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Smart Air Pollution Monitoring System Design and Implementation based on IoT

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Abstract: *Half of the world's inhabitance already lives in cities, and by 2050 two-thirds of the world's population are expecting to further move into urban regions, air pollution stills the 'biggest environmental health danger for decades, affecting individuals 'quality of life and comfort according to World Health Organization (WHO). In this research, a practical air Pollution monitoring system is suggested. This system can be used for monitoring Pollutions in the attitude of a specific region and to discover the air quality. The obligated system will concentrate on the checking of air pollutants concentrate with the assistance of a group of sensors and the Internet of things (IoT) with Particle photon.*

Keyword: *Air pollution; IoT; Particle photon; UBIDOTS; Sensors;*

1. INTRODUCTION

Air pollution is a major environmental health problem affecting developing and the developed countries alike. Air contamination is mainly caused by vehicles, generators, and industries [1]. Health problems have risen more rapidly, especially in urban areas of developing countries where industrialization and the growing number of pollutant emissions have been increasing from the various fixed and mobile sources scattered in all cities [1]. Concerns are caused not only by the ambient air quality in cities but also by the indoor air quality in rural and urban regions [2]. Inhaled air pollutants have a significant effect on human health that affects the lungs and the respiratory system; Mild allergic reactions such as throat, eye, asthma and sinusitis and nose inflammation, as well as certain severe issues such as heart disease, are also taken up by the blood and pumped all around the body as shown in Figure 1 . These pollutants are also deposited on soil, plants, and in the water, further contributing to human exposure [3].

In the IT arena, the Internet of Things is a new typical course a revolution in the transformation of data from things-to-things, human-to-human, and human-to-things. Depending on application requirements, IoT platforms use various methods and technologies to communicate (each has unique features) [4]. IoT is used in designing Air pollution monitoring system. It helps us to get access to data in real-time and remotely which allows the responsible and related authorities to monitor and analyze the system to make appropriate decisions and measures to avoid harming the living organisms and the environment which improves the efficiency and reliability of the system [5].

Souvik Manna and others presented Air pollution system with a wireless sensor network which is considered as effective use of IoT to handle vehicular pollution. Pollution can be collected on different city roads, and analyzed using WSN, Arduino Uno, RFID, and MQ sensors to measure carbon monoxide, sulfur dioxide, nitrogen dioxide, and methane. Taking advantage of the Quality Index (AQI), and an algorithm that is implemented to gather data, bring out duplicates, filter and summarize worthless readings in a simpler form, and develop Mobile Discovery Net (MODISNET) using GUSTO sensor technology to monitor and analyze pollution in real-time depending on traffic conditions, emissions, ambient pollutant concentration [6].

Bedoui and others used WSN, and ZIGBEE under LABVIEW environment to measure hydrogen, sulfide gas, humidity, and temperature. The results show the effectiveness of this technique in

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terms of detection speed and real-time response with low-cost and low power because of using ZIGBEE with WSN. The system includes three steps: first is data acquisition, second is wireless transmission, and finally is data processing. To improve the system, stations can be replaced by a small portable metering system that includes various gas sensors [7].

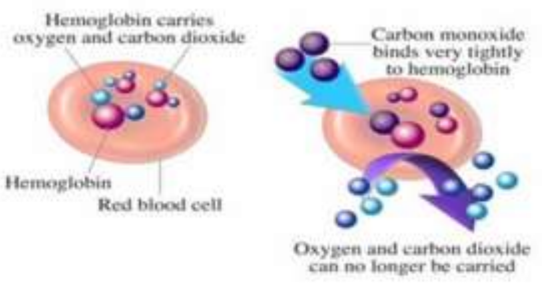

Figure 1 Air pollution affecting blood

Suganya, & Vijayashaarathi by using PIC microcontroller, WSN and ZIGBEE found solutions to difficult problems by implementing the internet/intranet on a smart Vehicle control device for detection of air pollution using WSN to measure NO2, humidity, temperature, CO2 using the sensor of each type respectively also the electric circuit has a cloud , Wifi, GPRS, LCD, MANET (Mobile Ad Hoc Network) and routing algorithm .The main system advantage is that it achieves better analysis of mobile vehicles, it can store measured gas values and vehicle details, and an android application can be created to provide an alert message for smartphones [8].

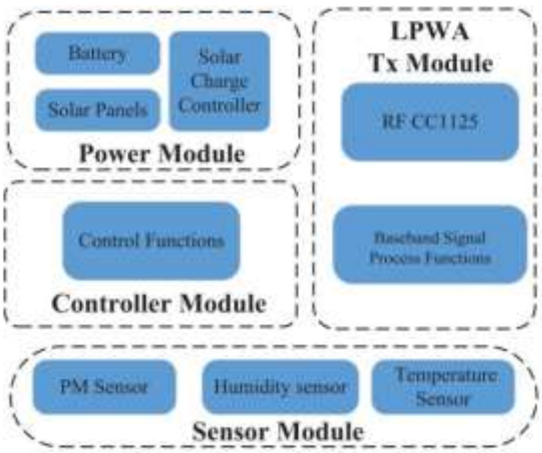

Figure 2 Proposed block system

Kan Zheng and others proposed the air indicated an LPWA-based quality control framework, the Networks which depended on (IoT) technologies that can use an emerging machine to machine communication technology (M2M). The system benefits are that the LPWA network can supply ranges of over 20 km, LPWA also enables devices to work with Long-lasting battery life (more than 10 years) or solar imaging. The practical circuit consists of sensor, MCU, battery, the workable components of the monitoring node are shown below in Figure 2 [9].

Kavitha and others proposed a design that can be used to monitor a specific area and measure air quality. Toxic gases, such as carbon monoxide (CO), liquefied petroleum gas (LPG), methane, butane, and air quality, and then obtaining sensor data collected and uploaded to Google, making it easier to monitor from any part of the world is based on IoT. The air quality can be displayed on the LCD screen and the alarm can also be triggered when the air quality drops to a certain level. The practical circuit consists of: 3 main sensors are MQ-6, MQ-7, MQ-135, DHT11 (temperature and humidity) sensor, Raspberry – pi, LCD, IoT shield [10].

Harsh Shah and monitored air quality by using IoT-based monitoring. Disadvantages of conventional monitoring: the tools are large, heavy, and expensive. The block diagram is shown in Figure 3 consists of:

1- Hardware: MQ135 gas sensor, Arduino Uno, Wi-Fi module ESP8266
2- 16x2 LCD, breadboard, 10K potentiometer, 220-ohm resistor, buzzer
3- MQ 6 LPG, temperature LM35, humidity SYH5220 sensors
4- 2- Arduino 1.6.13 Software and C Language [11].

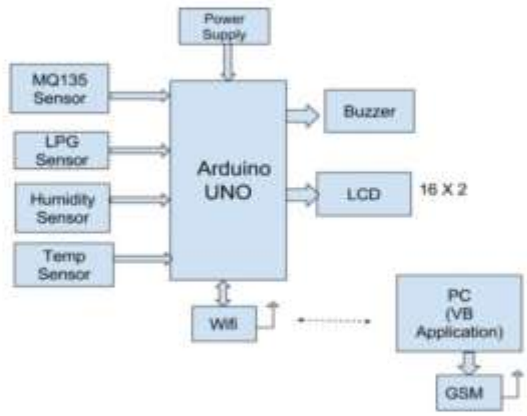

Figure 3 The proposed system's block diagram

The analysis of the literature finds out that most Air pollution monitoring systems differ in terms of the type of microcontroller, and the type of sensors used to simulate the practical circuit. Most of the studies used the microcontroller (Arduino) and (WSN) (Wireless Sensor Network), (ZIGBEE) technology, and used many different sensors to measure Air pollution.
System specifications are that it uses Particle Photon

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Volume 6, Issue 3, March 2021, pp. 1 – 10

which is makes the Broadcom Wi-Fi chip in a small module very useful as compared to other development kits, also the system is low cost, low power consumption, efficient, real-time results, can be implemented in different locations such as oil refineries, houses, industries, car parking, etc., and data is collected remotely by suitable IoT platform.

Section 2 explains the proposed framework. In Section 3, architecture and working principles. Project implementation is discussed in Section 4. The results in Section 5. Section 6 contains the conclusions and future works.

1. SYSTEM DESCRIPTION:

2.1 Components:

The proposed system consists of several components:

1- microcontroller represented by Particle Photon for controlling and wireless communication.
2- Power supply to load power to the system.
3- MQ4 sensor to measure methane gas (CH4).
4- MQ2 sensor for measuring smoke.
5- MQ7 sensor for carbon monoxide (CO) gas.
6- MQ135 sensor for carbon dioxide (CO2) gas.
7- Dust sensor (DSM501).
8- Breadboard.
9-different resistors.

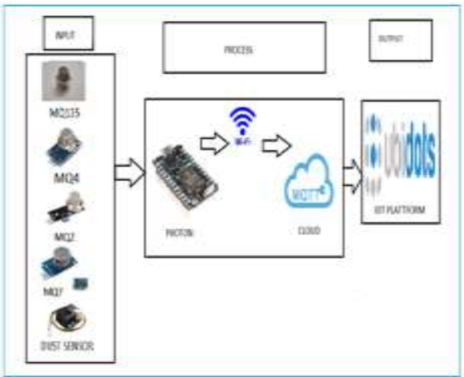

Figure 4 Structure of the system

2.2 The System's Overall Structure:

The system contains two parts the first part is the hardware components as indicated in the paragraph previously, and the second part is the programs. The sensors are programmed using the (Particle IDE) program and the programming language (C ++). Many necessary libraries for the system and sensors and UBIDOTS MQTT are loaded then upload the code to (Particle IDE) and get the data in real-time on IoT platform known as UBIDOTS through which we obtain data in the form of graphs, gauges, digital readings or tables (Excel) and many other formats are available within the platform where we choose the appropriate widget for our work, a structure of the system is shown in Figure 4.

2. DESIGN & WORKING PRINCIPLE:

3.1 Particle Photon Microcontroller

The Particle Photon is a single microcontroller development board much like the Arduino Nano, with a small form factor but with the added feature of having a built-in Wi-Fi module that we can control and program over the internet using the Particle cloud [12]. Photon also utilizes C/C++ programming language, which is completely the same as Arduino. Also, particle mingles of ARM Cortex M3 microcontroller with a Broadcom Wi-Fi chip in a very small sized module. These benefits make it very valuable comparing it with other production kits. The Photon pin diagram is shown in Figure 5. It has 18 GPIO pins, which are used to connect Particle Photon to other general-purpose devices by programming it according to the necessary function; sensors collect the actual data and send it through the GPIO pins to the photon [13].

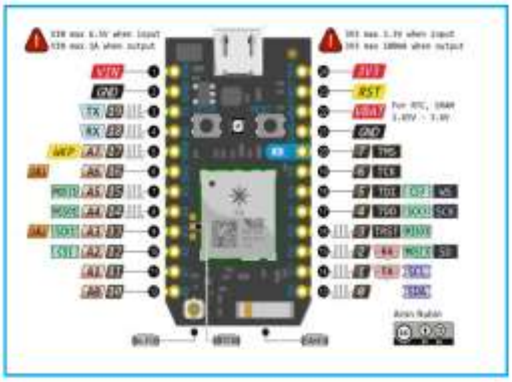

Figure 5 Pin diagram of particle photon

3.2 MQ4 sensor:

MQ-4 gas sensor shown in Figure 6 has a high sensitivity to methane in a wide range. The characteristic configurations are:

1. Good sensitivity for flammable gases.
2. Strong sensitivity with respect to natural gases
3. Appropriate for a long time and a low-cost usage.
4. Simple Driver Circuitry [14].

Figure 6 MQ4 sensor

3.3 MQ2 sensor:

MQ2 gas sensor module shown in Figure 7 is used for smoke Detection The gas concentration can be measured in ppm using the sensor module's analog pin. It can be used as an analog or digital sensor and the potentiometer can change the sensitivity [15].

Figure 7 MQ2 Gas Sensor

3.4 MQ7 sensor:

This sensor shown in Figure 8 is suitable for the Carbon Monoxide (CO) gas identifier. It can calculate a CO concentration of 10 - 10,000 ppm (part per million). The MQ-7 has 6 pins, 4 pins for signal extraction, and 2 pins for the instruction line for internal heating **[16].**

Figure 8 MQ7 gas sensor

3.5 MQ135 Gas Sensor:

MQ135 is used to measure Carbon Dioxide CO2 in the air. The resistance connected to MQ135 is different for various kinds of concentrated gases, so the sensitivity adjustment of components is necessary at the time of use. Its shown in Figure 9 [17].

Figure 9 MQ135 gas sensor

3.6 Dust sensor (DSM501):

It's shown in Figure 10. The principle of DSM501 is based on particle counting [17]. The DSM501 Sensor can detect particles with a diameter greater than 1 micron. Dust in the air masks it. The sensor's built-in heater will inhale air automatically. It is compact size and lightweight and simple to install and use.

Figure (10) Dust sensor

3.7 My Device UBIDOTS Platform :

The IoT framework used in this project is "UBIDOTS. Each user using "UBIDOTS" has API credentials to be used in the code. shown in Figure 11 and Figure 12. UBIDOTS is then connected to the hardware and the device measured data is sent to this IoT framework. In "UBIDOTS", the system is a virtual representation of the data source. Which takes data from the sensor and transmits data through a communication protocol known as MQTT to the "UBIDOTS" cloud, if the device is designed, it receives hardware data and is displayed inside the device in a variable. This is implemented in the code by using variable names. After data is expressed in a variable, it is visualized in the dashboards as a widget. In the form of a table or an indicator or a graph, etc. Alert messages or emails may also be given to users using events [15].

Figure 11 UBIDOTS -IoT platform

Figure 12 UBIDOTS log in

MQTT Message Queue Transport Remote Service. MQTT is a lightweight protocol that uses publish –sub-

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Volume 6, Issue 3, March 2021, pp. 1 – 10

scribe (pub/sub) architecture as shown in Figure (13) Used for machine-to-machine (M2M) connectivity processing over TCP/IP protocol via IoT environments. Andy Stanford-Clark and Arlen Nipper developed it at IBM in 1999 [18]. With a small footprint on the communication network and on the system itself, MQTT provides the ability to send and receive data in near real- time for IoT users. shortly, a message is posted on a server by the client to a certain subject and the message is sent to one or more clients who are subscribing to the same subject. The subject is defined by the place where clients send and collect data and its structure is organized in the same way as directories are structured in an operating system. [19].

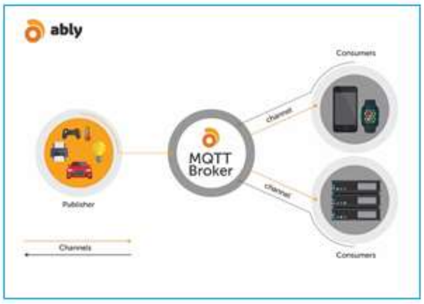

Figure 13 MQTT publish /subscribe protocol

PPM: is an abbreviation for "parts per million" and it also can be expressed as milligrams per liter (mg/L) is often used to describe concentrations of contaminants in air (as a volume fraction) [20].

3. IMPLEMENTATION OF THE SYSTEM:

Connecting of the electrical circuit is shown in Figure 14 below:

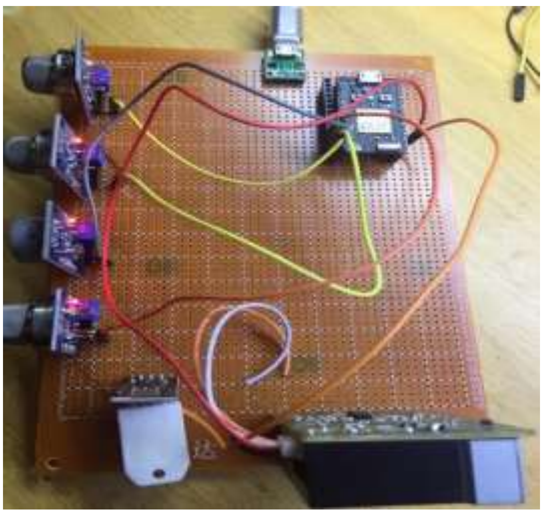

Figure 14 Designed electrical circuit

Particle IDE platform was used to generate the main code of the system and download the necessary libraries mentioned in paragraph 2.2. The IDE platform will upload the code to the board. IDE environment is using C / C ++ languages. The data was collected using the different sensors mentioned previously. The calibrated sensors made the analog output voltage proportional to the polluting gas concentration in Parts per Million (ppm). The Wi-Fi module transfers through the internet the measured data value to the server and is configured to transmit measured data to the platform of Ubidots. Ubidots offers data measurement access through any computer with internet access capabilities. The data gathered from the sensor was translated into a string and the information sent to the remote server was modified.

Steps of implementation of the system:

1- Connect sensors to particle photon and make calibration for gas sensors due to special equations for finding the slope of the curve for each sensor as in equation (1) and approximately equivalent equation as in equation (2) then they will sense all gases and give the Pollution level in PPM (parts per million).

Slope = (y2 –y1)/(x2-x1) **(1)**
Float sensor curve [3] = {x,y,slope}
Result=pow(10,(((log(Rs_Ro_ratio)-pcurve[1])/pcurve[2])+pcurve[0])) **(2)**
Where Rs: Sensing Resistance of the sensor
R0: Primary value of resistance in natural air

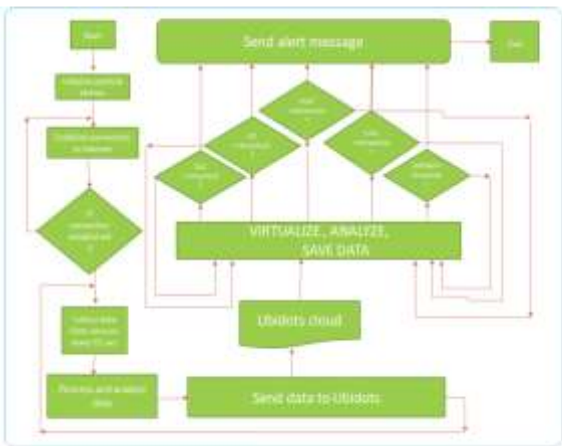

Figure 15 Flow Chart for implementing the system

1- Data is collected from the sensors mentioned previously.
2- Data is sent to the UBIDOTS application.

ISSN: 2456 - 3935
International Journal of Advances in Computer and Electronics Engineering
Volume 6, Issue 3, March 2021, pp. 1 – 10

3- The UBIDOTS introduces data location coordinates, system id, date and, time stamp, and then forwards it to the cloud.
4- In the cloud, the data processing is performed by analyzing the data and then visualizing it.
5- The user can access data and alert messages on the smartphone or a web application by participating in the crowdsensing. The steps are shown below in a flowchart in Figure 15.

4. RESULTS AND DISCUSSION:

A- indoor environment**:**
concentrations of *CO_2 gas* are shown in Figure 16 below:

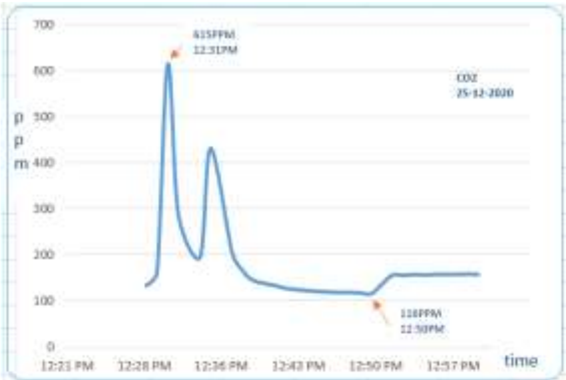

Figure 16 CO_2 concentration

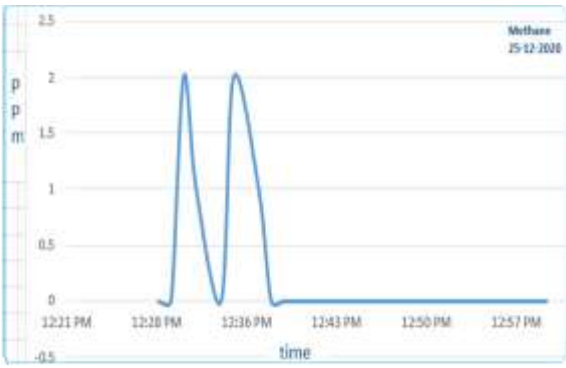

Figure 17 Methane concentration

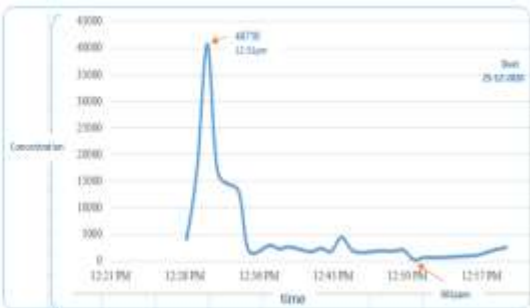

Figure 18 Dust concentration

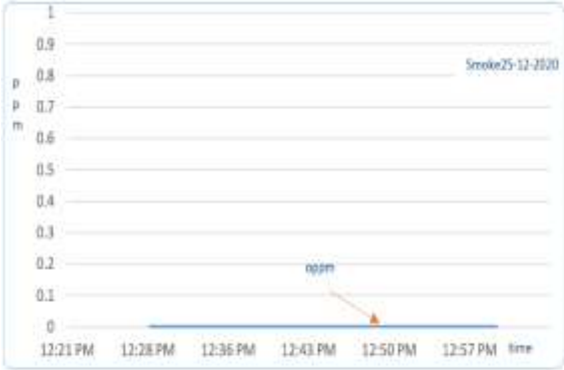

Figure 19 smoke concentration

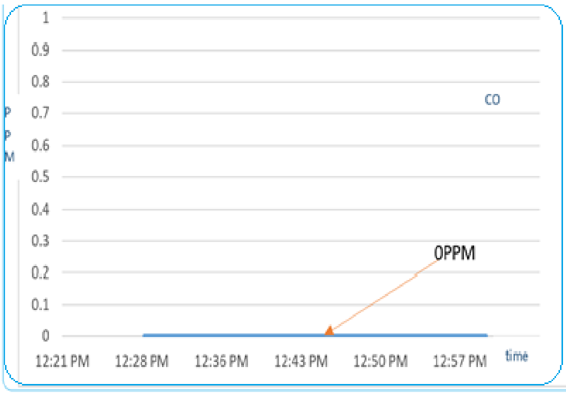

Figure 20 CO concentration

Figure 21 UBIDOTS dashboards for indoor environment

Monitoring results of sensors readings on the UBIDOTS platform is shown the below graphs. There are 5 variables used on the dashboard while x-axis represents date and time and the y-axis represents gas con-

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centrations in (ppm), to show the sensors data each sensor has its variable and widget. The shown Pollutants concentrations calculated in the study sites that included three areas, the first is an indoor environment, the second location is a car parking and finally, the system measured air pollution in natural outdoor environment represented by a public garden.

Figure 17 shows Methane concentrations. We noticed that each one of CO_2, dust, methane (CH_4) has values cause of closed environment, human traffic and Fuel-based heating methods, where dust, smoke, and CO concentrations are shown in Figures 18,19,20 respectively. My UBIDOTS dashboards for the indoor environment are shown in Figure 21.

B- Car parking:

concentrations of detected CO_2 gas are shown in Figure 22 below:

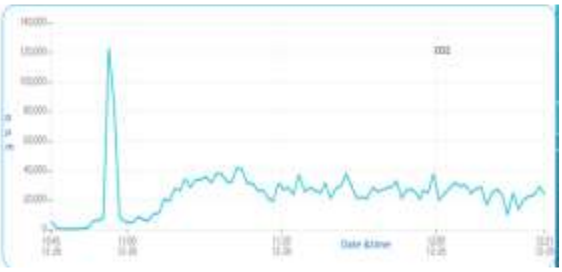

Figure 22 CO_2 concentration

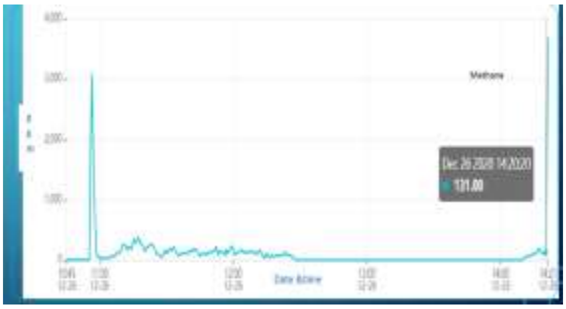

Figure 23 Methane concentration

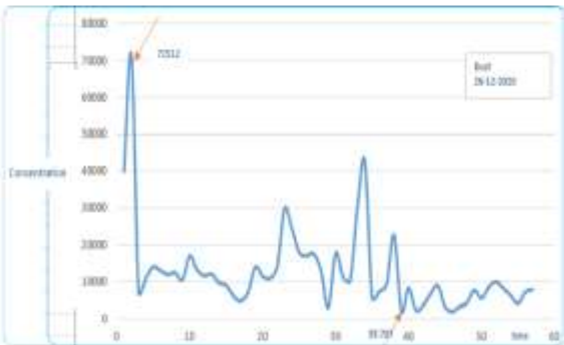

Figure 24 Dust concentration

Figure 23 shows Methane concentrations. Dust, smoke, and CO concentrations are shown in Figures 24,25,26 respectively

All gases raised their value in this environment this means that air pollution in car parking is higher than the rest proposed regions or other environments in this test cause of emissions that includes CO_2,NH_4, and dust from different vehicles this cause increase in Global Warming and cause significant changes in the Earth's climate, increasing CO_2 Climate risks resulting from this rise due to the increase in the average temperature, Rising seas levels and increasing climate extremes such as drought

Figure 25 Smoke concentration

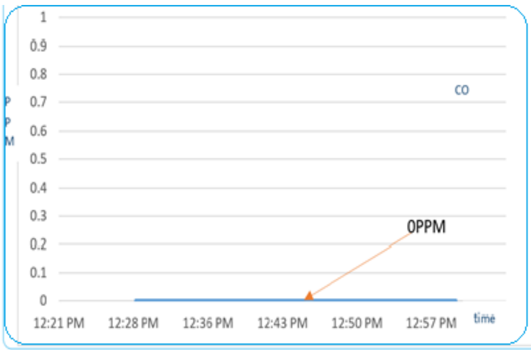

Figure 26 CO concentration

Figure 27 UBIDOTS dashboards for car parking environment

Figure 27 shows UBIDOTS dashboards for car parking

C- Natural outdoor environment(garden):

concentrations of CO_2 *gas* are shown in Figure 28 below:

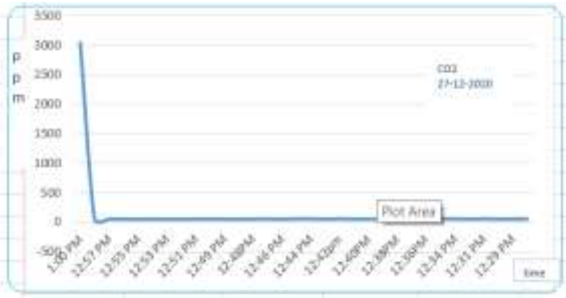

Figure 28 CO_2 concentration

Figure 29 shows below Methane concentrations

Figure 29 Methane concentration

Dust, smoke, and CO concentrations are shown in Figures 30,31,32 respectively

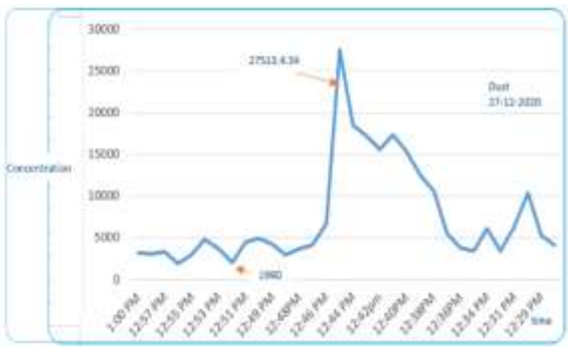

Figure 30 Dust concentration

We noticed an increase in CO_2 cause the process of photosynthesis in plants and low values for other gases. The highly flammable methane is considered one of the most dangerous gases, as it exceeds carbon dioxide by 25 times, about 40% of methane was produced from moist areas on the surface of the earth, where some types of micro-bacteria work on the anaerobic analysis of organic materials such as plant leaves and agricultural and animal wastes, and various agricultural activities contribute to the emission of this gas.

Figure 31 Smoke concentration

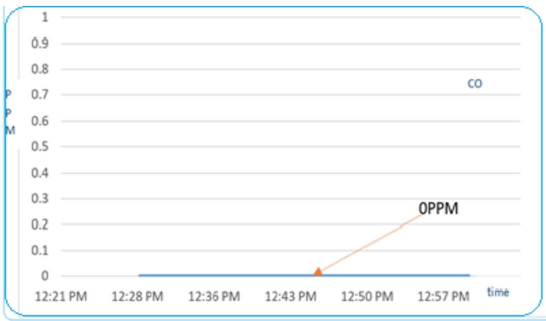

Figure 32 CO concentration

Figure 33 shows UBIDOTS dashboards for the outdoor environment

Figure 33 UBIDOTS dashboards for the outdoor environment

No carbon dioxide gas concentration is mentioned in the three locations, this is a good thing, because it is a heavy, very dangerous, and toxic gas, and inhaling quantities of it that may lead to inevitable death.

The UBIDOTS dashboard provides us with historical reports and we can view them anytime anywhere and we can get them as an excel table or as different types of widgets. These reports indicate Human readable dates like 25/12/2020 08:45:03 and the readable value of each measured gas from sensors.

These reports are used to monitor air pollution in different places as needed by virtualizing and analyzing data that interacts with the sensor, so these reports are very beneficial cause they apply us with practical and helpful that interacts with sensor, and to send warning messages to the relevant responsible authorities to avoid any danger threatening living creatures of all kinds.

5. CONCLUSION AND FUTURE WORKS:

In this research paper Designing a system for air pollution monitoring for detecting harmful concentrations of different gases based on IoT technology is important to send warning messages to the relevant responsible authorities to avoid any danger threatening living creatures of all kinds cause Air pollution causes many health problems. In this project gases including CO2, CO, Methane, dust, and smoke are monitored using MQ135, MQ4, MQ7, DSMA510, and MQ2 respectively. Data is continuously transmitted and displayed in real-time on the UBIDOTS platform via particle photon.

We can get daily, weekly and monthly data due to the use of the MQTT Cloud supported by the UBIDOTS platform. The proposed system is already used in houses, car parking, gardens, factories and oil refineries, and can be used anywhere and anytime as needed to get real-time readings. The responsible and related authorities can get this data, analyze it and make early warning if any of the gases exceed the threshold. The proposed system can be improved and developed in the future by:

1- using additional photon that includes more sensors to monitor the humidity and temperature and compare them to specific set thresholds.
2- Using solar cell panels instead of batteries, to ensure the continuity of energy all the time.

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