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CIF: An IoT - based Pollution Awareness Model through Carbon level Monitoring in Urban Areas

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Abstract

IoT has changed people's life to a better version. It has proved its impactful presence to industries as well as to human beings. Not that IoT tools are used in industrial applications but also they find their presence in monitoring climatic health. To be very precise, it can be used to measure the amount of carbon content in air. As IoT has profound applications, so in this article we have designed a cost effective IoT based wireless monitoring system that will help to measure the quality of air. We have put three sensors in the device as we wanted to measure carbon dioxide concentrations, level of dust and temperature and relative humidity through a C language written API. The results obtained are displayed on website as well as viewed on a Smartphone for further processing and analysis.

Keywords: Air, Carbon, Dust Density, IoT, CIF

1. Introduction

The increase in population, automobiles, industrialization in the urban areas necessitate for construction of large number of high rise buildings. The population inflow towards the urban areas deteriorate the quality of life due to unavailability of proper infrastructure. Air pollution refers to the existence of any undesirable or unwanted materials in atmosphere that can be hazardous to health of human beings or any other living organisms or puts any amount of negative impact to climate or to materials. Gaseous pollutants are of many types like that of ammonia, carbon mono-oxide, carbon dioxide, sulphur dioxide, nitrous oxide, methane and chlorofluorocarbons. Air pollution is the prime source not only to any kind of diseases and allergies and even can cause death. It is also harmful to other living organisms and food crops, and can also damage our environment. Both human activity and natural processes can cause pollution to air. Many wireless sensor based air monitoring devices are available in the market that collect data from a target region and route to the sink through the use of appropriate routing ptotocols [1]. There are many different ways through pollution can enter the Earth's atmosphere. Human beings or their high ambition activities are the leading contributors in making the air polluted. The results of high ambition activity are continuous smoke emissions from manufacturing industries and factories, vehicles, aeronautical machines, or from containers that hold aerosols. Secondly, cigarette smoking also contributes to air pollution to some extent. These pollution sources are undoubtedly man-made and hence these polluting sources have been termed as anthropogenic sources. There exist some natural sources of air pollution too, such as smoke and fumes generated from a uncontrolled wildfire or sometimes ash coming out from volcanic eruptions.Although these events do not occur on a regular basis but still, whenever it occurs, becomes a prominent contributor to environment pollution. The remark of WHO is utter surprising. A report released by WHO stated that large cities of poor and developing nations cause more air pollution than that of cities of developed nations. But many of the developed nations have their own environment pollution problems. After effects of air pollution on human beings are categorized as short-term or long-term.

Short-term effects are basically temporary. Pneumonia or bronchitis are some of the effects. In addition they may cause certain discomforts like that of nose, throat, eyes, or skin irritation. Pollutants suspended in air can also cause headaches, dizziness, and nausea . Foul smell from exhaust of factories, disposed garbage, or from sewerage lines are also treated as air pollution. Even though these odours are not so serious but still are very unpleasant [12]. Pollution's long-term effects are deadly which will exist for many years or sometimes it may be till person's last breath. A person can even die because of this. Heart disease, cancerous lungs, abnormality in respiratory track are some of the Long-term health effects of air pollution. The list of bad effects is not limited to these three body parts only. Other organs that get affected are long-term damage to nervous system, brain, kidneys, liver, and other organs.According to the statistics from WHO, approximately 2.5 million people die across the globe every year from after effects of pollution of air. While discussing solutions to pollution we only consider outdoor pollution whereas indoor air quality is also equally important [11].

Increase in pollution of air day by day due to increase in Industrialization and modernization in absence of proper air quality monitoring methods is posing a moral challenge in front of each individual as well as social responsibility to researchers and scientists. As a result, many of the industries have focused their efforts in developing some alternative methods which will help in measuring and improving air quality. In order to get the measure of air pollutants concentration, people are employing wireless monitoring systems. For instance, carbon monoxide, carbon dioxide, oxygen and nitrogen dioxide sensors have been joined in a Wasp-mote card. The idea is also extended to attach appropriate sensors on a mobile unit which can measure the level of CO in the atmosphere in real time. Now a day's air pollution is under acute monitoring so as to control industrial activities. Using calibration technologies, real time measurements of concentration of CO2, NO2, CO and O2 gas are being obtained. A web based mobile real time air quality monitoring system has been successfully designed and implemented. However, an integral solution is yet to be achieved. The principal objective of this solution is to obtain a solution that is cheap and has the ability to predict the concentration levels of several greenhouse gases leading to global warming and climate change.

We need a monitoring system that is efficient as well as can assess and monitor environmental conditions in case the environment quality parameters such as noise, CO and radiation levels exceed the prescribed level. When the environment is equipped with objects like sensors, micro-controllers and different other softwares then it becomes a smart environment a it is now self-protecting and self-monitoring. This smart environmental monitoring system monitors and controls the effect on animals, plants and human beings due to environmental changes. To predict the behaviour of a particular area of interest we first have to collect data and hence sensors are positioned at appropriate locations . The main aim is not only to efficiently monitor the required parameters remotely but also to send the data gathered from the sensors to cloud so as to estimate the projected trend. Hence Internet of Things (IoT) can come to our rescue at this juncture .

The Internet of Things (IoT) paradigm can be visualised as self-configuring and interconnected set of intelligent smart devices that has sensing as well as actuation capabilities having limited computing resources. According to various researches that are conducted recently cloud computing has proved to be a better alternative solution to tackle most of the challenges presented by IoT. Service composition is crucial in those environments where a single provider is not enough to fulfil user demands. This leads to Multi-clouds IoT Environment. The key environmental concern is the rapid growth in levels of energy consumption and emission of carbon associated with the use of cloud computing. The density of IoT application users, providers, and data centres is tremendously increasing leading to significant increases in network traffic [9] [20].

One of the biggest problems is environment pollution. When impurities mix with air, water and soil, pollution occurs. To safeguard ourselves and our family, we have to be watchful and need to keep an eye on the level of pollution. When pollution level crosses safe limits or certain threshold value, it needs to be purified. We have to quantify pressure of air, it's temperature, amount of radiation possibly Ultra Violet radiation, quality of air, smoke, Nitrogen Dioxide and Carbon Monoxide contents for air pollution control and hence sensors that can measure pressure and temperature, amount of Ultra Violet Radiation, record General Air Quality ,concentration of NO2, concentration of CO are needed to measure the amount of pollution in air [17]. Urbanization though brings modernization is always associated with multifaceted challenge related to urban environment due to growth in population, increasing economic activities, industrialization, change in lifestyles,that brings in a completely new set of challenges regarding E-waste management. Un-managed waste can lead to severe pollution [15] [18].

Urbanization leading to Pollution not only affect human beings and animals but also it has a devastating effect on the yield of crops [14].Monitoring water pollution is of equal importance. Amphibious vehicles have been designed for monitoring the quality of water without any human intervention.Fresh water is lacking in most of the countries around the world. pollution leading to global warming has created an alarming situation to ensure the availability of water for various day to day activities

[13] [19].The quality of air depends upon the percentage of its parameters. The important aspect of air quality is significantly affected by CO2.

2. Related Work

Petros Spachos et. al [8] have considered the issues related to indoor air quality and proposed an efficient model for monitoring and determining the level of carbon dioxide from concentration of air in real-time and provided alerts pertaining to quality in a periodical fashion. They have used a cognitive wireless sensor network system for real-time percentage monitoring of carbon dioxide in air to monitor a complex indoor environment. Their proposed model has the feature of enhanced data transmission real-time by validating and supporting the process of system development intended for real-time monitoring and alerting. Walter Fuertes et.al [2] have designed a cost effective wireless monitoring system, that has helped in measuring air quality referential parameters. Their model is mul tilayered and also distributed; all put together in an Arduino platform. The model consisted of some physical objects coupled in electronic circuits, softwares, sensors connected through a wireless medium that allows real-time monitoring of pollutant concentration in air. Softwares that are used have been developed using Scrum and Extreme Programming belongs to the class of Agile methodologies as they guarantee quality of software. The electronic device has sensors which can not only measure the level of CO but also the level of CO2 and density of dust concentrations, using a C++ language developed API.

Bulipe Srinivas Rao et.al [3] have proposed an IoT based advanced and efficient solution for monitoring the weather conditions at a particular place and make the information visible anywhere in the world. The model can monitor and control the environmental parameters such as temperature, relative humidity, light intensity and the level of CO with properly equipped sensors. Data collected is sent to web and is then plotted as graphs. As data is present in web, it can be accessed at anytime and from anywhere.

Daniel (Jian) Sun et.al [6] proposed a model named MOVES for comprehensive analysis of urban traffic carbon emissions. They came up with a mobile architectural design for monitoring carbon emissions using a set of equipments. The data collected was about flow of traffic, meteorological conditions, and carbon emitted from vehicles that had direct correlation with driving characteristics in and around the city of Shanghai. The data collected was sensitive and had to be dealt with very carefully for correlation evaluation. The crucial parameters influencing the carbon generation in urban traffic conditions were examined. Results obtained were impressive and played a significant role in guiding people in further minimizing the urban low-carbon transportation.

M. Newlin Rajkumar et.al [5] implemented an IoT framework with an objective to measure the emission of CO2 from public transport vehicles, manufacturing industries and forest fires. The carbon emission is sensed on a continuous basis. The designed system is smart enough to detect forest fires or wild fires very early because wildfires emit more CO2 as compared to any Urban or metro states. The module would trigger a Simple Notification Service (SNS) to the mobile phone if a particular area is having higher levels of CO2.

Gonc¸alo Marques and Rui Pitarma [10] have designed a model to keep an eye on quality of indoor air on a real time basis and activate the ventilation systems accordingly so as to improve the quality of air. The solution is based on Internet of Things Architecture. The model is made up of a hardware module, a web and a Smartphone. The model is wireless systems that have characteristics like it is modular, scalable; cost is low and easy to install. Data is collected in real-time and is accumulated over ThingSpeak platform. Compatible of the system is there even with a Smartphone that can provide ease of access to the captured data. Although user can examine the latest captured data he has even access to historical data represented in a graphical form. Ashwini.R et.al [4] proposed a cost effective and easily manufactured and installed model to reduce the greenhouse effect by real time monitoring and controlling of CO2 and CO emissions from vehicles and industries using IoT. The Internet of Things (IoT) provides internet connectivity to various categories of devices and helps to communicate and interact with the outside environment.

Gonc¸alo Marques et.al [16] has designed a robot named “iAirBot” that helps in monitoring the quality of air inside rooms on the premise of Internet of Things. The robot will be in touch with area residents with triggers. The performance of the model was promising. It connected various technological fields and knowledge. The model was unique as it was modular, scalable and it could share information over social networks. Cristian Toma et.al [7]investigated some of the prime operational issues that any real-time pollution monitoring system consisting of sensors, IoT communication protocols, communication channels, would face. Major focus of the proposed solution was security derived out of existing standards and best practices. The solution had the ability of interpreting and analyzing the accumulated data to generate what is known as pollution maps. The maps could be utilized to suggest some counter measure solutions in real-time like that of diverging traffic to reduce concentrations of air pollutants. Alternatively the solution could reduce pollution of a particular area at a particular instant of time by dynamically offering alternate routes when pollution Thresholds are reached.

JunHo Jo et.al [21] has demonstrated an IoT based model for monitoring the indoor air quality. The model was coined as “Smart-Air” that has the capability to monitor the quality of indoor air from anywhere and at any point of time. Monitoring was efficient and data was transmitted in real time to a web server through LTE. The model consisted of a microcontroller, couple of pollution detecting sensors, and a modem compatible with LTE. For analyzing the recorded information cloud computing is integrated to that web server for classifying and visualizing indoor air quality. Only authorized persons have the permission to monitor at any point in time and from anywhere. All data are uploaded in cloud through web servers for further analysis.

Year	Author	Includes CO_2 parameter	Includes environment temperature	Includes environment humidity	Data Filtering	Supports Wireless System	Provides service in Cloud
2015	Walter Fuertes [2]	Y	N	N	N	Y	N
2016	Petros Spachos [8]	Y	N	N	N	Y	N
2016	Bulipe Srinivas Rao [3]	Y	Y	Y	N	Y	Y
2017	Daniel (Jian) Sun [6]	Y	N	N	N	Y	N
2017	M. Newlin Rajkumar [5]	Y	N	N	N	Y	Y
2017	Gonçalo Marques [10]	Y	Y	Y	N	Y	N
2019	Ashwini.R [4]	Y	N	N	N	Y	N
2019	Gonçalo Marques [16]	N	N	N	N	Y	N
2019	Cristian Toma [7]	Y	Y	N	N	Y	N
2020	JunHo Jo [21]	Y	Y	N	N	Y	Y
	Proposed Model-CIF	Y	Y	Y	Y	Y	Y

TABLE I: Comparison table between different models

3. SYSTEM ARCHITECTURE

The prototype model supports five different layers to define the architecture and its communication system such as Data Collection Layer, Data Forwarding and Formatting Layer, Network Layer, Data Storage Layer and Application Layer as shown in figure- 1.

- **Data Collection Layer:**

This layer has been used to collect different kinds of required data from the environment to visualize the status of air quality. To achieve the objective of this layer multiple sensors with limited battery power are connected to an embedded system. The attached sensors basically stay with the surface and are underlying in the environment data with different levels of CO2. These sensors collect data from the environment and pass it to the next layer.

- **Data Forwarding cum Formatting Layer:**

Various embedded systems (ES) or if required, microcontrollers are used for collection and preprocessing of data. These devices are capable of getting data from sensors as well as can perform desired operations on the collected data because these devices are equipped with processing unit, a memory that is programmable and limited storage, . Different boards such as Arduino, Raspberry Pi, Adafruit Flora, Particle Photon and so on can be used for the said purposes. The responsibility of these devices to accept the collected data and forwards to the destination locally or globally for next level of processing.

- **Network Layer:**

The data sensed by the sensors and collected by ES has to be sent to storage layer or if needed directly to application layer through various wired or wireless networks. Collected data, if necessary, can be transferred to cloud by using altogether a different network technology called Ubiquitous Sensor Network technology. For communication over a short range either Bluetooth, ZigBee, Infrared devices are used and if storage of data on servers is necessary then we can use internet-enabled Wi-Fi, LAN or WAN. To establish the connection between the proposed model and server one WIFI module has been used in network layer.

- **Data Storage Layer:**

To monitor the quality of air or to analyze the data statistically, sometimes it is very much necessary to store collected information. One of the most preferable storage related to IoT applications is the Cloud storage. The data also can be stored in local or global database servers as per requirements. To implement the data flow between sensors and server all kinds of storage have been used in the proposed model.

- **Application Layer:**

This layer has been proposed as an interface to the different end users to monitor and analyze the collected information. Different display devices, web browser are used in the proposed model to provide a view of the collected information.

4. Sensor Infrastructure

- **DHT22**

To measure the parameters of the environment, DHT22 sensor is used for better result analysis. The temperature measure- ment is in the range from -40 to +125 degree Celsius with +-0.5 degree accuracy. DHT22 has a better humidity measuring capacity ranging from 0 to 100% having an accuracy of 2-5%. To measure humidity parameter a NTC sensor and another IC on the back side of the sensor is attached, which again has two electrodes for moisture holding. With the change in humidity, there is a change in conductivity or change in relative resistance of attached electrodes. The IC measures and processes this change in resistance and prepares it for the microcontroller to read and process. This sensor has four pins out of which VCC, GND, data pin are used for operations and another one is not used for any purpose.

- **MQ-135**

This is used for air quality control by detecting or measuring level of NH_3, Alcohol level, Smoke and CO_2. This comes with a digital pin which makes the sensor to operate without using a microcontroller. SnO_2 used in this sensor makes it more resistant and clears air as a gas-sensing material. With an increase in pollution level of gases, the resistance decreases for the gas sensor.

- **Optical dust Sensor**

The GP2Y1010AU0F is an optical dust sensor that is used to measure one of the air quality parameters i.e to sense dust particles. A diode that emits infrared radiations and a phototransistor are connected diagonally into the device so as to allow the reflected light of dust in air to be detected. Very fine particles like cigarette smoke is effectively detected by this sensor and hence is a commonly used component in air purifier systems. It consumes very low current consumption like 4.5V to 5.5V for operations.

5. System Modelling And Communication Mechanism

The revolution in the Internet of Things assists us to track and monitor anything and everything from anywhere at any moment without being present at that location. So neither the geographical location of the event nor the controller are hindrances of each other. Sole purpose for which the model is designed is to help for real time air quality monitoring with CO_2 level

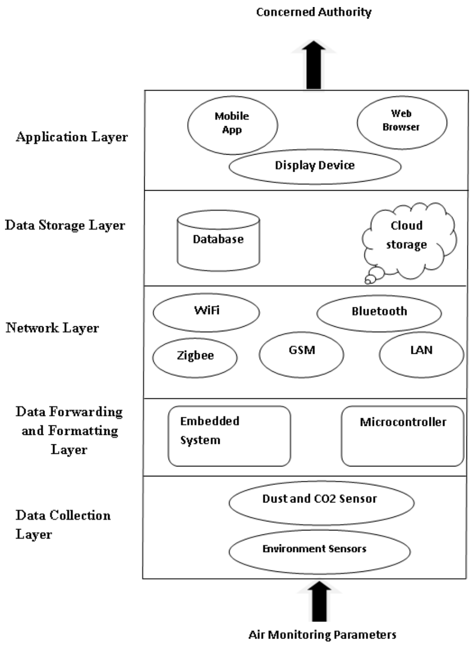


Fig. 1: Layering of Model for the Proposed Network

detection in online,offline or hybrid mode. End-to-end delivery of data is the most important property of our communication model. This calls for a layering architecture, and hence we have used various layers in our network communication. Since the entire communication process consists of data extraction, its acquisition and transmission from the environment to different users and hence layers need to be interconnected with each other. Using different layers data packets will be sent from source to destination undergoing different procedures. Using the following procedures the model Carbon level monitoring through IoT-based Framework (CIF) has been proposed.

A. Packet Creation Process

Formation of data packets and its processing is carried out at every monitoring board. The rate at which Packets are createdis equal to the rate at which sensors can transmit data. The data packet uses four different fields for communication.

Identity of Sensor

To uniquely identify the sensor in the network every sensor is assigned with an id. The id is used for packet communication between the sender and receiver in the entire network. The location of the sensors will stored along with their corresponding id to set up the path. If the sensor moves to a new location then its location can be updated due with the help of identification.

Time Stamp

During communication time stamp from the radio module is assigned to the packet when it is created. The order of processing of data packet depends on this time stamp. In any real-time scenario where an application has been designedto monitor CO_2, time is considered of great importance as it captures variation in levels of CO_2 over certain period of time.

Data Sensing

The data sensed by a sensor is passed on to radio module. Data fields store all vital information related to CO_2 and environment data with different metrics.

Data Storage

The information coming from sensor modules are stored in local database. The database has various attributes that capture information like remaining battery power, average Received Signal Strength Indicator (RSSI) for maintaining location information.

B. Packet Communication Process

When any data is collected from different sensors associated with environment in data collection layer, it is transmitted through a packet. Every packet has data along with sensorID, timestamp and its corresponding data. Every data packet will be collected and forwarded in data forwarding and formatting layer where microcontroller NodeMCU is used. It supports Wi-Fi transmission and uses the network layer to transmit the data to the destination server. The data will be stored in local as well

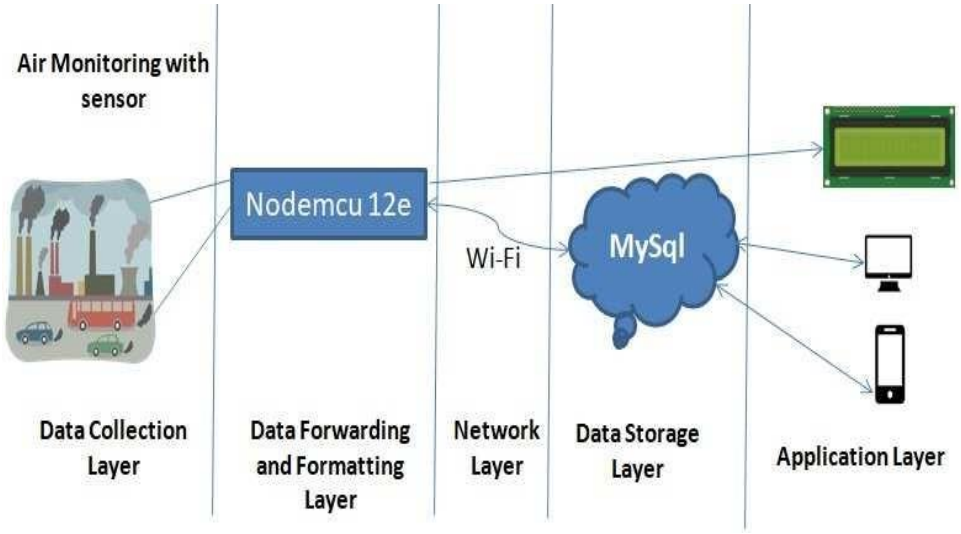


Fig. 2: Working Model of CIF

as global server for further processing and analysis in the data storage layer. The expected CO_2 level can be expressed interms of result and graph in the application layer at different times in real-time as shown in figure- 2..

C. CIF Configuration Process

To develop our real time model named ”CIF” we have used NodeMCU which is an open source IoT development board based on eLua to which we have integrated ESP8266 which will enable us to use the model both in access point mode as well as in stationary mode. The 10 GPIO pins that it has are numbered as D0 – D10 out of which one pin is a ADC pinand several other I2C and SPI communicators. Each of these I2C and communicators have multiple pins functionalities are different and possess their own pin configuration. To describe the proposed model we need to understand that all the pins ofall the components are not active, so the needed ones are connected by targeting complete pin configuration. Both dust sensor and MQ135 module generates analog signals as output. But NodeMCU-12e has only one in-built ADC pin. So we have addeda 8:1 MUX named CD4051s to select the outputs from sensors serially. To collect data from CD4051 module only 3 pinsneed to be selected, and from the appropriate combination of these selected pins we get data. To ADC of NodeMCU the only output pin of CD4051 is connected, which sends the combination through the selected line of chip and accordingly either dust sensor’s output signal or MQ135’s output signal is delivered through CD4051. The DHT22 sensor will produce digital data directly without the help of multiplexer. It can be directly connected to the NodeMCU for transmission of data to the server.

5. Experimental Result Evaluation And Analysis

To meet the objective of air quality monitoring the DHT22, dust sensor and MQ-135 are attached with the microcontroller as shown in figure- 3 to collect and propagate the data to the required server for analysis. NodeMCU, as per its functionality, will collect output analogue signal from all the sensors with the help of CD4051 multiplexer. Three select line of CD4051B is connected to NodeMCU via D6, D7 and D8 pins. NodeMCU has been instructed in such a way that first it send all LOW signal to select I0 channel of CD4051B, through which it reads the data from the MQ-135 and subsequently NodeMCU sends LOW signal through D6 and D7 and HIGH signal through D8 to select I1 channel through which dust sensor will send data to NodeMCU. The microcontroller is programmed using Arduino IDE that converts these analog signals to digital as and when needed. To represent environment conditions, DHT22 records values of both temperature and humidity of environment. Currentdate and time is also recorded by our model so that we can go for real time monitoring.

Figure- 4 shows the live demonstration results through serial monitor of the Arduino IDE. Values of different parameters generated from the designed model are represented with various units like temperature in degree centigrade, humidity in %, air quality in terms of PPM i.e. Parts per million and density of dust in mg/m^3. Similarly for real-time monitoring the model forwards data to the server so that anyone can access from throughout the globe with proper authentication. Wi-Fi is required so as to send digital data from NodeMCU to database server. Out of two modes Stationary mode and Access point mode of NodeMCU, the stationary mode has been used to develop the model to connect to the local Wi-Fi.

We have been using MySQL as the database and able to create a local server by using Apache as the web server. PhPMyAdmindatabase tool of MySQL is used for its user-friendly front end view of the database. PHP script is stored on the server side which will be called by the server. NodeMCU uses the script by using URL and GET method is used to transfer the data from NodeMCU to the server. The parameters that are displayed on the browser through a web page are also stored in a database

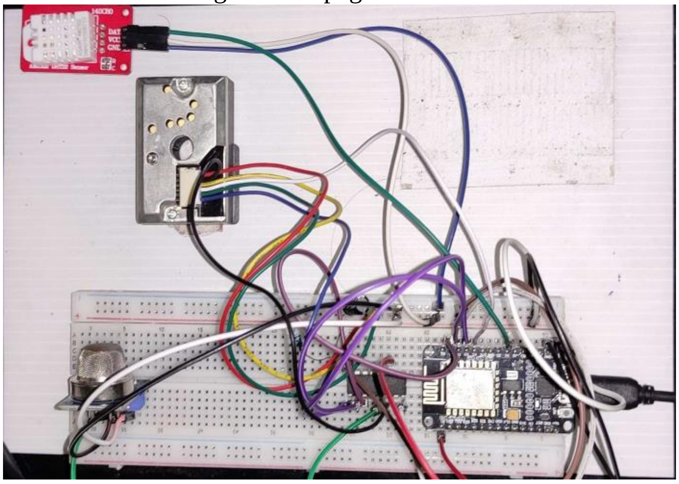


Fig. 3: Live Demonstration of CIF Model

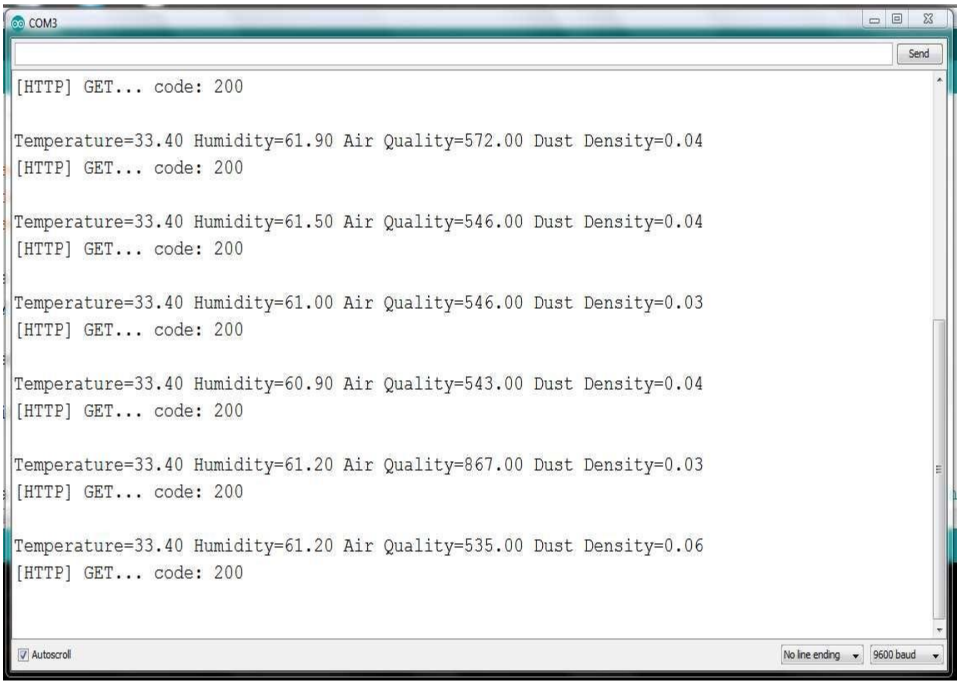
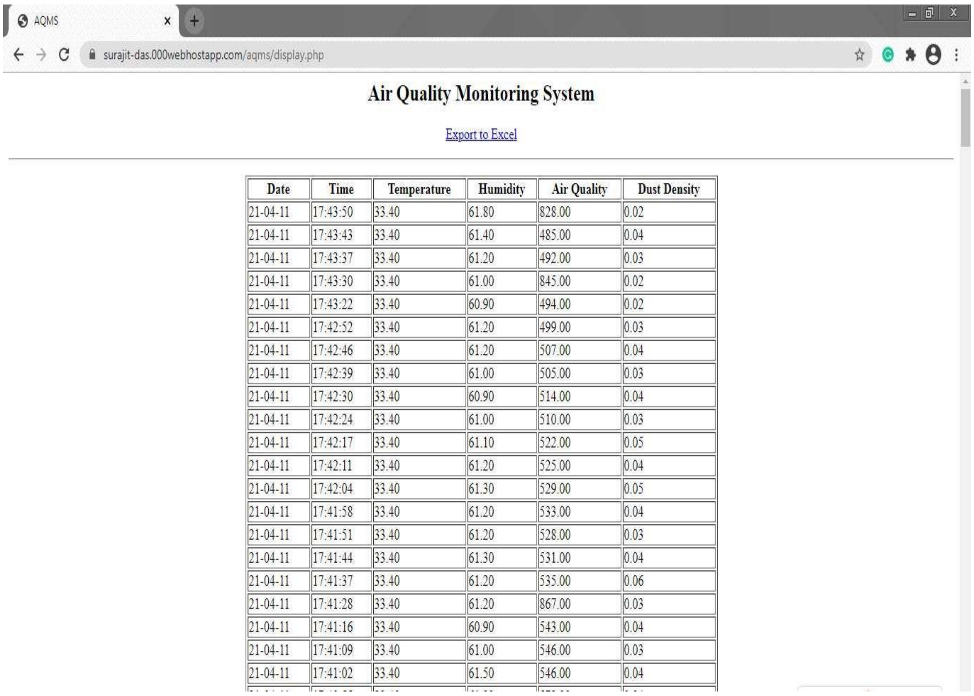


Fig. 4: Live Demonstration of CIF Model through Serial Monitor

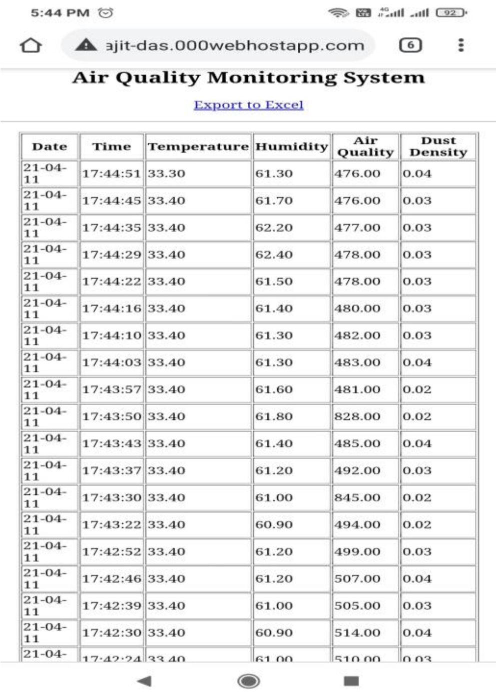
timestamped with current time and date as shown in figure- 5 and figure- 6. Also the experimental results can be viewed trough mobile application in real-time throughout the globe. Figure 7 shows the live demonstration of parameters acquired from the CIF model. For the instance view in mobile, the help of a third party application named Blynk has been taken, which is an open source IoT platform to control the IoT hardware remotely and also store and display the data sent by the model. The received data from CIF model has been forwarded to the Blynk server along with parallel to the database server.

All information collected from sensors that we have stored in databases can be extracted, if needed, for analysis. Condition of air and other parameters related to environment have been analyzed to show the status of the carbon level. For a case study, the model has been tested at different places in three different times. The vital signs of the environment have been recordedin morning, evening and night at different dates. Considering the situation of ideal environment it can be concluded that the temperature gradually increases in due time for several factors. The same situation has been demonstrated through the use of CIF model in figure- 8 by considering 100 different parameters. The DHT22 sensor of the model generates the real-time temperature data to provide the status of the environment to the registered users. Figure- 9, 10, 11 also represents different parameters to calculate the carbon level like environment humidity, air quality and percentage of dust density. To analyze the status of carbon level, parameters have been collected at different instant of times. While running the model it is concluded that during morning time humidity percentage is becoming more in comparison to other two times. Through figure- 10 data related to air quality has been displayed which gives a clear idea that due to maximum usage of vehicles and industries, the parameter provides the worst values for evening time where as it is better during morning time and then night. The entire comparison shows the fact about the status of air quality considering 100 numbers of readings at different times. For remote validation regarding correct response from sensors, data is collected individually at three different time slots i.e. in morning, in evening and at night. From figure- 11 it is evident that our model is working efficiently and sending data continuously to monitor the carbon level from remote locations. Dust density sensor has provided maximum during evening time, at morning it was lowest and at night intermediate result have been experienced and represented in figure- 11.


AQMS
surajit-das.000webhostapp.com/aqms/display.php
Air Quality Monitoring System
Export to Excel

Date	Time	Temperature	Humidity	Air Quality	Dust Density
21-04-11	17:43:50	33.40	61.80	828.00	0.02
21-04-11	17:43:43	33.40	61.40	485.00	0.04
21-04-11	17:43:37	33.40	61.20	492.00	0.03
21-04-11	17:43:30	33.40	61.00	845.00	0.02
21-04-11	17:43:22	33.40	60.90	494.00	0.02
21-04-11	17:42:52	33.40	61.20	499.00	0.03
21-04-11	17:42:46	33.40	61.20	507.00	0.04
21-04-11	17:42:39	33.40	61.00	505.00	0.03
21-04-11	17:42:30	33.40	60.90	514.00	0.04
21-04-11	17:42:24	33.40	61.00	510.00	0.03
21-04-11	17:42:17	33.40	61.10	522.00	0.05
21-04-11	17:42:11	33.40	61.20	525.00	0.04
21-04-11	17:42:04	33.40	61.30	529.00	0.05
21-04-11	17:41:58	33.40	61.20	533.00	0.04
21-04-11	17:41:51	33.40	61.20	528.00	0.03
21-04-11	17:41:44	33.40	61.30	531.00	0.04
21-04-11	17:41:37	33.40	61.20	535.00	0.06
21-04-11	17:41:28	33.40	61.20	867.00	0.03
21-04-11	17:41:16	33.40	60.90	543.00	0.04
21-04-11	17:41:09	33.40	61.00	546.00	0.03
21-04-11	17:41:02	33.40	61.50	546.00	0.04

Fig. 5: Live Demonstration of CIF Model through Web view



Date	Time	Temperature	Humidity	Air Quality	Dust Density
21-04-11	17:44:51	33.30	61.30	476.00	0.04
21-04-11	17:44:45	33.40	61.70	476.00	0.03
21-04-11	17:44:35	33.40	62.20	477.00	0.03
21-04-11	17:44:29	33.40	62.40	478.00	0.03
21-04-11	17:44:22	33.40	61.50	478.00	0.03
21-04-11	17:44:16	33.40	61.40	480.00	0.03
21-04-11	17:44:10	33.40	61.30	482.00	0.03
21-04-11	17:44:03	33.40	61.30	483.00	0.04
21-04-11	17:43:57	33.40	61.60	481.00	0.02
21-04-11	17:43:50	33.40	61.80	828.00	0.02
21-04-11	17:43:43	33.40	61.40	485.00	0.04
21-04-11	17:43:37	33.40	61.20	492.00	0.03
21-04-11	17:43:30	33.40	61.00	845.00	0.02
21-04-11	17:43:22	33.40	60.90	494.00	0.02
21-04-11	17:42:52	33.40	61.20	499.00	0.03
21-04-11	17:42:46	33.40	61.20	507.00	0.04
21-04-11	17:42:39	33.40	61.00	505.00	0.03
21-04-11	17:42:30	33.40	60.90	514.00	0.04
21-04-	17:42:24	33.40	61.00	510.00	0.03

Fig. 6: Live Demonstration of CIF Model through Mobile view

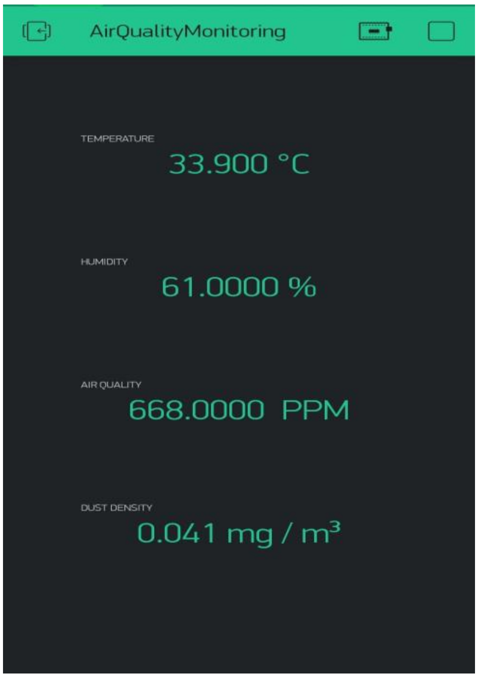


Fig. 7: Live Demonstration of CIF Model through Blynk App Interface

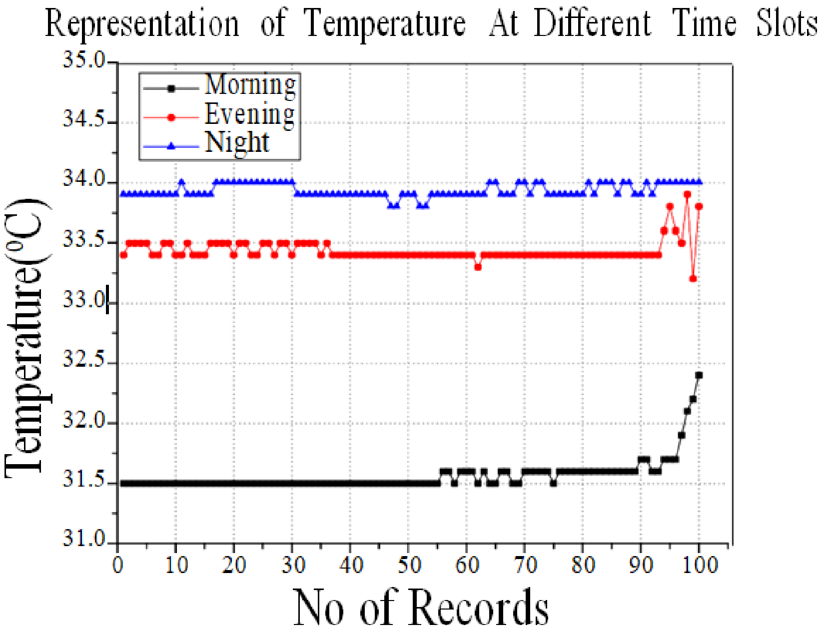


Fig. 8: Temperature at different Times Using CIF Model

6. Performance Analysis

The performance analysis of the model has been done based on error rate, delay rate and the time relevant value. The designed CIF model minimizes the error rate with the minimum delay and provides the time relevant data in real time. Also it enhances the response time due to parallel processing mode of collected data from sensors. The AWS cloud server is also used to support large scale calculation and analysis of data.

Authors have developed the iAQWi-Fi model [10] monitoring by considering three different parameters like temperature, humidity and dust density percentage to monitor the level of carbon in air. Using the same principle CIF model has been designed to meet the objective with one more extra parameter i.e. air quality in parts per million. Both the models are able to collect data from different sensors and forward data to the global server. Authors have used ThingSpeak as global server to show the result in real-time to all the users. But due to local processing of data and filtration mechanism CIF produces better data than iAQWi-Fi. Figure-12, 13 and 14 specifies the comparison between CIF and iAQWi-Fi w.r.t. temperature, humidity and dust density. Every figure represents 100 numbers of records for every parameter and concludes that CIF performs better than iAQWi-Fi. All parameters are also calculated using a hygrometer, thermometer and SYGA formaldehyde detector manually to collect humidity, temperature and dust density. Also for verification data has been retrieved by using the developed model to find the enhancement percentage of CIF over iAQWi-Fi. For every parameter the absolute difference between the value we are getting from the sensor and the value given manually by several devices has been considered. Table-II specifies the collected data at different time slots. The time slot specifies the average of 100 records collected during that time. Similarly five different data has been represented from five different time slots. In general the performance of CIF over iAQWi-Fi for temperature is enhanced by 26%. Similarly for humidity and dust density enhancement of CIF over iAQWi-Fi [10] is foundas 13% and 24% respectively.

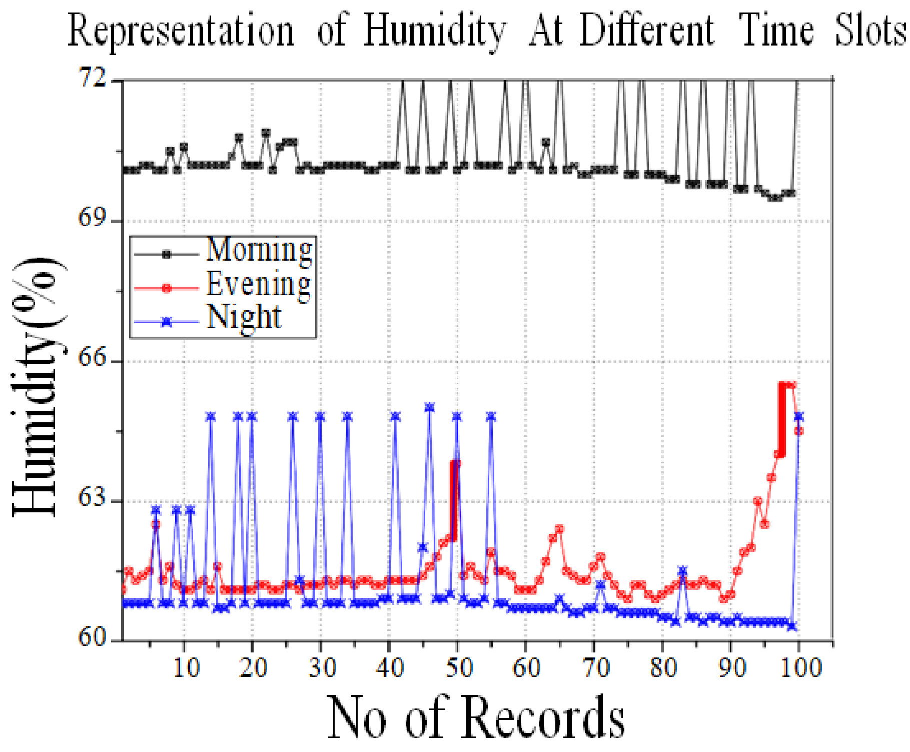


Fig. 9: Humidity at different Times Using CIF Model

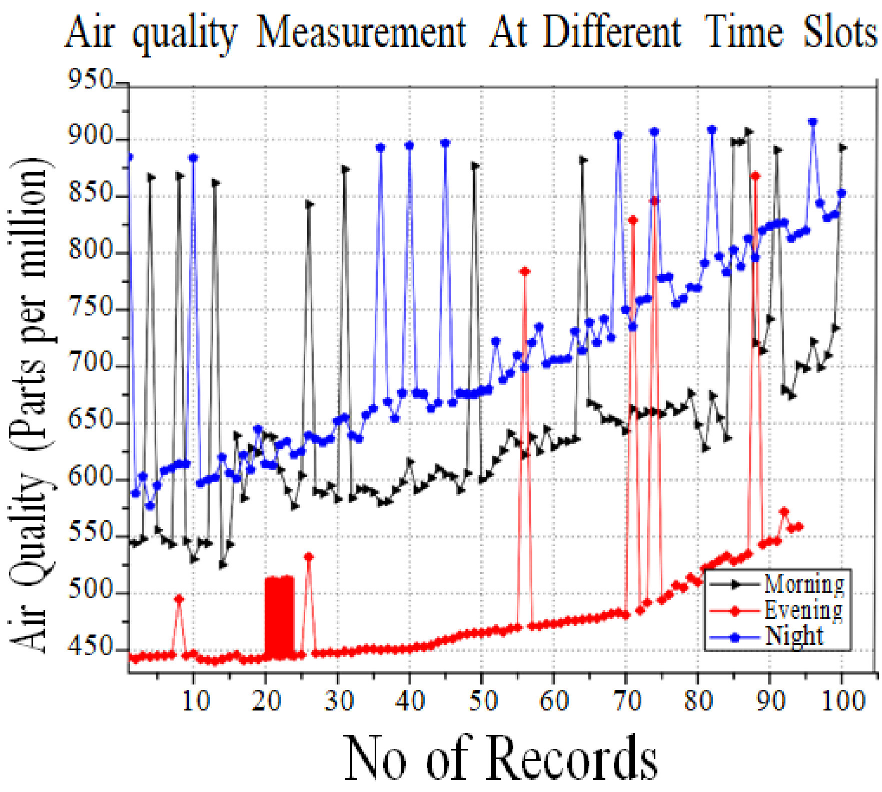


Fig. 10: Air Quality at different Times Using CIF Model

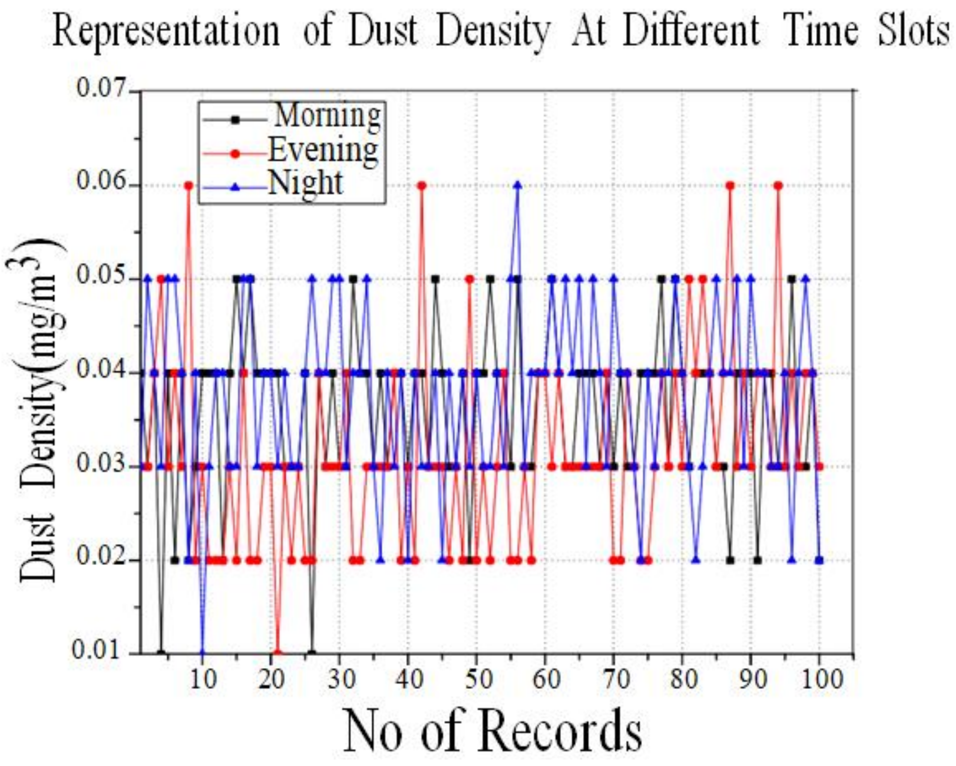


Fig. 11: Dust Density at different Times Using CIF Model

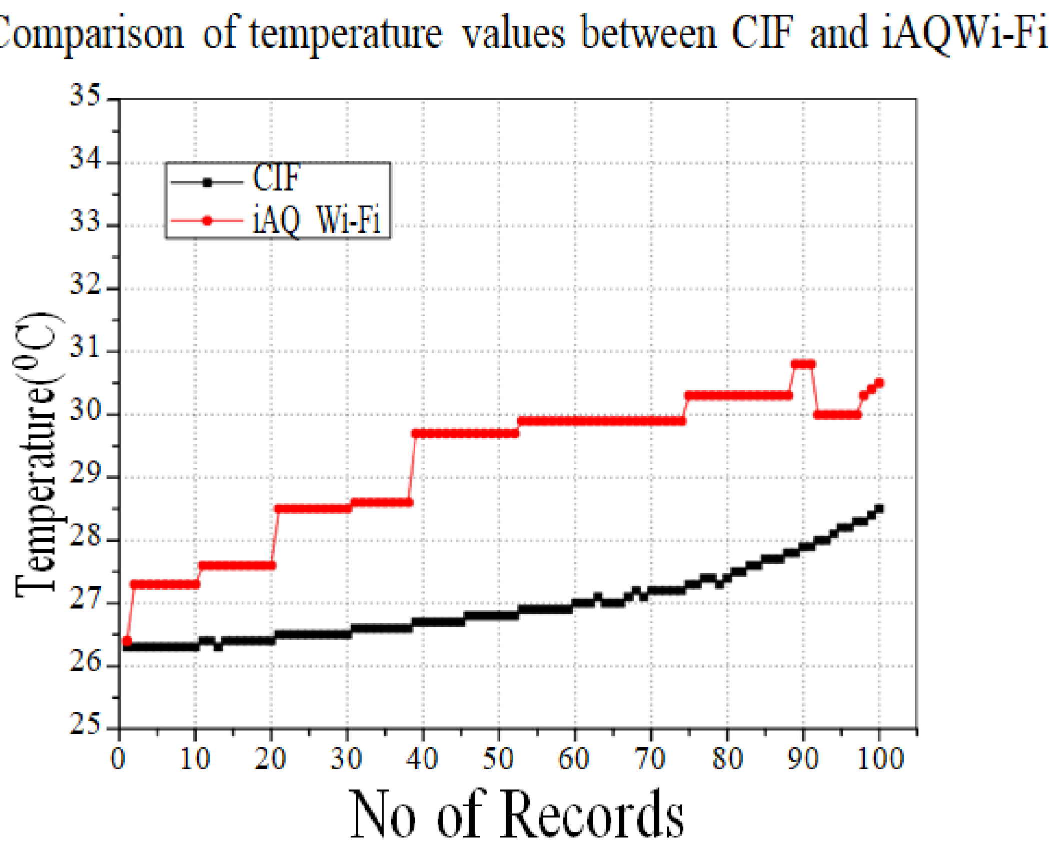


Fig. 12: Performance Analysis w.r.t. Temperature

The average delay between collecting and sending the data is very minimum and lies between 1.3 to 1.6 seconds. The delay used in the circuit is 1 second for all data to be collected from sensors to the global server. So the delay to send the data from the model to the server is 0.3 to 0.6 seconds as local memory of microcontroller is used for calculations. Though the delay depends on the network speed and the traffic, in an idle case the total delay would be 1 second. For a typical individual carbon rate calculation model responds equally from the beginning of the day to night. The carbon rate is found to be lowest at the beginning of the day in morning as less number of users emits CO_2. Amidst the, after the lunch the carbon rate and environment parameters rises during evening time as most of the vehicles and industries will be in running condition. The normal carbon rate toward the evening is intermediate in a peak time of transportation and operations in industries. After the entire day of operations during the night when environment gets polluted, the carbon rate raises more and lies in the vicinity stage out of a normal condition. The designed model provides the status of environment data and status of CO_2 which lies in between the expected range in all three times. So by considering all the parameter like minimum error rate, minimum delay and the time relevant data we can conclude that the CIF model is working quite accurately and provide us the real time data with minimum error and minimum delay over iAQWi-Fi [10].

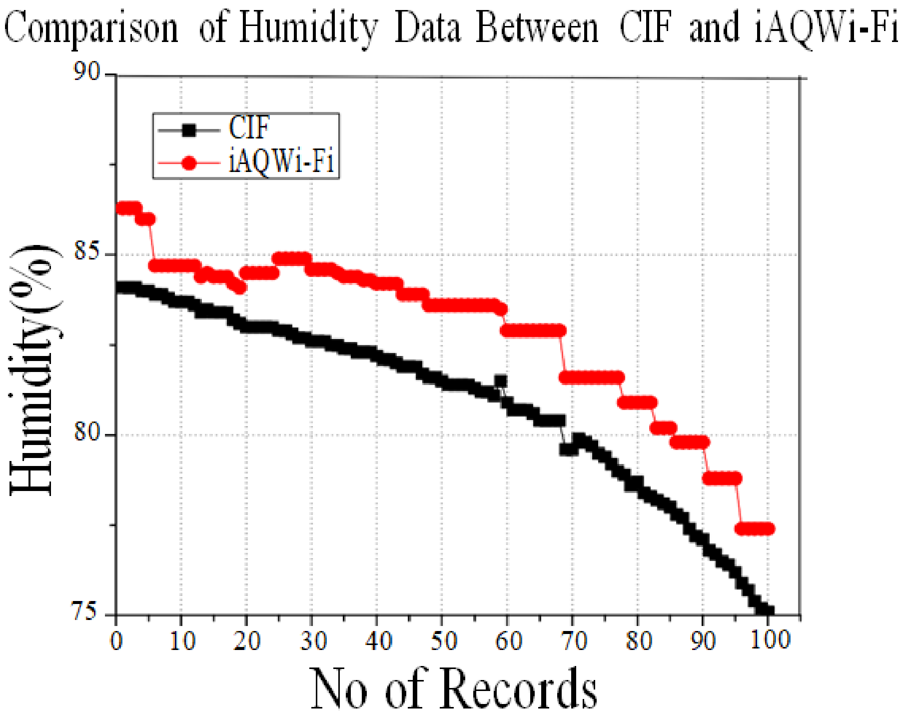


Fig. 13: Performance Analysis w.r.t. Humidity

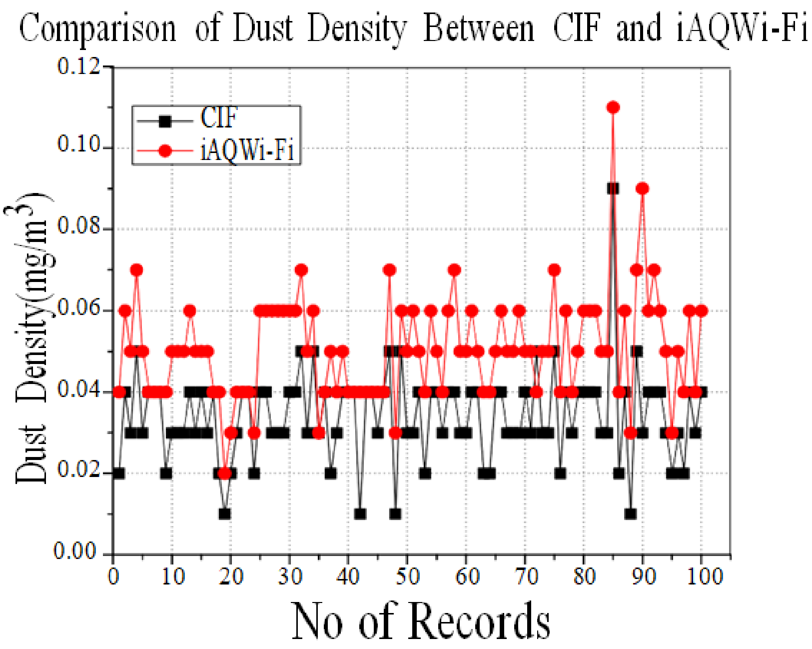


Fig. 14: Performance Analysis w.r.t. DustDensity

Sl No.	Room Temperature			Humidity			Dust Density		
	CIF	iAQ Wi-Fi	Enhancement Rate in CIF	CIF	iAQ Wi-Fi	Enhancement Rate in CIF	CIF	iAQ Wi-Fi	Enhancement Rate in CIF
T1	26.3	26.4	1.47	84.1	86.3	0.26	0.02	0.025	4.8
T2	26.7	27.2	2.77	83	84.5	2.20	0.04	0.048	2.7
T3	27	29.9	3.74	82.3	84.3	0.82	0.05	0.055	3.64
T4	27.5	30.3	2.41	80.6	82.9	2.5	0.04	0.051	2.87
T5	30.4	31.9	3.12	75.4	77.4	1.39	0.04	0.048	2.64

TABLE II: Performance Enhancement of CIF over iAQWi-Fi

7. Conclusion And Future Scope

Detection of CO_2 level along with air quality parameters is now-a-days is a necessity for everyone to protect themselves from various issues. So in this work, we have used the features of Wireless Sensor Networks, a framework based on Internet of Things and a paradigm of real-time air quality monitoring to design our model ”CIF”, which can monitor the density of dust, quality of air along with other environment parameters like humidity and temperature from any position or location and at any moment of time. As CO_2 level affects the environment conditions, humidity and room temperature are also included as vital parameters in the model. CIF is capable of monitoring carbon dioxide concentration and alerts about the dangerous instances in real-time. The performance of the proposed model has been tested with an existing model iAQWi-Fi and provides better result with high impact. The CIF model was compared with respect to parameter processing like temperature, humidity and dust density percentage with iAQWi-Fi monitoring system. Including that our proposed model provides information about air quality parameter to get the real-time status of the CO_2 level. On the basis of experimental result analysis it can be concluded that CIF performs better than iAQWi-Fi model and enhances the result around 14% in real-time. Other parameters like oxygen level can be included to make the model a robust one by adding appropriate sensors in the CIF model. Most importantly we can add modules like GPS and GSM which can notify authorities about environment’s critical situation and its exact location. Also some security features like data encryption and different access control mechanisms can be added to counter any unauthorized access and malicious attacks by foreign agents.

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