proposed architecture

chip mounted on it. The speciality of NodeMCU is that it is WiFi enabled which helps in online data transfer. The data from NodeMCU is sent to Raspberry Pi , where communication is through MQTT protocol which receives all the messages, filters them and publishes the messages to subscribed clients. An application named Mosquitto acts as broker between NodeMCU and Raspberry pi. Then the data from Raspberry pi is sent to cloud server named Thingspeak in which communication is through HTTP protocol. The collected data from cloud server is made into an android mobile application indicating the air quality in different stations by certain parameters such as Moderate, Healthy, Unhealthy and Hazardous according to the quality of air.

3.3 Protocols Implemented

3.3.1 MQTT Protocol

Message Queuing Telemetry Transport is one of the most generally utilized protocols utilized internet protocol (Internet Protocol (IP)) in IoT ventures. MQTT is structured as

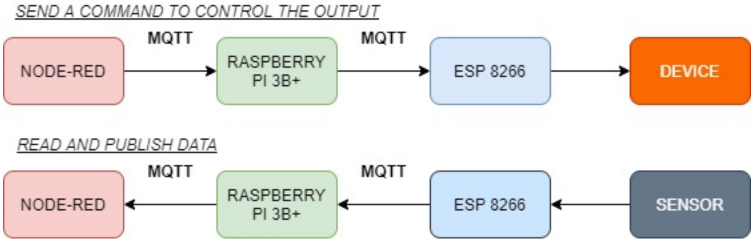

Figure 3.2: Data transfer in MQTT protocol

Figure 3.3: Mosquitto Broker

a lightweight messaging protocols that utilization publish in activities to trade information among clients and the server. Focal points like its small size, low power utilization, minimized data packets and simplicity of execution make the convention perfect of the "machine-to-machine" or "Internet of Things" world.

MOSQUITTO BROKER:

Mosquitto is an open source software that is developed for non-TCP communication between IoT gateways and cloud platform. Mosquitto acts as an interface between NodeMCU and Raspberry pi.

The main benefits of the mosquito broker is that it eliminates insecure connections, easily scales, manages connect client states and reduces network strain.

3.3.2 HTTP Protocol

The Hypertext Transfer Protocol (HTTP) is an application-level convention for conveyed, collective, hypermedia data frameworks. This is the establishment for information correspondence for the World Wide Web. HTTP is a non exclusive and stateless convention which can be utilized for different purposes too utilizing augmentations of its solicitation strategies, error codes, and headers. Essentially, HTTP is a TCP/IP based communication protocol, that is utilized to convey information (HTML records, picture documents, inquiry results, and etc.) on the World Wide Web. The default port is

TCP 80, yet different ports can be utilized too. It gives an institutionalized method to PCs to speak with one another. HTTP determination indicates how clients' solicitation information will be built and sent to the server, and how the servers react to these solicitations.

CHAPTER 4

HARDWARE DESCRIPTION

4.1 Printed circuit board design and fabrication

The Printed Circuit Board (PCB) for our project is designed using the ProteusTM software developed by the Labcentre Electronics ©. The schematics is shown in the figure 4.1. The Schematics contains the component labels, firstly there are 3 sensing elements namely the (i) MiCS-5524 MEMS Sensor for sensing the Carbon Monoxide, (ii) the MQ 135 Gas sensor for sensing Particulate matter PM2.5 and Carbon Di-Oxide Concentration, (iii) DHT11 Temperature and Humidity module. We also have Analog to Digital Conversion module that is used to convert the analog signals from the sensors, it is the Adafruit © ADS1115 16-bit ADC module which is deployed in the PCB board. Node MCU ESP 8266 board is used as the Microcontroller for its very efficient capabilities.

The positive terminals of the sensors are connected commonly along with positive terminals of the NodeMCU and ADS 1115 and are connected to the output of the decoupling capacitor from the IC 7805 5V DC regulator. The Negative terminals are grounded properly. The supply is provided with a power jack jumper embedded in the PCB. The data pins of the MiCS-5524 and the MQ 7 gas sensors are connected to the A0 and A1 pins of the ADS 1115 ADC module respectively. The data pin of the DHT 11 is connected to the D6 digital pin of the Node MCU board. We have deployed two LED indicators for Power and Wi-Fi connection, they are connected to the 5V and D3 pin of the Node MCU respectively with suitable resistors connected in series. The PCB is tested and populated with components. The component layer is shown in the figure 4.2 and the tracks and connections of the bottom is shown in the figure 4.3.

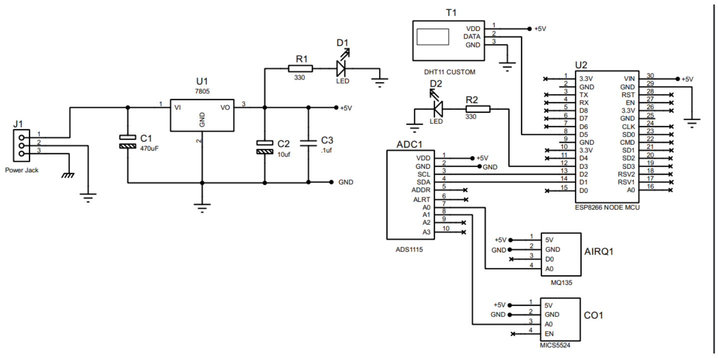

Figure 4.1: Schematic Design and connections of the PCB.

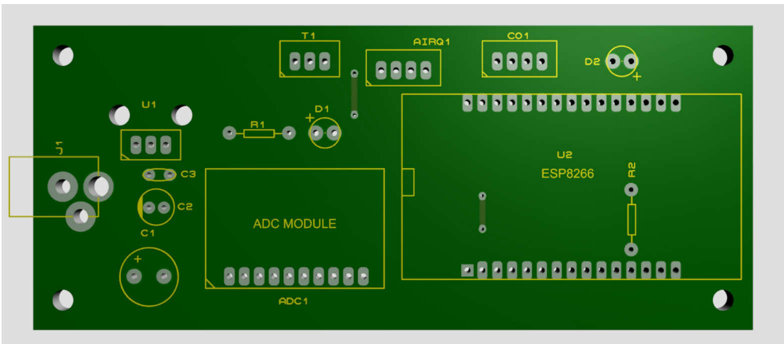

Figure 4.2: Top Layer of the PCB with component Labels

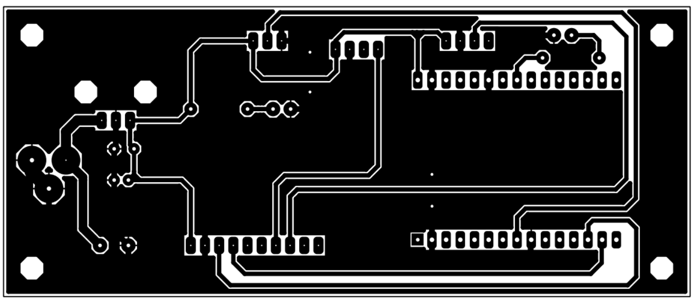

Figure 4.3: PCB bottom layer showing the copper tracks

4.2 Sensor details

4.2.1 MiCS-5524 - Carbon Monoxide sensor:

Adafruit MiCS-5524 Gas Sensor Breakout. This breakout makes it easy to use this nice sensor from SGX Sensortech. The MiCS-5524 is a robust MEMS sensor for indoor carbon monoxide and natural gas leakage detection, it's suitable also for indoor air quality monitoring; breath checker and early fire detection. This sensor is sensitive to CO (1 to 1000 ppm), Ammonia (1 to 500 ppm), Ethanol (10 to 500 ppm), H2(1 - 1000 ppm), and Methane / Propane / Iso-Butane (1,000++ ppm). However, it can't tell you which gas it has detected.

Features:

- Smallest footprint for compact designs(5*7*1.5mm)
- Robust Mems Sensor for harsh environments.
- Low Cost applications.
- Short lead- times.

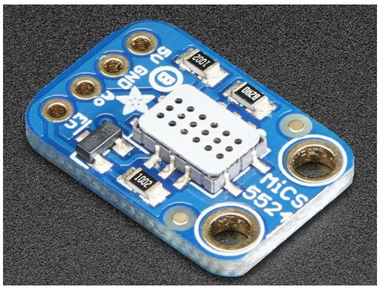

Figure 4.4: MiCS-5524 Carbon Monoxide MEMS sensor

4.2.2 MQ-135 Gas Sensor:

Air quality sensor for detecting a wide range of gases, including NH3, NOx, alcohol, benzene, smoke and CO2. Ideal for use in office or factory. MQ135 gas sensor has high sensitivity to Ammonia, Sulfide and Benze steam, also sensitive to smoke and other harmful gases. It is with low cost and particularly suitable for Air quality monitoring application.

Features

- High Sensitivity
- High sensitivity to Ammonia, Sulfide and Benzene
- Stable and Long Life
- Heater Voltage: 5.0V
- Dimensions: 18mm Diameter, 17mm High excluding pins, Pins - 6mm High
- Long life and low cost

Model			MQ135
Sensor Type			Semiconductor
Standard Encapsulation			Bakelite, Metal cap
Target Gas			ammonia gas, sulfide, benzene series steam
Detection range			10～1000ppm(ammonia gas, toluene, hydrogen, smoke)
Standard Circuit Conditions	Loop Voltage	V_c	≤24V DC
	Heater Voltage	V_H	5.0V±0.1V AC or DC
	Load Resistance	R_L	Adjustable
Sensor character under standard test conditions	Heater Resistance	R_H	29Ω±3Ω (room tem.)
	Heater consumption	P_H	≤950mW
	Sensitivity	S	Rs(in air)/Rs(in 400ppm H_2)≥5
	Output Voltage	Vs	2.0V～4.0V （in 400ppm H_2）
	Concentration Slope	α	≤0.6(R_{400ppm}/R_{100ppm} H_2)
Standard test conditions	Tem. Humidity		20℃±2℃；55%±5%RH
	Standard test circuit		Vc:5.0V±0.1V；V_H: 5.0V±0.1V
	Preheat time		Over 48 hours

Table 4.1: Specification of MQ-135

Figure 4.5: MQ-135 Gas Sensor

4.2.3 DHT-11 Temperature and Humidity module:

The DHT11 is a basic, ultra low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin. Its fairly simple to use, but requires careful timing to grab data. The only real downside of this sensor is you can only get new data from it once every 2 seconds, so when using our library, sensor readings can be up to 2 seconds old.

Features:

- Low cost.
- 3 to 5V power and I/O.
- 2.5mA max current use during conversion (while requesting data).
- Good for 20-80% humidity readings with 5% accuracy.
- Good for 0-50°C temperature readings ±2°C accuracy
- No more than 1 Hz sampling rate (once every second)
- Body size 15.5mm x 12mm x 5.5mm
- 4 pins with 0.1" spacing

The following table will explain the range , target ad description of each sensor.

Detailed Specifications:

Parameters	Conditions	Minimum	Typical	Maximum
Humidity				
Resolution		1%RH	1%RH	1%RH
			8 Bit	
Repeatability			±1%RH	
Accuracy	25℃		±4%RH	
	0-50℃			±5%RH
Interchangeability	Fully Interchangeable			
Measurement Range	0℃	30%RH		90%RH
	25℃	20%RH		90%RH
	50℃	20%RH		80%RH
Response Time (Seconds)	1/e(63%)25℃, 1m/s Air	6 S	10 S	15 S
Hysteresis			±1%RH	
Long-Term Stability	Typical		±1%RH/year	
Temperature				
Resolution		1℃	1℃	1℃
		8 Bit	8 Bit	8 Bit
Repeatability			±1℃	
Accuracy		±1℃		±2℃
Measurement Range		0℃		50℃
Response Time (Seconds)	1/e(63%)	6 S		30 S

Table 4.2: Specification of DHT-11 Sensor module

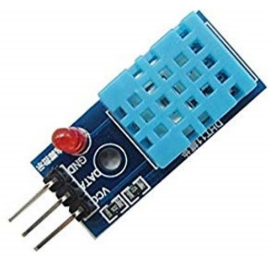

Figure 4.6: DHT-11 Temperature and Humidity module

Sensor	Pollutant	Description	Range
MiCS-5524	Carbon Monoxide	Sensor sensitivity to 1-1000ppm with MEMS based increases with analog voltage when gas concentration increases. Sensor powered with 5VDC through adapter and power backup with battery attached. concentration of 1 to 1000ppm	Concentration of 1 - 1000 ppm.
MQ-135	Particulate matter PM 2.5 Carbon Dioxide	The output from sensor is analog voltage which is 0-5v. Wide detecting scope and stable & long life. Sensor composed micro AL2O3 ceramic tube & Tin Dioxide (SnO2) sensitive layer.	Air quality of 10-300ppm. Carbon Dioxide of 10–1000 ppm
DHT-11 module	Temperature Humidity	The sensor can measure temperature from 0°C to 50°C and humidity from 20% to 90% with an accuracy of ±1°C and ±1%, operating voltage 3.5V to 5.5V.	temperature from 0°C to 50°C and humidity from 20% to 90%

Table 4.3: Sensor details

4.3 Raspberry Pi 3B+:

The Raspberry Pi(Image of pi board is given in figure 4.8) is a low cost, credit-card sized computer that plugs into a computer monitor or TV, and uses a standard keyboard and mouse. It is a capable little device that enables people of all ages to explore computing (specification of pi board is given in table 4.1), and to learn how to program in languages like Scratch and Python.

Figure 4.7: Raspbrry Pi 3B+

Microprocessor	1.3 GHz ARM Cortex-v8 Quad Core
Chipset	Broadcom BCM2837
RAM	1 GB SDRAM
USB	4 ports (USB 2.0)
HDMI	Full size connector (video output at 1080p)
SD Card	Micro SD
Input Voltage	DC 5V
Camera Interface	CSI port for connecting the Raspberry Pi camera
Display Interface	DSI port for connecting the Raspberry Pi touch screen display
Graphics	VideoCore IV 3D graphics core
Ethernet	10/ 100
Dimensions	85mm x 56mm x 21mm
GPIO	40 pins

Table 4.4: Specification of Raspberry Pi 3B+

4.3.1 Features

- Quad Core 1.2GHz Broadcom BCM2837 64bit CPU
- 1GB RAM
- BCM43438 wireless LAN and Bluetooth Low Energy (BLE) on board
- 100 Base Ethernet
- 40-pin extended GPIO
- 4 USB 2 ports
- 4 Pole stereo output and composite video port
- Full size HDMI
- CSI camera port for connecting a Raspberry Pi camera
- DSI display port for connecting a Raspberry Pi touchscreen display
- Micro SD port for loading your operating system and storing data
- Upgraded switched Micro USB power source up to 2.5A

4.4 NodeMCU - ESP8266

ESP8266 module (Image of ESP board is given in figure 4.6) has a powerful enough onboard processing and storage capability that allows it to be integrated with the sensors and other application specific devices through its General-purpose input/output (GPIO) with minimal development up-front and minimal loading during run time(Image of ESP board is given in below figure 4.2),. Its high degree of on-chip integration allows for minimal external circuitry, including the front-end module, is designed to occupy minimal PCB area.

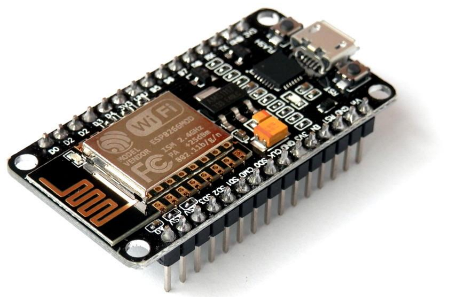

Figure 4.8: NodeMCU - ESP8266

Parameters	Specification
Microcontroller	ESP8266
Memory	32 bit
Processor	TenSilica L 106
Processor Clock	80MHz-160MHz
RAM	36Kb
Storage	16 Mb
Built-in WiFi	2.4GHz supports 802.11 b/g/n
ADC Pin	1(10bit Resolution)
GPIO pins	10
Operating Voltage	3.0V 3.6V
Operating Current	80mA(Average)
Operating Temperature Range	-40oC - 125 oC

Table 4.5: Specification of NodeMCU ESP-8266

4.5 ADS1115 - 16 - bit ADC

The ADS1115 is a precise 16bit ADC with four multiplexed inputs - Each input can be used on its own, or in pairs for differential measurements. It has an internal calibrated reference for high accuracy. On running the ADS1115 at low speed the internal sampling rate is not lowered, since this is how delta sigma converter operates, by over-sampling. The internal oscillator is set at 1MHz, and reduced to 250kHz for the ADC clock.

4.5.1 Features

- Resolution: 16 Bits
- Programmable Sample Rate: 8 to 860 Samples/Second
- Power Supply/Logic Levels: 2.0V to 5.5V
- Low Current Consumption: Continuous Mode: Only 150µA Single-Shot Mode: Auto Shut-Down
- Internal Low-Drift Voltage Reference
- Internal Oscillator
- Internal PGA: up to x16
- I2C Interface: 4-Pin-Selectable Addresses
- Four Single-Ended or 2 Differential Inputs
- Programmable Comparator

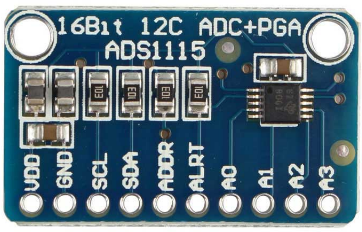

Figure 4.9: ADS1115 - 16 - bit ADC

CHAPTER 5

SOFTWARE DESCRIPTION

5.1 Arduino Integrated Development Environment:

Arduino is a micro-controller development board series - Uno, Mega, Nano, Mini etc. are a few examples. Now, any micro-controller(here it is the Atmega 328 IC on the Arduino Uno or Atmega 1280 on arduino Mega) that needs to be programmed is basically fed with a hex code version of the code written in high level (English) language. So, arduino development boards are fed with the code via their Arduino IDE. Now, Integrated Development Environment (IDE) is basically a software that enables better and assisted code editing, compiling and debugging. The Arduino IDE runs on the Java Platform. You can co-relate this to Eclipse, which is another IDE for Java. So the language java has different IDEs that ease the usage of the language for a particular purpose. However, Eclipse doesn't support the functions and commands that work on arduino board. So, this Arduino IDE basically has inbuilt functions and commands that though work on Java platform, are customized to run on the arduino dev. board. Thus Arduino IDE serves for code editing, its compilation, debugging and then burning the code into the arduino dev. board.

5.2 NodeRED

Node-RED provides a browser-based flow editor that makes it easy to wire together flows using the wide range of nodes in the palette. Flows can be then deployed to the runtime in a single-click.JavaScript functions can be created within the editor using a rich text editor. A built-in library allows you to save useful functions, templates or flows for re-use.

The light-weight runtime is built on Node.js, taking full advantage of its event-driven, non-blocking model. This makes it ideal to run at the edge of the network on

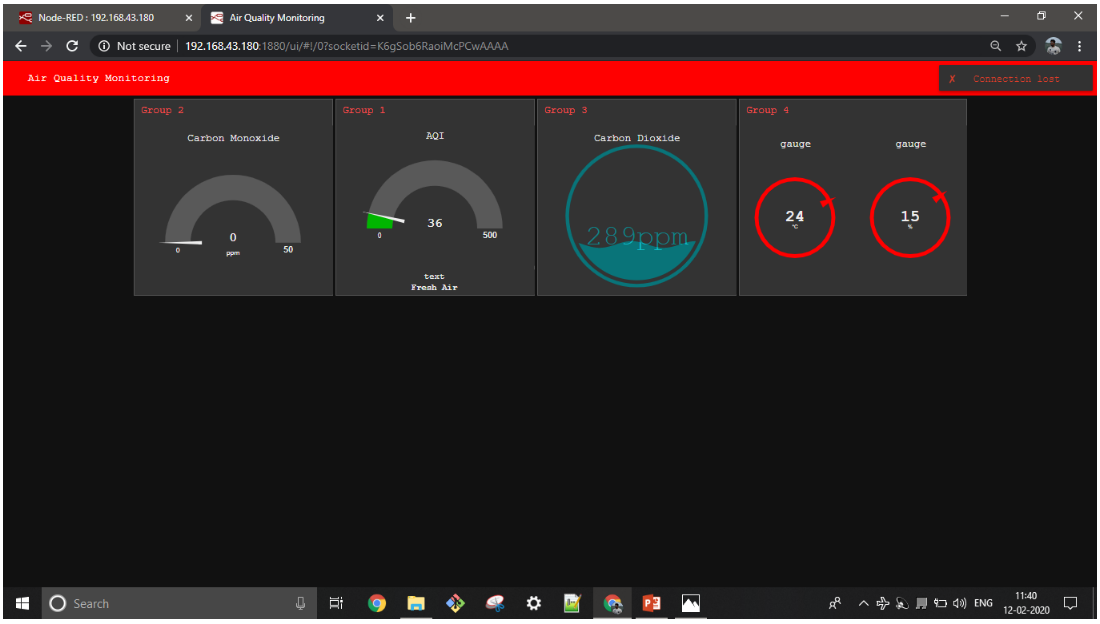

Figure 5.1: NodeRED UI

low-cost hardware such as the Raspberry Pi as well as in the cloud.

5.3 MIT App Inventer

In this project, MIT App Inventor has been used as an Android Package kit (APK). Pollutant Parameters such as PM2.5,PM10, Carbon Monoxide, Carbon-di-oxide, temperature and humidity are tracked and their values are showcased in the android app by means of respective units such as PPM,AQI etc. The individual pollutants are also monitored with current trends respective to time vs pollutant(in PPM,AQI etc.) represented in terms of a graph. In case of any doubt, Help button can be clicked to know more about the individual pollutant parameters range, properties and sensors implemented. Separate icon indicating the database is also implemented. It shows the values of the individual pollutants with their history for last one week which is used for analysing purposes.

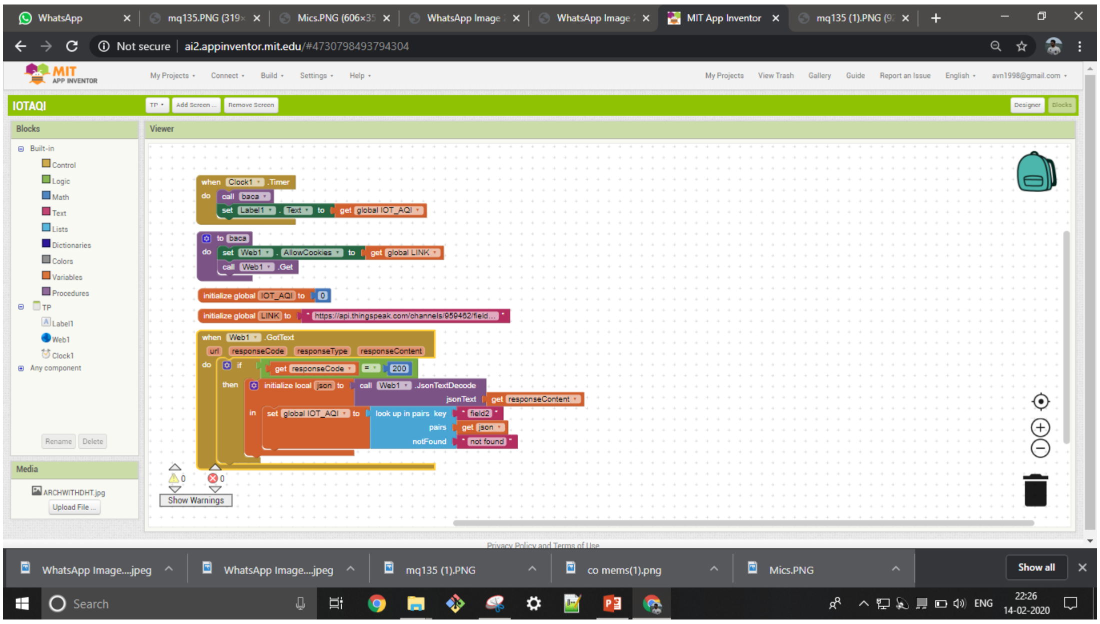

Figure 5.2: The MIT App inventor code design

5.4 Thingspeak

Thingspeak is an IoT analytics platform service that allows you to aggregate, visualize and analyze live data streams in the cloud. Thingspeak provides instant visualizations of data posted by your devices to Thingspeak. With the ability to execute MATLAB® code in Thingspeak you can perform online analysis and processing of the data as it comes in. Thingspeak is often used for prototyping and proof of concept IoT systems that require analytics.

5.4.1 Key features

Thingspeak allows you to aggregate, visualize and analyse live data streams in the cloud. Some of the key capabilities of Thingspeak include the ability to:

- Easily configure devices to send data to Thingspeak using popular IoT protocols.
- Visualize your sensor data in real-time.
- Aggregate data on-demand from third-party sources.
- Use the power of MATLAB to make sense of your IoT data.
- Run your IoT analytics automatically based on schedules or events. vi.

- Prototype and build IoT systems without setting up servers or developing web software.
- Automatically act on your data and communicate using third-party services like Twilio® or Twitter®.

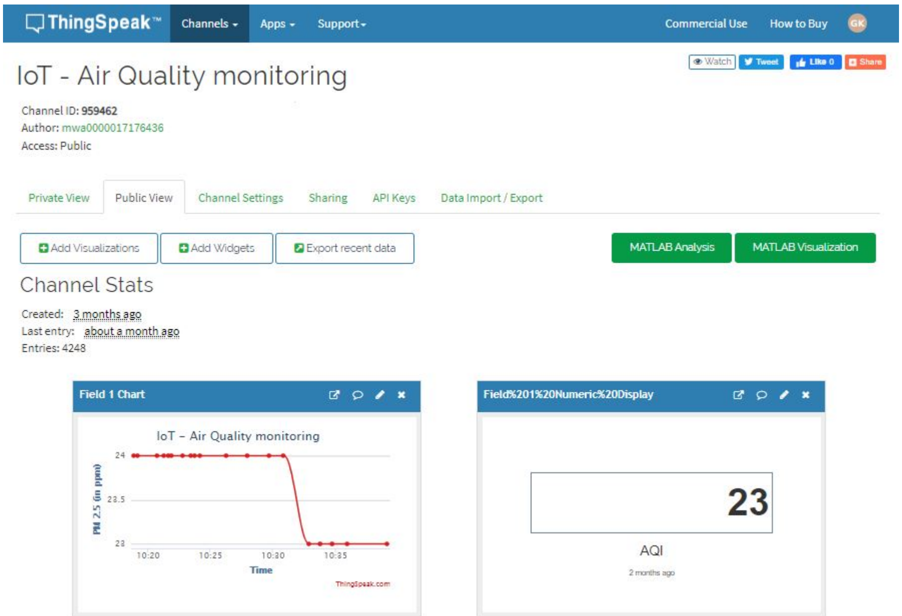

Figure 5.3: ThingSpeak Dashboard

CHAPTER 6

IMPLEMENTATION AND RESULTS

6.1 Sensor Calibration

Sensor calibration is a technique for improving sensor execution by expelling basic blunders in the sens or yields. Auxiliary mistakes are contrasts between a sensor's anticipated yield and its deliberate yield, which show up reliably every time another measurement is taken. The table 6.1 is the datasheet of MiCS 5524 containing the graph

Concentration (ppm)	Sensitivity of MiCS-5524 Rs/R0	Concentration (ppm)	Sensitivity of MQ-135 Rs/R0
1.34	3.47	10	1.009
6.84	0.9823	100.3	1.0245
13.26	0.5845	202.7966	1.0232
18.31	0.4667	506.3298	1.0014
146.168	0.1018	1015.239	0.9999
420.37	0.0467		
3013.038	0.0100		

Table 6.1: Datasheet values of Sensors MQ-135 and MiCS-5524

plotted with different pollutants such as CO, Hydrogen, Ethanol, Ammonia, Methane, Propane, Iso-butane. We separately plot the carbon Monoxide in the form of a graph as shown in Figure 6.2. The graph containing points for CO are plotted and implemented into the equation A+B $\times$ exp(C*X). This equation is programmed to NodeMCU. The figure 4.2 also contains the datasheet values of MQ 135 pertaining Air Quality. We separately plot the Air Quality in the form of a graph as shown in figure 6.3. The graph containing points for Air Quality are plotted and implemented into the equation A+B $\times$ e(C*X) using the Microsoft Excel. This equation is programmed to NodeMCU for calibration of specific pollutant for the sensors. The following figures shows the exponential functions for each pollutants.

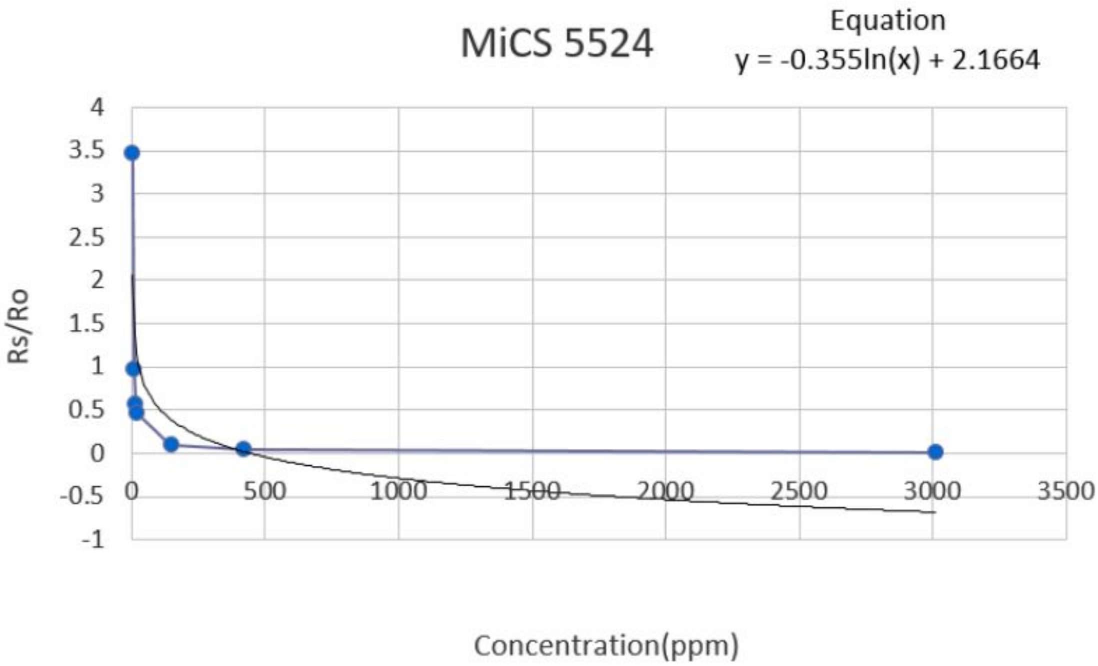

Figure 6.1: Equation for MiCS-5524 for carbon Monoxide plotted graphically

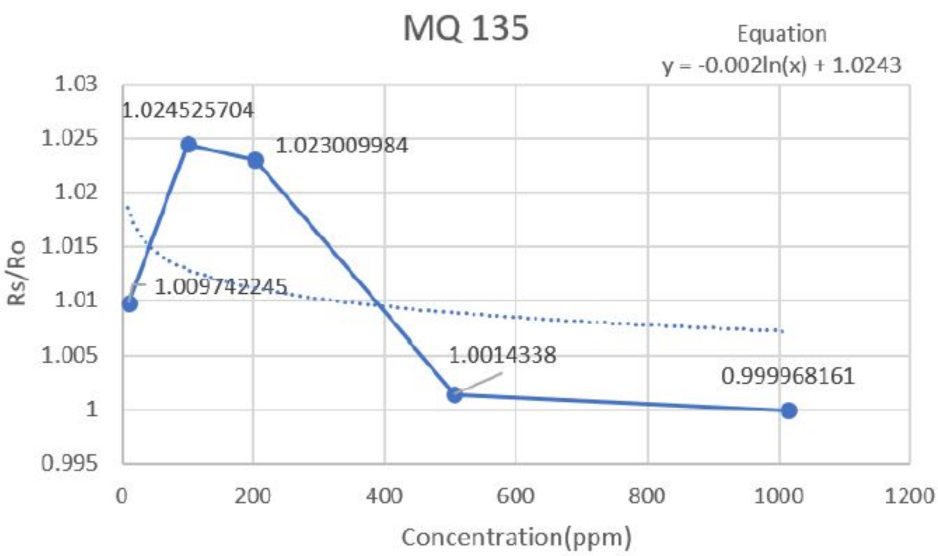

Figure 6.2: Equation for MQ-135 for PM2.5 and CO2 plotted graphically

6.2 System Implementation

The system is implemented in Techpark 15th floor to access the quality of the air in the immediate surrounding and the reading of the system are visualized both using mobile application and the online monitoring tool. The thingspeak Cloud is being deployed for both visualising and recording.

Figure 6.3: Prototype of the System

Figure 6.4: Prototype of the System

CHAPTER 7

RESULTS AND DISCUSSIONS

7.1 Observation

Date: 4th March 2020	MiCS 5524		MQ-135		MQ-135		DHT-11		DHT-11	
Time IST (GMT +5:30)	Carbon Monoxide(PPM)		PM 2.5 (AQI)		Carbon Dioxide(PPM)		Temperature(◦ C)		Humidity (%)	
	Location 1	Location 2	Location 1	Location 2	Location 1	Location 2	Location 1	Location 2	Location 1	Location 2
09:00:00	1.26	1.32	42.00	48.00	301.00	288.00	26.00	26.00	16.00	16.00
09:30:00	1.80	1.90	45.00	46.00	302.00	256.00	28.00	28.00	16.00	16.00
10:00:00	0.84	0.80	50.00	52.00	311.00	245.00	28.00	28.00	15.00	15.00
10:30:00	0.50	0.50	56.00	53.00	260.00	301.00	28.00	28.00	15.00	15.00
11:00:00	1.36	1.96	61.00	65.00	236.11	306.00	29.00	29.00	15.00	15.00
11:30:00	1.96	2.10	61.00	66.00	245.30	261.00	29.00	29.00	14.00	14.00
12:00:00	2.16	2.70	87.00	81.00	217.00	266.00	30.00	30.00	14.00	14.00
12:30:00	2.74	2.90	80.00	75.00	300.00	266.00	32.00	32.00	14.00	14.00
13:00:00	1.58	2.00	75.00	88.00	298.00	274.00	32.00	32.00	13.00	13.00
13:30:00	1.72	1.80	88.00	90.00	294.00	311.00	32.00	32.00	13.00	13.00
14:00:00	1.50	1.55	80.00	72.00	294.00	312.00	32.00	32.00	13.00	13.00

Table 7.1: Results for study conducted using the hardware prototype at two locations

After a five hour monitoring of the SRM campus at two locations with our prototype we recorded data pertaining to five parameters that are mentioned in the earlier part of this paper. All the sensors were checked and are calibrated and the data is validated with online pollution monitoring forums.

The table 5.1 shows the five hour data of the parameters at 2 different locations. The graphical plots 5.2(a), 5.2(b), 5.2(c) shows the comparison between the two locations. *(Note: The Temperature and humidity is highly similar so it is not compared)*

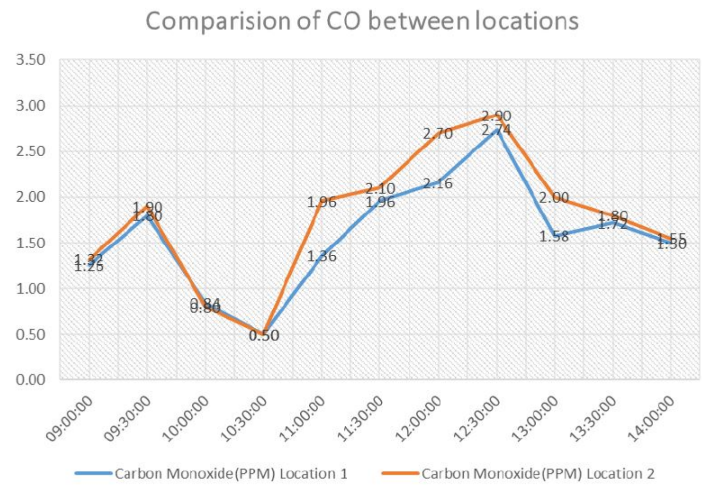

Figure 7.1: graph plot comparing CO concentration between 2 locations

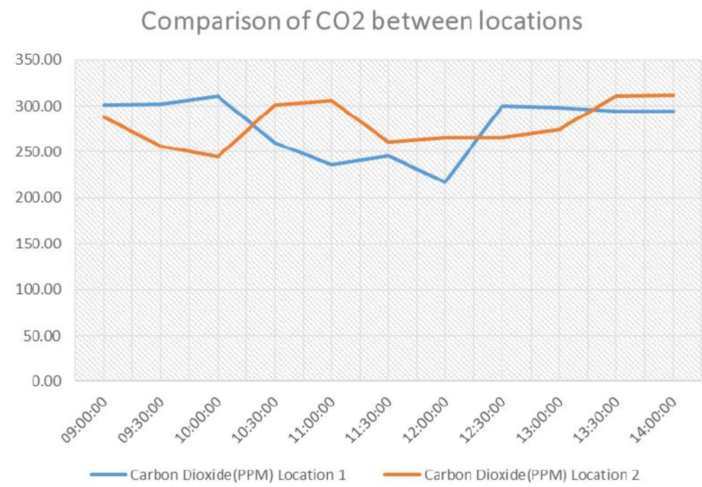

Figure 7.2: Graph plot comparing the CO2 concentration between 2 locations

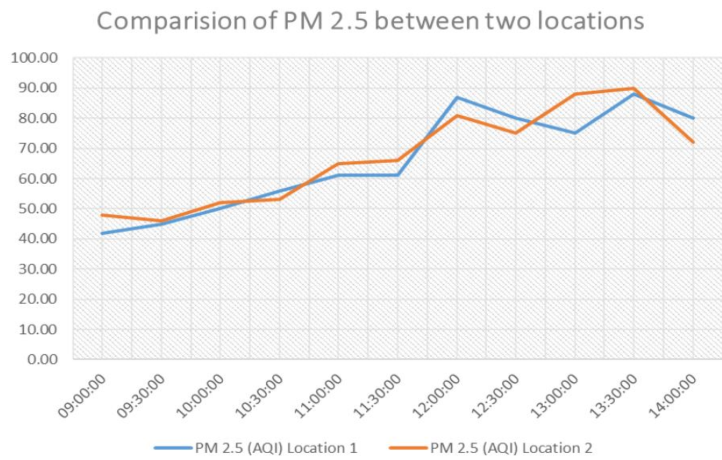

Figure 7.3: Graph comparing the concentration of PM2.5 between 2 locations.

7.2 Android Application Output

In this project, MIT App Inventor has been used as an Android Platform. Pollutant Parameters such as PM 2.5, Carbon Monoxide, Carbon-di-oxide, temperature and humidity are tracked and their values are showcased in the android application by means of respective units such as ppm, AQI, etc. / The individual pollutants are also monitored with current trends respective to time vs pollutant (in ppm, AQI etc.) represented in terms of a graph. In case of any doubt, help button can be clicked to know more about the Individual pollutant parameters range, properties and sensors implemented. / Separate icon indicating the database is also implemented. It shows the values of the individual pollutants with their history for last one week which is used for analysing purposes.

Figure 7.4: Android application Welcome page

The outputs for the android application are shown in figure 7.1 and figure 7.2. The above screen is the welcome screen and the middle screen is the display screen for pollutants and their concentrations and the right screen is the graphs showing each pol-

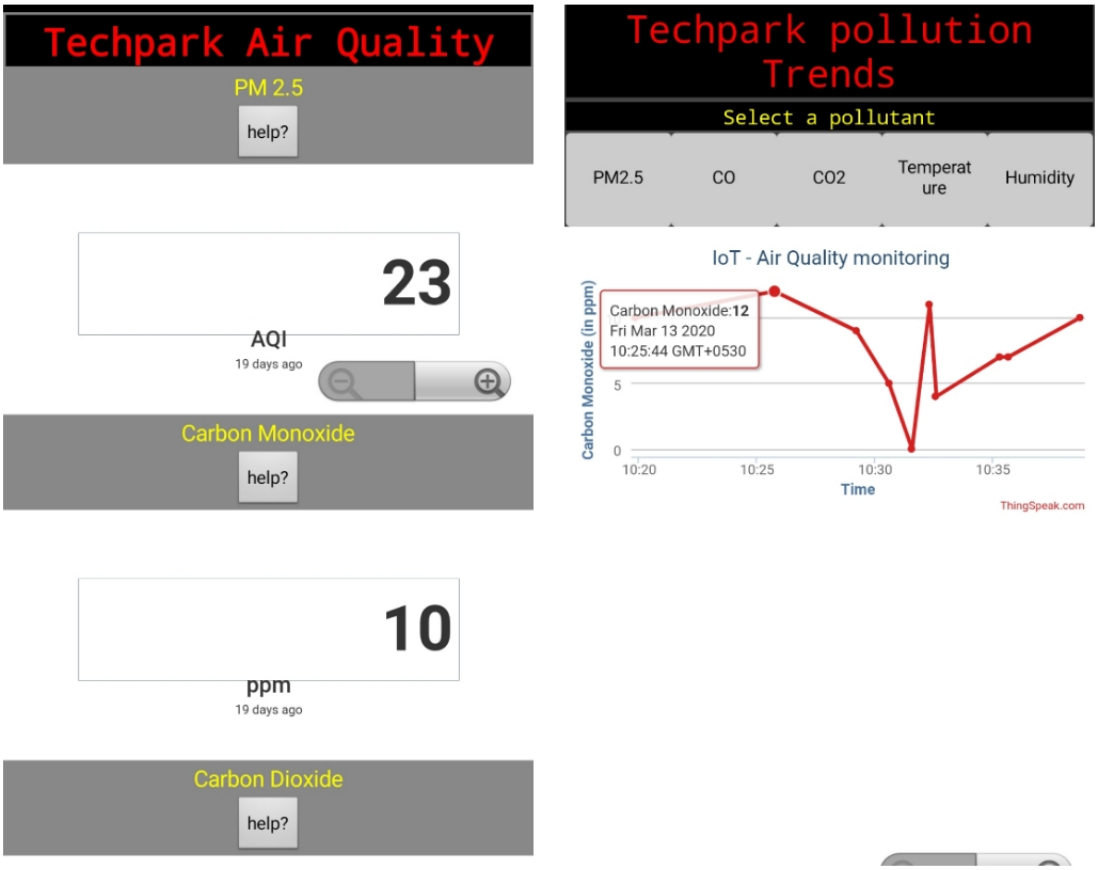

Figure 7.5: Android application output

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CHAPTER 8

CONCLUSION

The below graphs are the comparison of the air quality in two locations. From this we can monitor the pollution level in the SRM campus.

8.1 Remedies for pollution

Naturally the pollution is often controlled by the following plantation of green plants that will improve the air Quality of our surroundings.

8.1.1 Ways to reduce concentration of pollutants from CO:

While Rubber plants are created as straightforward thought houseplants, they in like manner improve indoor air quality, as showed by ponders drove by NASA. Their immense leaves can ingest airborne engineered substances and separate them, rendering them harmless. They acclimatize inhaled out carbon dioxide and convert it to breathable oxygen. Elastic plants in like manner take out microorganisms and structure spores observable all around. Elastic plants are tolerant of dismissal along these lines can be grown successfully by those with little contribution in plants. They should be allowed to dry out between watering. Elastic plants handle under-watering better than overwatering. They can prosper in decrease light, so they do well in a combination of indoor conditions. Elastic plants can over the long haul show up at 8 feet tall at whatever point given the right conditions, so should be planted where there is space for them to create.

8.1.2 Ways to reduce concentration of pollutants from Carbon-di-oxide:

According to Tom Crowther, an expert at ETH Zürich, and senior maker of the study, "Investigation shows clearly that timberland rebuilding is the best natural change game plan available today," said "On the off chance that we demonstration now, this could cut carbon dioxide in the atmosphere by subordinate upon 25 percent, to levels last watched pretty much a century back," .It could take more than a hundred years to add enough create forest to get sufficient degrees of carbon decline. Then 40 billion tons of carbon dioxide (CO2) from devouring non-sustainable power sources are being added to the air every year, said Glen Peters, explore boss at Norway's Centre for International Climate Research. Trees-all plants surely use the imperativeness of light, and through the method of photosynthesis they take carbon dioxide (CO2) from the air and water beginning from the most punctual stage.

8.1.3 Ways to reduce concentration of pollutants from PM2.5:

Toxins discharged from PM2.5 sensor are hazardous and cause numerous issues to human wellbeing. Trees assume a crucial job in decreasing the grouping of poisons by going about as a bio channel. In high urban territories, end of mechanical outflows from PM2.5 isn't practically practicable. In this manner, urban areas should build up numerous measures to diminish PM2.5 fixations. Planting trees assumes a significant job. Foliage goes about as a bio-channel of air contamination which helps in improving air quality as the leaves have harsh surface and huge contact region. A few past investigations have assessed the measure of PM2.5 expulsion from urban zones by vegetation. Studies have demonstrated that planting of trees have evacuated around 300 metric huge amounts of air poisons from Christchurch, New Zealand. The investigations propose that urban vegetation have an immediate and beneficial outcome on human wellbeing by diminishing PM2.5.

CHAPTER 9

FUTURE ENHANCEMENT

1. The proposed project is limited with monitoring with only five parameters. This can be improved by adding several more sensors that will sense and monitor the other pollutant and parameters with regards to the Air Quality monitoring.

2. The proposed project is now limited to very few locations in SRM campus this can be increased to many places for improved and overall data set.

3. WSN technology of the proposed architecture can be improved to form and internet of Nodes (ION) apart from the EDGE-IoT.

4. Implementation of Monitoring station will help in increased awarenss of the quality of air in the campus atmosphere.

5. The more stations that are implemented will result in increase in chance of triangulating position of air polluted area.

APPENDIX A

KEYWORDS

A.1 Wireless Sensor Network

A WSN is a network comprising of sensor hubs. Every sensor can recognize certain components like pneumatic force, air pressure, and water quality. WSNs are utilized in a wide assortment of settings, including individual pollutant monitoring systems such as ours. WSNs are identified with the idea of Internet of Things (IoT). All the pollutants are monitored and using this WSN and communicates through the Wi-Fi network.

A.2 The Sensor Layer

the sensor layer consists of the field devices like the sensors and the ADC modules. In this project we are using the MiCS-5524, MQ-135, DHT-11 sensor modules for sensing the Carbon Monoxide, PM 2.5, CO2, Humidity and Temperature.

A.3 The Networking Layer

The Networking layer contains the major communications between the field devices such as the sensors and the ADC module, and the NodeMCU ESP8266 from each location. The communication protocols used are described in the upcoming sections. The major protocols used are the Message Queuing Telemetry Transport (Message Queueing Telemtry Transport (MQTT)) protocol and the standard HTTP Protocol. Communication between the ADC to the NodeMCU ESP 8266 is wired by I2C protocol, however all the other communication in this layer are completely wireless and, are operated using Wi-Fi communications.

A.4 The Application Layer

The Raspberry Pi 3B+ is used as the IoT Edge device for this system configuration, all the data are transmitted to the cloud application channel – Thingspeak TM from MathWorks ©. The application layer is configured mainly using the standard Internet protocol as the Hyper Text Transfer Protocol (Hyper Text Transfer Protocol (HTTP)). The android mobile application is deployed in this layer.

APPENDIX B

AIR QUALITY STANDARD

B.1 AQI colour code

Air Quality Index is defined as an overall scheme that transforms the weighed values of individual air pollution related parameters (for example, pollutant concentrations) into a single number or set of numbers. The result is a set of rules (i.e. most set of equations) that translates parameter values into a more simple form by means of numerical manipulation. If actual concentrations are reported in parts per million (Parts Per Milion (PPM)) or parts per billion (Parts Per Billion (ppb)) along with standards, then it cannot be considered as an index. At the very last step, an index in any system is to group specific concentration ranges into air quality descriptor categories. According to Indian government Central board of Pollution control, the breakpoints of the AQI colour codes are shown in the following

AQI Category (Range)	PM_{10} 24 Hr	$PM_{2.5}$ 24 Hr	NO_2 24 Hr	O_3 24 Hr	CO 8 Hr (mg/m^3)	SO_2 24 Hr	NH_3 24 Hr	Pb 24 Hr
Good (0 – 50)	0-50	0-30	0-40	0-50	0-1.0	0-40	0-200	0-0.5
Satisfactory (51 – 100)	51-100	31-60	41-80	51-100	1.1-2.0	41-80	201-400	0.5-1.0
Moderately polluted (101 – 200)	101-250	61-90	81-180	101-168	2.1-10	81-380	401-800	1.1-2.0
Poor (201 – 300)	251-350	91-120	181-280	169-208	10.1-17	381-800	801-1200	2.1-3.0
Very Poor (301 – 400)	351-430	121-250	281-400	209-748*	17-34	801-1600	1200-1800	3.1-3.5
Severe (401 – 500)	430+	250+	400+	748+*	34+	1600+	1800+	3.5+

**One hourly monitoring for mathematical calculations only*

Table B.1: AQI Colour code Breakpoints

B.2 AQI caculation

$$AQI = \frac{(PMobs - PMmin)(AQImax - AQImin)}{PMmax - PMmin} + AQI$$

- PMobs - Observed 24-hour average concentration in ppm.
- PMmax - Maximum Concentration of AQI colour category that contains PMobs
- PMmin - Minimum concentration of AQI colour category that contains PMobs.
- AQImax - Maximum AQI value for colour category that corresponds to PMobs
- AQImin - minimum AQI value for colour category that corresponds to PMob
- AQImin - minimum AQI value for colour category that corresponds to PMobs.

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