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IOT Enabled Indoor Air Quality Monitoring

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Abstract: Air quality is used to describe the quality of air present within a particular area. It is a direct indicator of the pollution levels in the area and can be used to refer to the health of the beings in that area. Air quality can be determined indoor as well as outdoor with the same basic variables being taken into account but some variables are imperative to determine the indoor air quality while they may not as relevant outdoors and can be used just as a reference. The paper presents a cluster of nodes implemented both indoors and outdoors in order to determine the air quality of the surroundings in a more comprehensive manner. These nodes are controlled with the help of a microcontroller which enables the functioning of the sensors in order to collect data. The data can be accessed on an android app which is designed as per the particular needs of the paper. In order to make the measurement of air quality more reliable and accurate, temperature and humidity are also taken into account.
Keywords: air quality, IOT, Android app, Sensor Networks.

Introduction

Air pollution is a growing problem nowa days and is a matter of great concern worldwide. Air is a combination of Nitrogen, oxygen, water vapor and various other gases. But the constituents in air can be altered by human activities which may cause problems for humans, plants & animals. The quality of the air is expressed in terms of the concentration of air pollutants present in air like Carbon Dioxide, Carbon Monoxide, Nitrogen Oxide, Nitrogen Dioxide, Ozone and various dust particles. The threshold values specified by the European Environment Agency [1] for these pollutants are 10, 350, 40, and 120 $\mu g/m^3$, respectively.

Sensor Networks have advantages of being compact, easy to install and inexpensive. The major advantage sensor networks provide is remote access and real time monitoring with minimal human interference. While being a feasible resource it also has a few minor issues related to the hardware capacity, memory, speed of communication etc.[4]Android apps are a platform on which data can be transmitted easily and in larger quantities without slowing the functioning of the system as these apps are supported by smart phones and tablets which have high RAM and processing capabilities are un-parallel. These apps make it possible for the data to be presented in a concise form even from a distant location

Pollution is not just the air condition in the outdoor environment but it is also present indoors-in our offices, schools and homes which causes various health problems like building related illness and sick building syndrome[2].

Generally, in industrialized countries, the population spends about 80%–90% of time inside buildings and is therefore exposed to harmful indoor pollutants. Indoor air quality is generally assessed by separately measuring CO, temperature, and humidity [3]. This information, even if fused, is insufficient to allow a good characterization of indoor air quality.

Air quality monitoring is an essential need of the hour in order to keep a check on the concentration of pollutants for this sensor modules can be employed rather than establishing a network station which would rather be expensive. The sensor data can be stored and transmitted wirelessly to an android app interface in order to make the data available to the masses at any point of time. Air quality depends on various factors which may differ when estimating air quality indoors and outdoors.

Ventilation is a major concern in order to avoid indoor air to get contaminated as proper air flow is a must in order to neutralise the emission from indoor sources. High temperature and humidity levels can also be an indicator of increasing pollution contents and hence we take these factors into considerations and accommodate their readings as well. Tin oxide sensors (e.g., Figaro, Nemoto[5]) are inexpensive and fair selective gas sensors. To overcome some of their limitations such as cross sensitivities [6], [7] and a temperature and humidity dependence behaviour [8], appropriate sensor data processing is required.

Carbon monoxide (CO) sources inside a house are cooking activities, tobacco smoke or any kind of incomplete combustion. It is colourless, odourless, tasteless air pollutant, hence impossible to detect without sensory devices. It reduces the oxygen carrying capacity of the blood, thus leading to breathing problems and suffocation. Carbon dioxide (CO_2) is a colourless and odourless gas. It is a normal constituent of the atmosphere at 330-400 ppm. Concentration of Carbon Dioxide gives an indication of the ventilation inside a building . Particulate matter also known as aerosol is a complex mixture of extremely small particles of a number of components, including organic chemicals, smoke, soot, dust, salt, acid droplets, metals, and soil.

There are two categories of particles i.e. inhalable coarse particles, such as those found near roadways and dusty industries, are larger than 2.5 micrometers and smaller or equal to 10 micrometers in diameter. Fine particles such as those found in smoke and haze, are 2.5 micrometers in diameter and smaller. The size of particles is directly linked to their potential for causing health problems. Particles that are 10 micrometers in diameter or smaller can pass through the trachea and nose and enter the lungs. Once inhaled, these particles can affect the heart and lungs and cause serious adverse health effects further more these particles can aggravate asthma and bronchitis and various other breathing related infections. All these factors are important and need to be taken into consideration while estimating the Air Quality Index of a region. This takes into account the concentration and the time over which the concentration of the pollutant remains constant we can calculate dose of the pollutant. Different air pollutants differ in concentration and hence have different concentration ranges and different pollutants require a function to convert the pollutant concentration into Air Quality Index concentration.

Sensor Network:

Sensor networks are an efficient method to implement arrays of sensors or a group of sensors. Network sensors allow to increase the monitoring area and also improve upon the accuracy of the readings as multiple array of sensors are available to cross-check the readings in order to ensure genuine data. The hardware incorporates a Bluetooth HC-05 module which is responsible for the wireless data transmission thus making the data available on the android app. The network includes 3 basic elements: 1) Sensing nodes; 2) Bluetooth HC-05; 3) Android application.

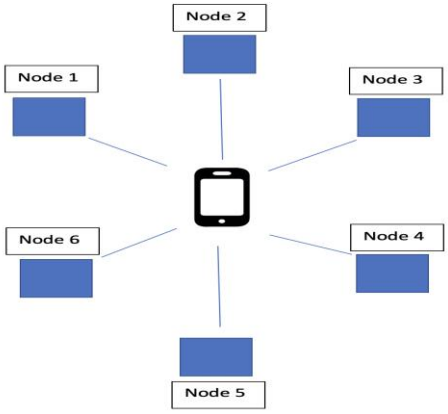

Fig: Network Architecture

Component Description:

MQ-135:

This gas sensor has a wide detecting scope along with a fast response thus making it feasible for use. This sensor is useful while detecting benzene, NH3, smoke, CO2 etc. For the paper MQ-135 is used for detecting the concentration of CO2. As the concentration in parts per million is the standard depiction of the concentration the sensor uses the analog pin for the output. A regular MQ-135 sensor uses Tin dioxide(SnO2) as the sensing material whose resistance depends upon the concentration of the pollutant gases. The sensor consists of a tin dioxide layer, a perspective layer inside the aluminium oxide micro tubes and a heating element. The heat element oxidises the ethyl alcohol into acetic acid, as this cascades with the tin dioxide layer the resistance decreases. RL is used to convert the resistance variation into a suitable voltage variation. As the pollutant concentration increases the resistance of the gas sensor decreases. We need the ratio of Rs/Ro in order to determine the concentration in PPM[9].

$$\text{Resistance of sensor(Rs): } Rs=(Vc/VRL-1)\times RL$$

The above formula helps in determining the resistance of the sensor in order to estimate the concentration of CO2 in the atmosphere.

RL: Load Resistance

Ro: Resistance at 100ppm of NH_3

Rs: Resistance at various concentration of the gases.

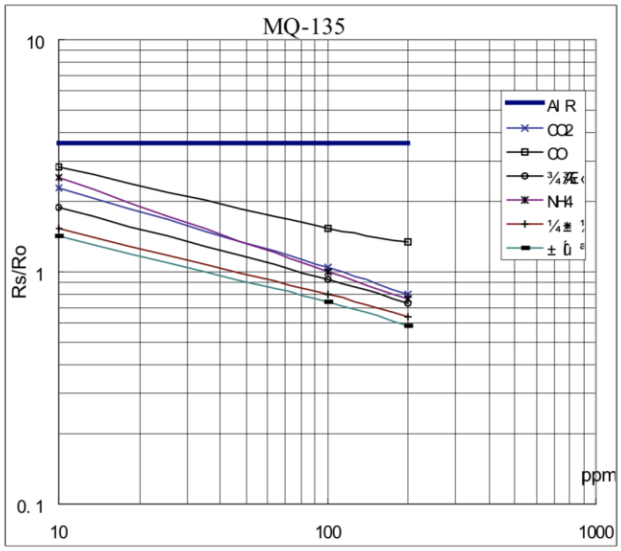

Figure : Sensitivity characteristics of MQ-135 for several gases

MQ-7:
The MQ-7 gas sensor is sensitive to carbon monoxide and hence is used in determining the CO concentration in the atmosphere. Tin Dioxide sensitive layer, a heating element are all present inside a MQ-7 sensor just like an MQ-135 sensor. The heating element provides the appropriate conditions for the proper function of the sensitive components.
The surface resistance of thecan be obtained with the help of the voltage signal output of the load resistance. This can be found with the help of the formula.[10]
Rs\RL = (Vc-VRL) / VRL

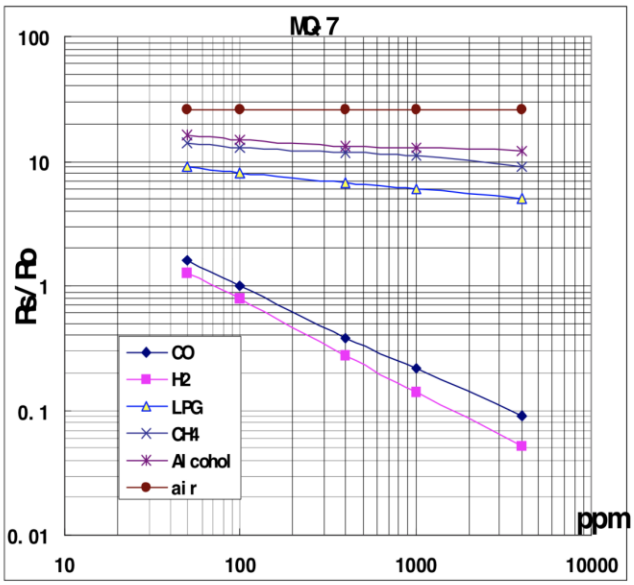

Figure: SenstivityCharacterstics of MQ-7 for several gases

The MQ-7 sensor consists of a micro AL_2O_3 ceramic tube a tin dioxide sensitive layer and measuring electrode using a heater.

MQ-4:
The MQ-4 sensor has a high sensitivity for natural gas (CH_4) and also is a bit sensitive toalcohol and smoke. Being a member of the MQ family this sensor also has a micro AL_2O_3 ceramic tube a tin dioxide sensitive layer and measuring electrode using a heater.[11]

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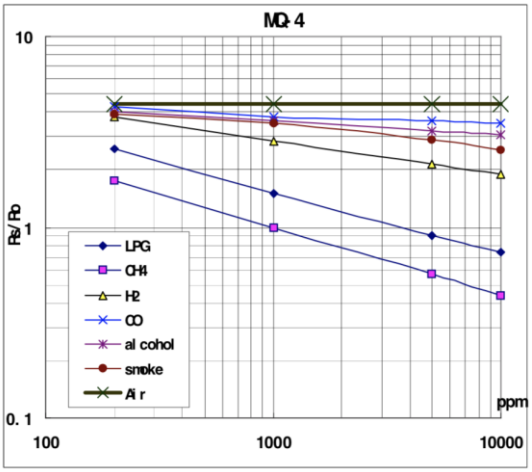

Figure: Sensitivity Characteristics of MQ-4 for several gases

Optical dust sensor:

The GP2Y1010AU0Fis a dust sensor that provides analog output and the dust density of the particles is displayed in microgram per meter cube. The sensor consists of a light emitting diode whose light is spotted with the help of a lens and a slit, also a photodiode is used to detect the light reflection. When no dust is detected the voltage output is even. When there is dust the sensor detects the light reflected from the dust particles, this produces a current propotional to the amount of light detected and a voltage pulse is generated. The sensor also has an amplifier circuit that amplifies the detected signal.[12]

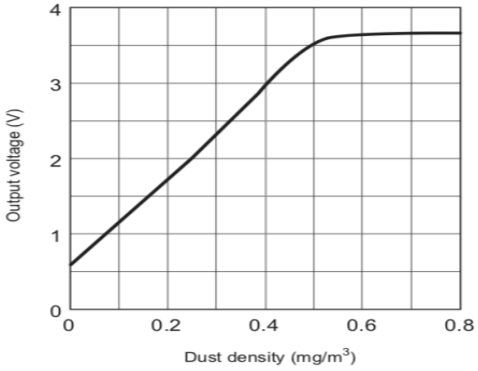

Fig: Output voltage corresponding to the dust density

DHT-11:

This sensor is responsible for determining the humidity and temperature of the surroundings. The sensor is based on digital signal acquisition technique which makes the sensor reliable and also provides long term stability. When the DHT receives a signal from the micro controller it switches from low power consumption mode to running mode, once the start cycle is completed it sends a response signal that specifies the relative humidity and temperature information. Once the DHT has sent the data it switches to low power mode until it receives another instruction from the microcontroller.

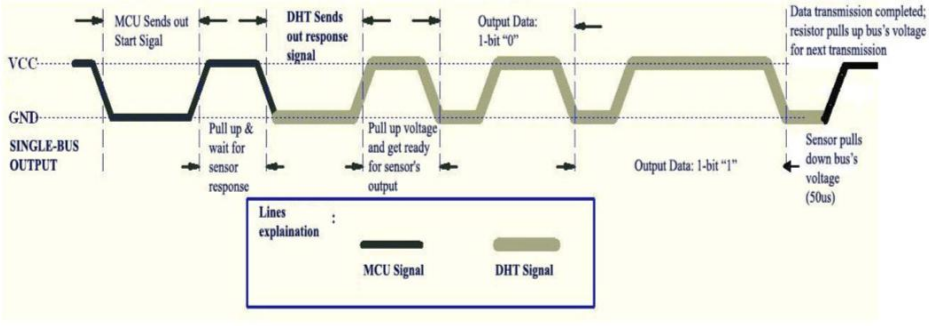

Fig: The communication process in a DHT sensor

The DHT sensor is an important part of the implementation as it can be a direct indication of unusual concentrations of various pollutants in the air. Moreover it provides an comprehensive approach in determining the pollutants concentration in the surrounding air as all the MQ sensors have their readings dependent on the relative humidity and temperature of the surroundings. The graphs below represent the dependence of the MQ sensors on humidity and temperature.[13]

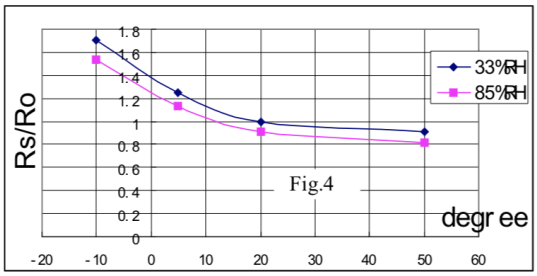

Fig: MQ-135 dependence on temperature and humidity

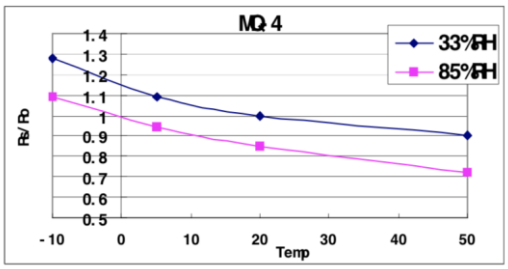

Fig: MQ-4 dependence on temperature and humidity

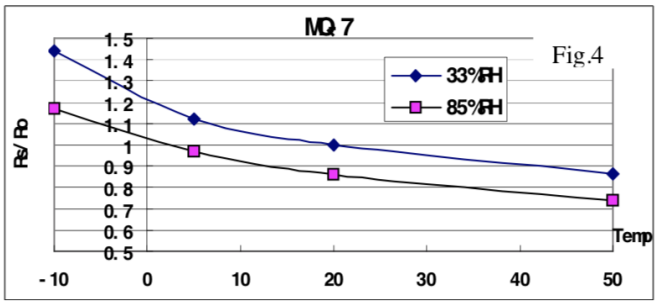

Fig: MQ-7 dependence on temperature and humidity

Bluetooth Module:

This module is designed for wireless serial communication and is based on serial port protocol. The module is uses 3Mbps modulation with complete 2.4GHz radio transceiver and baseband. The Bluetooth module allows UART interface along with an adjustable baud rate. The Bluetooth module operates in 2 modes 1) AT command Mode: This mode is used when the default settings of the module need to be altered. 2) Communication Mode: This is the mode used for wireless transfer of data thus enabling all the data collected from the sensor to be transferred from the microcontroller IDE to the android device running the android application.[14]

Android Application:

The android application which receives the data of the sensors and displays the data has been designed with the help of an online open source tool known as the MIT App Inventor 2. It is a visual programming environment enabling easy fully functional apps. Applications are designed with graphical user interface and the applications designed can run on android devices. The Inventor uses blocks and various modules to make the application functional.

Implementation:

The sensors are assembled along with the microcontroller and wired up. The Arduino Mega is provided power using a USB/ external power source. Each sensor has different calibration time and thus the setup is turned on and left for a few minutes before collecting the readings. The readings are displayed on the IDE. These readings need to be parsed in order to comprehend the readings on the android app. Without parsing the readings will be displayed serially thus confusing the user regarding the concentration of each pollutant.

The Bluetooth module enables the wireless transfer of the readings from the IDE to the connected android device. The parsed data is transferred to the android application and displayed in respective boxes thus providing the user an easy access to the air quality data.

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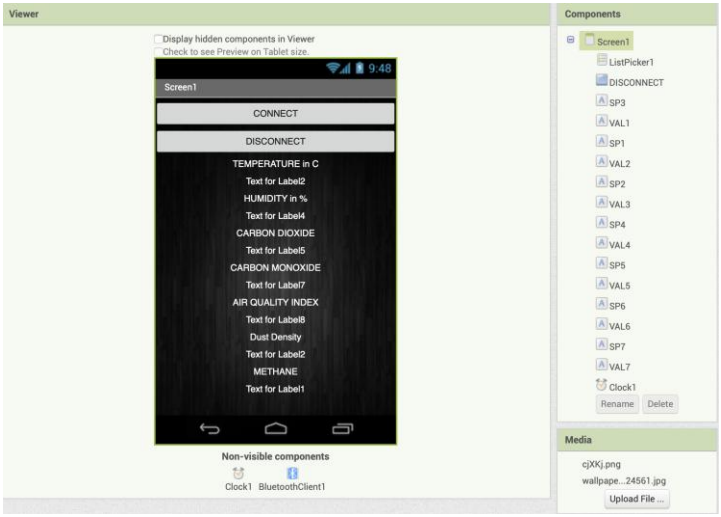

Fig: Android application interface

The above figure depicts the android application screen before the readings are generated . Each label provides a separate space for a particular pollutant.

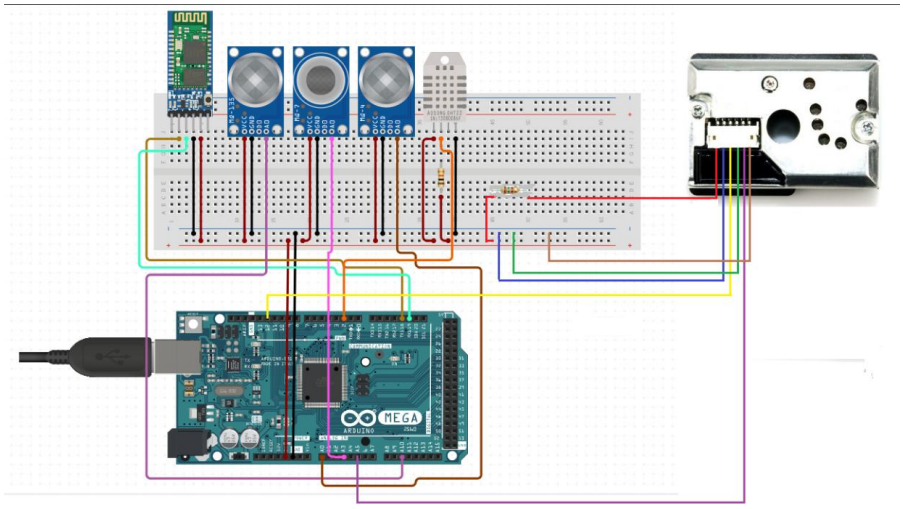

Fig: The hardware circuit

The above fig shows the hardware implementation of the sensors along with the microcontroller.

Observations:

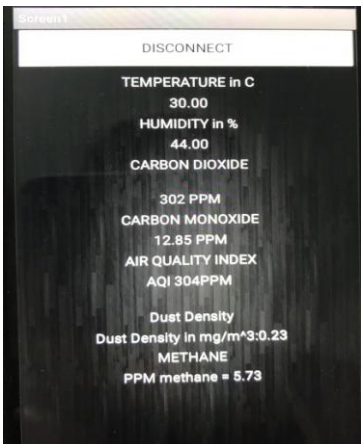

Fig: Output of App Display

The figure above shows the readings of each sensor thus indicating the concentration of each pollutant in air. These readings are scene on the android application designed with the help of app inventor thus making the data easily available for the crowd. Moreover the readings are collected in real time as they are refreshed at an interval of every one second.

Conclusion:

Theair quality of a room does not just depend on the concentration of air pollutants but also is dependent on the relative humidity and temperature as these factors give us a complete understanding of the air quality which is subject to change with changes not in just dust, CO2, CO or methane but also the changes in relative humidity and temperature.

The android application provides a hassle environment for all the users to access the data remotely and the users do not need to rely on various websites to get a conclusive data instead the app provides a complete comprehensive view of the changes in air condition in real time.

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