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Pollution Monitoring System using RF communication

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Abstract - *In recent days the level of pollution is increasing rapidly due to factors like industries, urbanization, increasing in population, vehicles which drastically affect human health. This project is basically a system which continuously monitors the pollution levels by sensing different factors responsible for pollution like gases (CO, SO_2 and NO_2, etc.), particulate matter (dust), noise, humidity and temperature. Hence this project monitors air as well as noise pollution. Proposed system uses RF based communication. Efficient sensors are used to measure values of gases, noise and dust accurately. All the sensors are connected to RF Slave Modules through MCU. Slave modules transmit the data processed by MCU which is collected by the sensors, to the master module. The RF master module is connected to a monitoring device using a TTL module. Finally, the data to be monitored is shown graphically on a software application*

***Key Words*: Air pollution, noise pollution, RF communication, sensors, pollution monitoring, AQI, STM micro-controller.**

1. INTRODUCTION

Environmental problems have always been an important issue around the world. One of the most serious problems related to our daily lives is Air and Noise pollution. Carbon monoxide, nitrogen oxides, sulphur oxides etc. gases are major pollutants in Environment. Also dust constitutes in increases the air pollution. Noise pollution is also increasing day by day due to high intensity of sound produced by machines in various industries, factories and vehicles. Air pollution causes headaches, dizziness and nausea. Long-term health effects from air pollutants include cardiovascular disease, carcinoma, and respiratory diseases like emphysema. Air pollution also can cause long-term damage to people's nerves, brain, kidneys, liver, and other organs. Loud noises can cause hypertension, high stress levels, tinnitus, deafness and other harmful and disturbing effects. This project is used to monitor air and noise pollution in real time. It consists of three parts; Sensing, Communication and Monitoring. Sensors used in this project are very effective. The gases to be sensed are Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2) and other types of pollutant like Dust are monitored in this project. Humidity and temperature that affect human health are also measured for monitoring purposes. Noise sensors with capacity to measure up to 160 dB are used to detect the level of Noise. Radio Frequency is used for communication between Master-Slave modules that are connected to monitoring systems and sensors respectively. Ultra-High Frequency which ranges from 300 to 3000 MHz is allowable frequency for communication.

2. Literature Review

Pollution is increasing at an alarming rate every day. Air is the most sensitive element of the environment which is polluted momentarily by the elements emitted to air. Noise pollution is also a major type of pollution which is increasing day by day. To know the level of Air pollution, Noise pollution as well as air quality. The proposed project is a Pollution Monitoring System that works mainly for monitoring the pollution occurring in a meteorological city. Even though, Industrialization increases the degree of automation and at the same time it increases the pollution by releasing unwanted gases and causing noise in the environment. Smart air pollution monitoring system has been proposed in 2018 by Kennedy Okokpujie [1], the system was developed using the Arduino microcontroller. The air pollution monitoring system was designed to observe and analyze air quality and log data to a distant server, keeping the information updated over the web. A wireless sensor network [2] for air pollution monitoring systems in industrial areas was developed in 2016 by Prof. D.K. Kamat of Sinhgad Academy of Engineering. In this project monitoring with air related parameters was done through wireless Zigbee modules. Sensors are connected, one sensor to each node. Research paper on IOT based Air and Sound Pollution Monitoring System [3], was submitted by Lalit Mohan Joshi in 2017. In this paper pollution monitoring by using wireless embedded computing system for example technology like IOT. Another research paper on pollution monitoring system [4] is submitted in IEEE conference in which Arduino UNO and MQ sensors are used.

3. Proposed Model

The system to be developed is a wireless network consisting of various sensors to measure gas, noise, humidity and temperature. To attain this, the sensor network is placed at different places in which the factors are to be monitored. The sensor reads the surrounding data and as the sensors are connected to the transmitter, it transmits the data to the receiver for processing. The output of the sensor data is converted to transfer data using RF communication. The sensor used in this project uses I^2C and UART based communication to give data as well as to receive commands. The received data in turn is processed and it is displayed using proper GUI software and can be monitored in real time.

4. Block Diagram

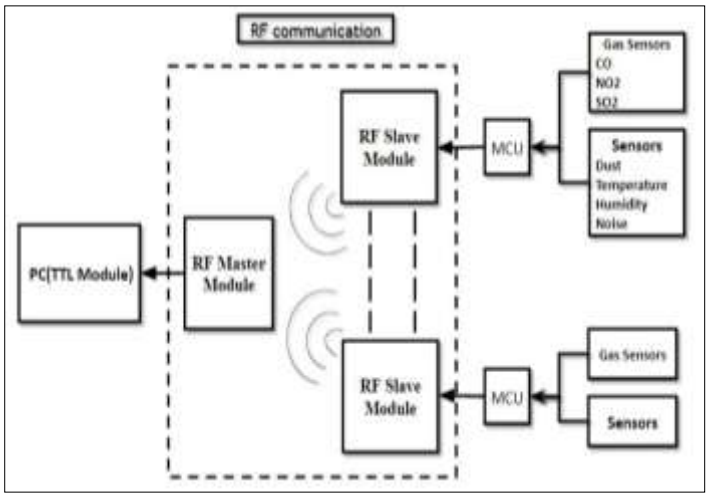

Fig -1 Block diagram of the system

The block diagram of this shows that the system is divided into three sections i.e. detection, communication and monitoring. Detection means sensing various gases like CO, SO_2 and NO_2 with other components like Noise, Particulate matter, temperature as well as humidity. There are two types of dust detected by this system: PM2.5 and PM10. The networks consisting of various sensors are deployed at desired places where we want to monitor the pollution. The sensors detects the components for example the gas sensors usually works on the principle of chemical reaction i.e., the substances in the sensor reacts with the gases and this chemical energy is converted into electrical energy meaning produces electrical current or results into change in resistance or potential difference. The output of the sensors can be in the form of analog as well as digital signals. The sensors used in this system gives two types of digital outputs: I^2C and UART. Similarly, voltage and current are analog outputs as the microcontroller can accept both analog and digital signals. The sensor connected to the microcontroller sends signal to it. The data is stored in queue in UART and it is interfaced with RF slave modules. We can use 'n' number of slave modules which can be modified according to different environments and can be placed at different locations where the pollution monitoring is required. RF slave modules send the data using RF communication to the RF master receiver. At the receiving side (Master), it is connected to a monitoring device like a computer through USB TTL module. The baud rate of the UART is 9600 bps. A solution for monitoring the noise and air pollutant levels is that when the parameter value crosses its threshold value range which is fixed and this value is compared with variation in sensor data. For example, CO levels in air in a particular area exceeding the normal levels in the environment then it is notified or an alert is sent by the microcontroller to the monitoring device. Same for all the gases and noise.

5. Factors to be monitored

5.1. Gases

- Carbon Monoxide(CO)

Carbon monoxide is a colourless, odourless and tasteless gas and it is highly toxic in nature. CO is a by-product of burning of fuel and other carbon based substances. CO poisoning is relatively common and can lead to deaths as it cannot be detected by human senses. Carbon monoxide poisoning symptoms are similar to flu and can include headache, dizziness, chest pain, vomiting, etc. Hence it is very hard to confirm the CO poisoning due to flu-like symptoms. Excessive exposure can result into consciousness loss, arrhythmias, cerebral ischaemia, hypoxia, etc.

- Nitrogen Dioxide(NO_2)

Nitrogen dioxide is reddish brown gas which has sharp, strong and biting odour which is majorly produced and released in the atmosphere industries producing nitrogen based fertilizers. It also acts as an intermediate in the production of nitric acid (HNO_3). Nitrogen oxides are also released to the air from the exhaust pipes of automobiles, and during processes like arc welding, electroplating, engraving, dynamite blasting, etc. Millions of tons of gas are released by the industries every year and it contributes to rising air pollution. Health effects due to exposure of NO_2 include skin irritation and burns but long exposures like in the workplaces in the industries can lead to edema, bronchitis, pneumonia, etc.

- Sulphur Dioxide(SO_2)

Sulphur dioxide is a colourless gas which has nasty, sharp and suffocating odour. It reacts easily with other elements in the air to form harmful compounds, such as sulphuric acid (H_2SO_4), sulphurous acid (H_2SO_3) and sulfate particles. Sources of SO_2 emissions include power plants, chemical manufacturing industries, mineral ore processing factories and burning of fossil fuels in automobiles. Naturally SO_2 is produced due to volcanic activity. Breathing SO_2 gas can cause irritation to the nose, throat which causes coughing, wheezing, choking, or a tight feeling around the chest. High concentrations of SO_2 inhalation can affect lung function, worsen asthma attacks, and aggravate existing heart disease and chronic bronchitis in sensitive groups. People with lung diseases, children and older people are more affected by SO_2 exposure. Other than human health impacts, Sulphur dioxide also contributes to acid rain which causes direct harm to trees and plants by damaging their tissues and, subsequently, decreasing plant growth.

5.2. Dust

Dust is formed of fine particles of solid matter. It typically consists of particles within the atmosphere that come from various sources like soil, dust brought by the wind, smoke from volcanic eruptions and other man made sources like various industries. Pollens from plants, human and animal hairs, textile and paper fibers, minerals from outdoor soil, and human skin cells and plenty of other materials which can be found within the environment constitute as dust. The aerodynamic properties of the dust particles change with the size of them. These properties decide how they are travelling in air and how they can be eliminated from it. The sizes of these particles are measured through different standards. For example PM10 and PM2.5 are sizes of dust particles. Here 'PM' stands for Particulate Matter and 2.5 and 10 are the sizes of the different types of dust. PM2.5 refers to the atmospheric particulates with size less than 2.5 micrometres, which is about 6% of the radius of human hair. Similarly PM10 consists of particles with size less than 10 micrometers. Hence the size of the particles determines the health effects due to them. For example particles larger in size are generally filtered in the nose and throat via cilia and mucus, but particulate matter with size less than 10 micrometers, can settle in the bronchi, alveoli and pleura present in the lungs and can cause respiratory problems. Effects of inhaling dust includes coughing, sneezing, hayfever, difficulty in breathing, asthma attacks and reduced lung function

5.3. Noise

Noise is an undesirable sound considered to be unpleasant, loud, intense or disruptive to hearing. It is defined as any sound that is undesired or interferes with one's hearing of something According to physics; noise is indistinguishable from sound, as both are vibrations through a medium, such as air or water. The difference comes when the brain receives and distinguishes between a sound and noise. Hence for both sound and noise the unit of measurement is decibel (dB). Noise pollution is the generation of noise with adverse effects on human and animal life. Noise pollution can affect both psychological and physical health of a person. Constant exposure to noise can cause hypertension, high stress levels, hearing impairment, sleep disturbance, etc. Some studies also show weakening of immune system and birth defects due to noise pollution.

5.5. Temperature

Definition of temperature is that it is the intensity or degree of heat present in a substance or object, especially as expressed according to a comparative scale. Temperature can be said as the manifestation of the thermal energy present in the matter which is the source of occurrence of heat. Temperature measurement is expected as most physical, electronic, chemical, mechanical, and biological systems work best within certain temperature ranges. Temperature sensing is generally done either through direct contact with the heat source, or remotely, using radiation energy without direct contact with the source.

5.5. Humidity

The definition of humidity is that it is the concentration of water vapour present in the atmosphere. Water vapour is the gaseous form of water. As the temperature increases the amount of water vapour needed to achieve saturation also increases and vice-versa. There are three primary measurements of humidity namely absolute humidity, relative humidity, and specific humidity. Absolute humidity specifies the water vapour content of air and is expressed in either grams per cubic metre or grams per kilogram. Relative humidity is the amount of water vapour in the air proportionate to what the air can hold at a given temperature. Specific humidity is basically ratio of the mass of water vapour in air to the total mass of the mixture of air and water vapour. In this project we are measuring the relative humidity and its unit is %RH.

6. Sensors

In this case we are using two types of gas sensors: electrochemical gas sensor and metal oxide gas sensor.
The details of the sensors used in the project are as follows:

6.1. Mics-6814

This sensor is responsible for the detection and measuring of Carbon Monoxide and Nitrogen Dioxide gases. This sensor is a metal oxide sensor. Its principle of working is that the resistance of the detecting substance in sensor changes in the presence of the target gases. Or in very simple terms, as the concentration of gases like NO_2 which is an oxidizing gas, increases the resistance will increase and for reducing gases like CO the resistance decreases. This way we can distinguish between nitrogen dioxide and carbon monoxide.

Table -1

Company	CGX sensorTech
Mounting Style	SMD
Range	CO= 1 – 1000ppm, NO_2= 0.05 – 10ppm
Indoor/outdoor	Outdoor

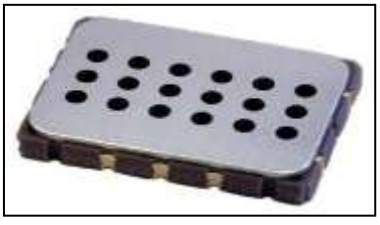

Fig -2 Mics-6814

6.2. 3SP_SO2_20 C Package 110-602

As the name suggests this is a Sulphur dioxide sensor and typically its response time is less than 15 seconds. The sensor used to detect SO_2 is an electrochemical sensor which generates a current proportional to the volumetric fraction of the gas. Here a catalytic metal is chosen to optimize the reaction of the objective gas. The gas to be measured enters through the capillary diffusion barrier and reacts with the electrode present in the sensor. The electrons that resulted from the electrochemical reaction flow from the working electrode through an outer circuit based on the amount of gas that is reacting respectively. The resulting current due to the flow of electrons is the output signal of the sensor. The working electrode current is linearly proportional to that of the gas concentration. An electrode of opposite polarity is provided to complete the circuit of the electrochemical cell. The counter electrode functions solely as the second half of the cell, and forms a path for electrons to enter or exit the electrolyte.

Table -2

Company	SPEC sensor
Output	Current
Indoor/outdoor	Outdoor
Measurement	0 to 20 ppm (20ppb+)

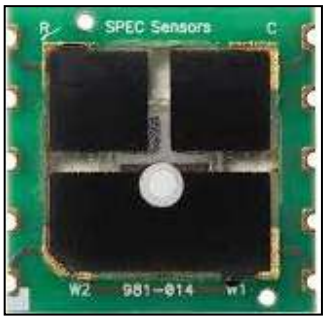

Fig -3 3SP_SO2_20 C Package 110-602

6.3. SM-UART-04L

SM-UART-04L is a Particulate Dust Sensor which detects both PM2.5 and PM10 dust particles. This dust sensor uses LASER technology for the detection of particulate matter. This sensor detects dust particle concentration in the atmosphere by using the optical sensing method. A laser light emitting diode and a photoelectric sensor both are optically arranged in such a way that in the sensor such that the photo sensor detects the reflected laser LED light by dust particles in the environment. By using the sensor's pulse pattern received from signal output it can differentiate between small and large particles, providing both PM2.5 and PM10 outputs.

Table -3

Company	Telaire Amphenol sensors
Output type	UART
Particle size	PM2.5, PM10
Indoor/Outdoor	Outdoor

Fig -4 SM-UART-04L

6.4. AM2320

Temperature and humidity both are measured by a single sensor. It uses specialized temperature and humidity acquisition technology to ensure that the product has a very high reliability and great long term stability. This sensor consists of a capacitive moisture element and an integrated precision temperature measurement component, and connected with a high-performance microprocessor. I^2C communication is used by this sensor to transmit the data it sensed. The range is given below:-

Table -4

Company	Telaire Amphenol sensors
Mounting style	UART
Range	PM2.5, PM10
Indoor/Outdoor	Outdoor

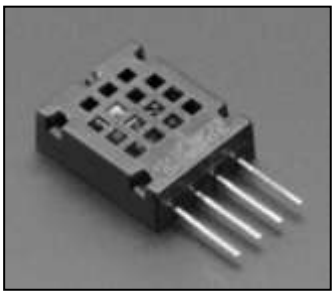

Fig -5 AM2320

6.5. Noise sensor ICS-40730

Noise sensor is basically a low noise bottom-ported MEMS microphone whose output is differential and analog in nature. The Microphone is omni-directional hence it has a resolution of 360 It has a signal to no ise ratio (SNR) of 74 dB. SNR as the name suggests it is the ratio of signal power to the noise power. With increase in SNR indicates signal reception is good and there is less noise. This sensor can detect a maximum noise level of 160 dB.

Table -5

Company	InvenSense
Output Type	Analog
Frequency Range	25Hz ~ 20kHz
Signal to Noise ratio	74 dB
Sound Pressure Level	160 dB

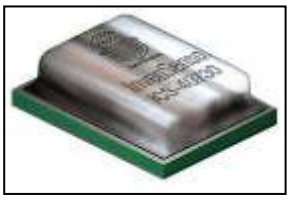

Fig -6 ICS-40730

7. Microcontroller

The microcontroller used in this system is manufactured by STMicroelectronics and its name is STM32F030C8T6TR which has a high performance Arm Cortex-M0 32-bit RISC core. It operates in 48 MHz frequency. The memory of the microcontroller is upto 256 Kbytes of Flash memory and up to 32 Kbytes of SRAM. All standard communication protocols are available in this MCU. For example it contains two I²Cs, upto two SPIs and upto six USARTs. It also has seven general-purpose 16-bit timers, an advanced-control PWM timer and a 12-bit ADC. The STM32F030C8T6TR microcontroller operates between -40 to +85 ℃ temperature range from a 2.4 to 3.6V power supply.[5]

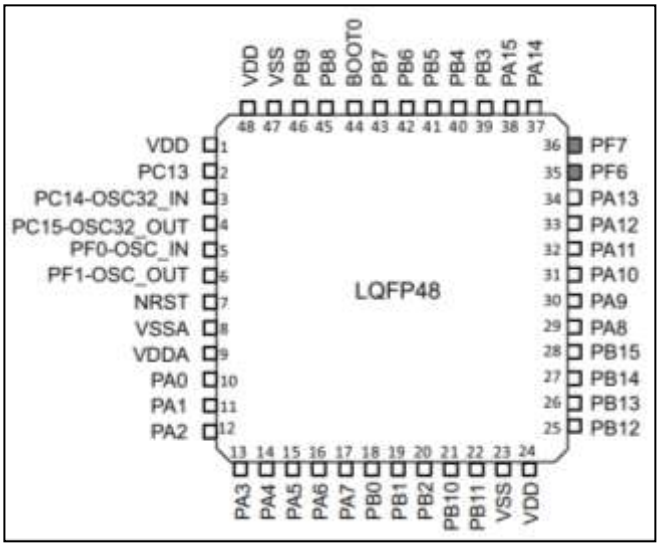

Fig -7 Pin package of STM32F030C8T6TR

8. Communication Technology

Radio frequency communication is the mode of communication used between master and slave module in this system. RF refers to the frequencies that fall within the spectrum related to radio emission propagation. RF current creates electromagnetic fields when applied to an antenna that propagates the applied signal through space. RF propagation occurs at the speed of light and doesn't need a medium like air so as to travel. RF waves occur naturally from solar storms, lightning, and from stars in space that radiate in the EM spectrum. In RF wireless communication systems, waves in RF bandwidth are used to transfer information between a transmitter (Tx) and a receiver (Rx). RF systems are often classified as either terrestrial-based or space-based systems. Terrestrial microwave systems are limited in distance and line-of-sight propagation is the limiting factor. A RF module is usually a tiny electronic device which transmits and receives radio signals between two devices. As RF does not need line of sight propagation it is favoured for many applications. RF communications incorporate a transmitter and a receiver. They are of various types and ranges. The RF module is applicable for various types of shapes and sizes of small electronic circuit boards. These modules typically includes a PCB, antenna, transmit or receive circuit, and serial interface for communication with the main processor. Some can transmit up to 500 feet. RF modules are widely utilized in electronic design due to the problem of designing radio circuitry.

9. Air Quality Index (AQI)

AQI is the base of the of the monitoring a part of the project i.e., the concept of an air quality index (AQI) that transforms weighted values of individual air pollution related parameters (e.g. SO_2, CO, visibility, etc.) into one number or set of numbers is widely used for air quality communication and deciding in many countries. After literature reviewing the subject 'Air Quality Index' the air quality monitoring methods and protocols, Indian National Air Quality Standards (INAQS), an AQI system is devised. The AQI system relies on maximum operator of a function (i.e. selecting the utmost of sub-indices of individual pollutants as an overall AQI). The target of the air quality index is to quickly disseminate air quality information (almost in real-time) that entails the system to account for pollutants which have short-term impacts. Eight parameters (PM10, PM2.5, NO_2, SO_2, CO, O_3, NH_3) having short-term standards are considered for near real-time dissemination of AQI.[6]

10. Graphical User Interface (GUI)

GUI is the monitoring part of the project and we can see the different amounts of gases present around the slave system. Also the quantity of other components like dust, noise intensity, temperature and humidity are also shown in the application. We are using gauge type of meter to represent the volume of gases. We can view all the areas where the sensor network is placed. Different tabs can be given to different places as shown in the figure. A meter for AQI is also used in the GUI which shows the air quality index by using the data provided by the gas and dust sensors. The data shown by this interface is in real-time and it is of the present day. But all the previous data starting from the installation of

the sensor network is stored and can be seen by the user any time. The stored data can also be uploaded to the cloud for backup purposes.

Fig -8 Screenshot of GUI

11. Future scope

Better monitoring system can be achieved by using more number of sensors with better efficiency that are not included in this project. The recorded data can be stored and backup to cloud easily as it uses computer application at the end. This project is used in outdoor for monitoring due to this it is possible to use solar cells to power the slave's modules placed at day and at different areas to reduce the power consumption. At night we can always use the power supply in the sensor network. By using pollution control system, we can reduce the effects of gases to causes of pollution and dangerous for health. We can control various diseases such as asthma, lung problems.

12. CONCLUSION

Air and noise pollution is becoming a severe environmental problem because of its great impact on the health of people and also on the global economy. Typical air pollution systems are not able to provide real time pollution data of high resolution because of low scalability and lack of data availability. Majority of air and noise pollution is caused by the industries and automobile vehicles. Hence there is a need to develop a real-time uninterrupted pollution monitoring system that can overcome the mentioned problems. To implement this there is a need to deploy the sensor network in the environment for collecting the data and to analyze the data. By deployment of the sensor networks we can constantly oversee the environment conditions and the sensor can interact with other objects wirelessly. Then the collected data and analysis results will be available to the end user through the RF modules which are connected to a suitable display device like a personal computer.

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